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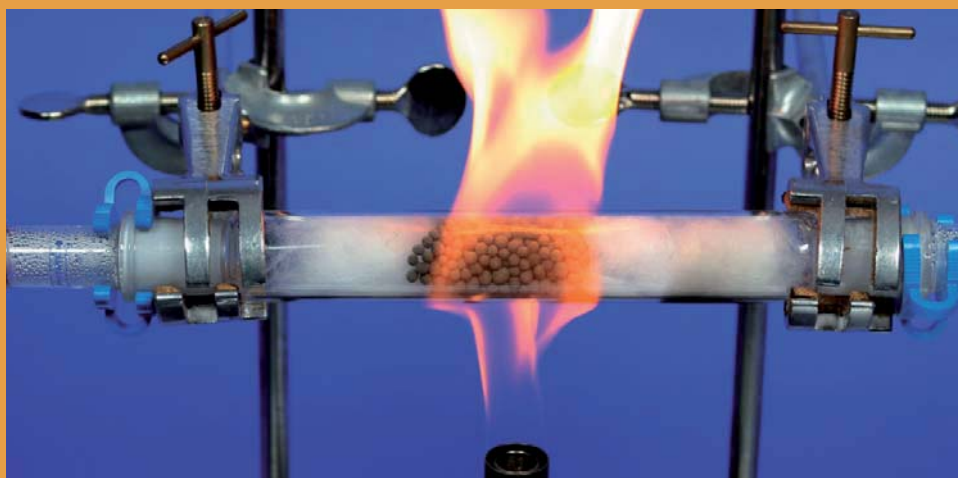
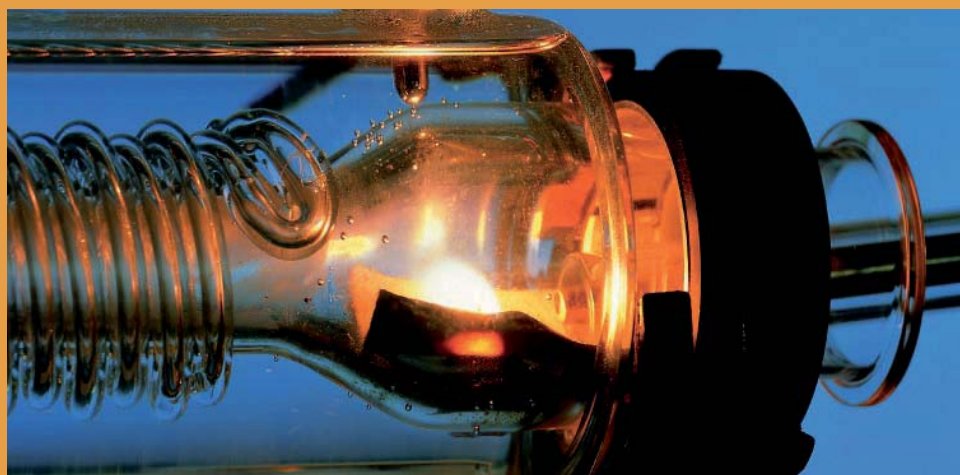
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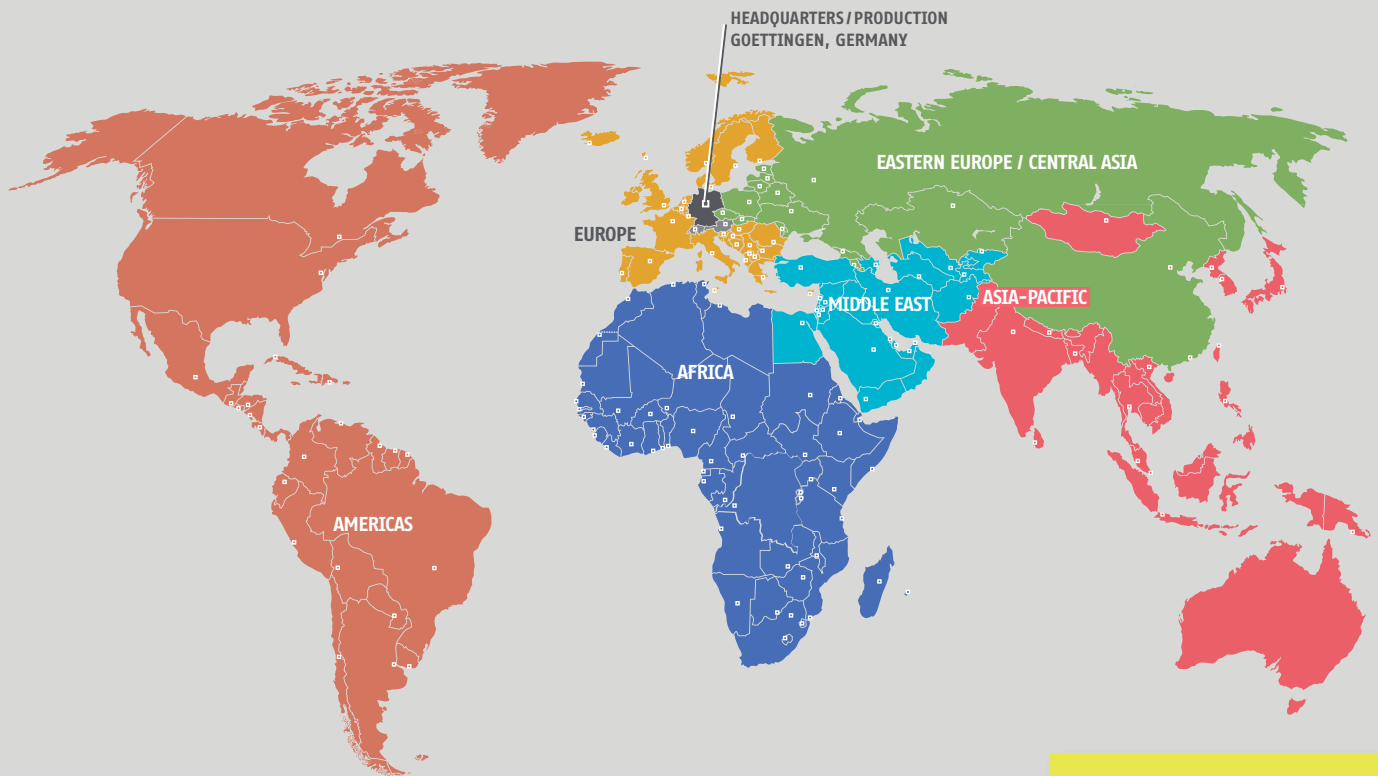


# Chemistry / Pharmacy

## University Experiments

# Global network

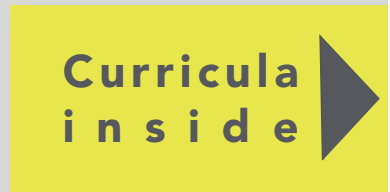
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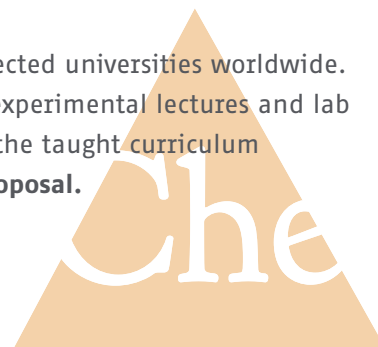
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# Chemistry: Curricula Compliant Experiments – for your educational needs

PHYWE™ experiments have been matched to the curricula of more than 30 selected universities worldwide. The interaction between PHYWE's experiments and the supporting content of experimental lectures and lab course has led to the creation of a teaching package that is highly relevant to the taught curriculum worldwide. **Give us your requirements and we will send you a customised proposal.**

## Chemistry

### Bachelor of Science Courses – Reference Curriculum



Content	Preparatory Courses	1. Sem.	2. Sem.	3. Sem.	4. Sem.	5. Sem.	6. Sem.
Laboratory Experiments	Basics in General, Analytical, Organic and Inorganic Chemistry (Chapter 3)***	General Chemistry (Chapter 4)	Analytical Chemistry (Chapter 5)	Inorganic Chemistry (Chapter 8)	Organic Chemistry (Chapter 9)		Technical Chemistry (Chapter 10)
			Physical Chemistry (Chapter 7)			Biochemistry (Chapter 11)	
Lecture, Tutorial, Experiments		General Chemistry (Chapter 4)	Inorganic Chemistry (Chapter 8)	Organic Chemistry (Chapter 9)	Biochemistry (Chapter 11)	Spectroscopy (Chapter 6)	
			Physical Chemistry (Chapter 7)				
Elective Subject					Microbiology **	e.g. Biotechnology, Material Chemistry (Chapter 11)	
Interdisciplinary Subject		General Physics *	Electro-chemistry (Chapter 7.6)		Molecular Analytics (NMR) and Spectroscopy (Chapter 6)		
Theoretical Courses			Mathematics	Statistical Thermodynamics	Theoretical Chemistry		
Bachelor Thesis							Bachelor Thesis

More than 80% of the experimental courses are covered by PHYWE experiments!

PHYWE Experiments available in this catalogue

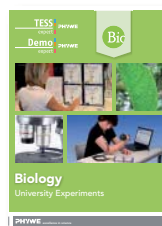
\* Please refer to TESS expert Physics catalogue

\*\* Please refer to TESS expert Biology catalogue

\*\*\* Also refer to TESS beginner/advanced brochure



TESS expert and Demo expert Physics



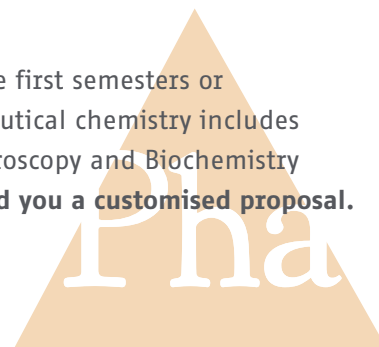
TESS expert and Demo expert Biology



TESS beginner / advanced brochure

# Pharmacy: Curricula Compliant Experiments – multidisciplinary education with PHYWE

Pharmacy is one of the most multidisciplinary subjects taught in natural sciences. The first semesters or introductory courses cover general topics in physics, biology and medicine. Pharmaceutical chemistry includes the classical main topics of chemistry: Inorganic, Organic, Analytical Chemistry, Spectroscopy and Biochemistry with reference to pharmaceutical topics. **Give us your requirements and we will send you a customised proposal.**



## Pharmacy

### Bachelor of Science Courses - Reference Curriculum

Content	1. Sem.	2. Sem.	3. Sem.	4. Sem.	5. Sem.	6. Sem.
Laboratory Experiments		General Biology **	Organic Chemistry (Chapter 9)	Spectroscopy (Chapter 6)	Pharmacognosy Microscopy of medical plants **	Clinical Chemistry***
	General Chemistry (Chapter 4)	Inorganic Chemistry (Chapter 8)	Analytical Chemistry (Chapter 5)		Human Physiology ***	Microbiology **
Lecture, Tutorial, Experiments	General Physics *	Physical Chemistry: Gas Laws, Viscosity, Thermodynamics (Chapter 7)		Biochemistry (Chapter 11.1)		
		Chromatography (Chapter 5.3)	Human Physiology ***	Histology ***	Pharmaceutical Technology	
Elective Subject		Disposal, Environment Protection (Chapter 10.3)		Immunology	e.g. Biotechnology (Chapter 11.2)	
Theoretical Courses	Mathematics	Pharmacokinetics	Pharmacognosy		Pathophysiology	Pharmaceutical Engineering
Bachelor Thesis						Bachelor Thesis

**More than 70% of the experimental courses are covered by PHYWE experiments!**

PHYWE Experiments available in this catalogue

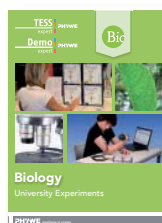
\* Please refer to TESS expert Physics catalogue

\*\* Please refer to TESS expert Biology catalogue

\*\*\* Please refer to TESS expert Medicine catalogue



TESS expert and Demo expert Physics



TESS expert and Demo expert Biology



TESS expert and Demo expert Medicine



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A strong partner for more than 100 years –  
Tradition ■ Partnership ■ Innovation ■ Quality



Past

Present

Future

Tradition  
Partnership  
Innovation  
Quality

■ made  
■ in  
■ Germany

## The teaching and learning platform **curricuLAB™** – future experimentation without limits

curricuLAB is a powerful **teaching and learning platform** for science experiments. Apart from the provision of **learning contents**, it also enables the **acquisition of measurement values** in a didactic context and it **can be configured** based on your desires and requirements – experimentation without limits!

### Features

- Independent of the user terminal – desktop PC, laptop, tablet, or smart-phone
- Independent of the operating system
- One platform for all PHYWE devices
- Location-independent and network integrated – access from wherever you are
- Interactive – image-assisted, editable instructions
- Report function – with interactive elements



**curricuLAB** | PHYWE

Computer-assisted experimentation

CONTENT

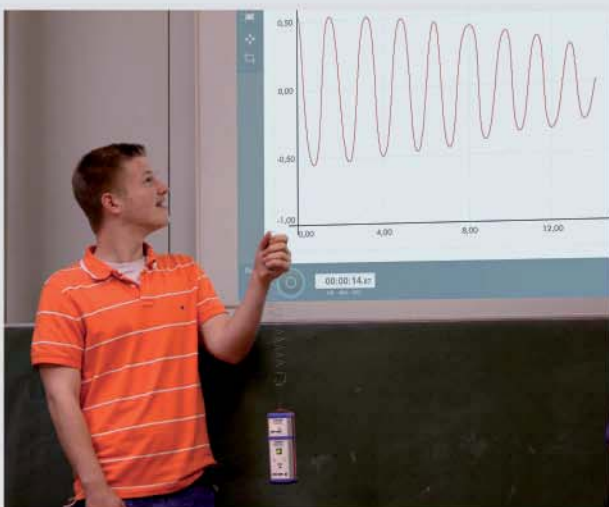
MANAGE

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(plug-in)

COLLECT

ANALYZE



Connecting interactive teachware with hands-on experiments





# 1 Introduction

## 1.1 How to use

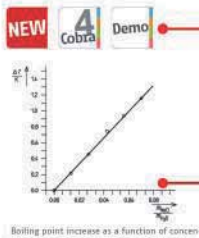

### How to use the catalogue pages

The TESS and Demo expert catalogue is adapted to the PHYWE reference curriculum. PHYWE's experiments fit to the content of experimental lectures and lab courses of schools, colleges and universities. The description of each experiment offers you a lot of information:

**7 Physical Chemistry**  
7.7 Phase Equilibrium

### Boiling point elevation - Raoult's law with Cobra4

P3021060



**NEW** **4 Cobra** **Demo**

**Principle**  
Raoult's law states: The vapour pressure of an ideal solution is directly dependent on the vapour pressure of each chemical component and the mole fraction of the component present in the solution.  
That's why the boiling point of a solution is always higher than that of the pure solvent. The dependence of the temperature difference (elevated boiling point) on the concentration of the solute can be determined using a suitable apparatus.

**Tasks**

1. Measure the increase in the boiling point of water as a function of the concentration of table salt, urea and hydroquinone.
2. Investigate the relationship between the increase in boiling point and the number of pellets.
3. Determine the molar mass of the solute from the relationship between the increase in boiling point and the concentration.

**What you can learn about**

- Raoult's law; Henry's law; Ebullioscopic constants; Chemical potential; Gibbs-Helmholtz equation; Concentration ratio; Degree of dissociation

**Main articles**

Cobra4 Wireless-Unit	12601-00	1
Cobra4 Sensor-Unit Chemistry	12630-00	1
Software Cobra4 - multi-user licence	14550-61	1
Heating mantle f. roundbottom flask, 250ml	49542-93	1
Apparatus for elevation of boiling point	36820-00	1
Power regulator	32788-93	1

**Related Experiment**

- Boiling point elevation P3021001
- Temperature meter digital, 4-2 13617-91

**Function and Application**  
Modern, user-friendly designed instrument for measuring temperature and temperature differences at four different measuring points.

**Benefits**

- Two demonstrative 4 digit LED display (+ sign), with 20 mm high digits for presentation of the values measured at the selected measuring points.
- RS 232 interface for simultaneous display and evaluation of the measured values from all four measuring points with a computer.

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Experimental setup

Description of main principle

Tasks for students

Related scientific topic

List of main articles

Complete list see: [www.phywe.com](http://www.phywe.com)

Article number

Pictograms for quick overview, e. g. **Demo** for experiments also suitable for demonstration

Exemplary measurement result

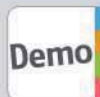
Variations of the main experiment (e.g. the same experiment with PC-interface) and experiments with similar topics

Key device of the experiment, alternative or closely related experiments with the interface Cobra4 or the video analysis software measure Dynamics

### Pictograms for a quick overview of categories, related films or information:



Experiments with the computer based measuring system Cobra4



Experiments suitable for demonstration



Experiments with laser



Nobel Prize awarded experiment



Computer based measuring in addition to Cobra4



Experiments with radioactivity



Product movie available. Go to [www.phywe.com](http://www.phywe.com)



New and completely revised experiments



Training recommended

## How to use the didactic literature

Extensive experimental literature is available for all our university level experiments. Rely on the advantages of our TESS™ and Demo expert experiment descriptions:

- All experiments are uniformly built up
- Experiments cover the entire range of classical and modern chemistry
- Didactically adapted descriptions – enables direct preparation by the student
- Developed and proven by practitioners – comfortable and reliable performance
- Excellent measurement accuracy – results agree with theory
- Computer-assisted experiments – easy, rapid assessment of results
- Modular experimental set-up – multiple use of individual devices, cost effective and flexible

Related topics and Principle and task to introduce the subject.

Picture, Equipment list and Instruction for the execution of the experiment guarantee easy conduction of the experiment.

More than 650 experiments described!

Theory and evaluation includes full theory of the experiment and shows graphical and numerical experimental results.

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**Precipitation titration: Determination of both chloride and iodide with Cobra4**

**TEC**

**Related topics**  
Stoichiometry, Potentiometer, Silver nitrate, Titration

**Principle**  
Precipitation reactions which take place stoichiometrically and rapidly, with equilibrium product that is sparingly soluble, can also be analysed volumetrically. In the example product that contains both chloride ions and iodide ions is titrated with a silver nitrate solution that contains both chloride ions and iodide ions is titrated with a silver nitrate solution is used to follow the course of the titration and the equivalence points are determined from points of the potential curve.

**Material**

1 Cobra4 Wireless Manager 12930-00	2 Volumetric pipette, 10 ml 12930-00	1 Pipettor 12930-00
1 Cobra4 Sensor-Unit Chemistry 14550-01	1 Funnel, glass, top dia. 55 mm 14550-01	1 Funnel, glass, top dia. 55 mm 14550-01
1 Cobra4 Sensor-Unit Chemistry 14550-01	3 Volumetric flask 100 ml, IG 12980-00	3 Volumetric flask 100 ml, IG 12980-00
1 Software Cobra4 - multi-user licence 07542-26	3 Glass beaker DURAN® 100 ml 18475-00	3 Glass beaker DURAN® 100 ml 18475-00
2 Holder for Cobra4 with support rod 31839-04	1 Precision Balance Sartorius 01805-02	1 Precision Balance Sartorius 01805-02
1 Adapter, BNC-plug/socket 4 mm. 64798-00	1 Spoon, special steel 37692-00	1 Spoon, special steel 37692-00
1 Reference electrode, AgCl 31839-04	1 Wash bottle, plastic, 500 ml 07276-11	1 Wash bottle, plastic, 500 ml 07276-11
1 Silver foil, 150X150X0.1mm, 25 g 46209-01	1 Silver nitrate, cryst., 15 g 36513-01	1 Silver nitrate, cryst., 15 g 36513-01
1 Emery paper, medium, 5 sheets 37720-00	1 Potassium chloride, 250 g 36888-00	1 Potassium chloride, 250 g 36888-00
1 Scissors, straight, 180 mm 37692-00	1 Water, distilled, 5 l 37697-00	1 Water, distilled, 5 l 37697-00
1 Retort stand, 210 mm x 130 mm, h = 500 mm 07276-11	1 Lab protecting glasses w/ 46209-01	1 Lab protecting glasses w/ 46209-01
3 Right angle clamp 47334-03	1 Glove, Neoprene, med. 36513-01	1 Glove, Neoprene, med. 36513-01
1 Connecting cord, 32 A, 500 mm, red 46209-01	1 Cobra4 Sensor-Unit Dro 37720-00	1 Cobra4 Sensor-Unit Dro 37720-00
1 Alligator clips, insulated, red, 10 pcs. 46209-01	Additional material 36888-00	Additional material 36888-00
1 Magnetic stirrer Mini / MST 36513-01	1 PC with USB-port, Wind 36888-00	1 PC with USB-port, Wind 36888-00
2 Magn. stirring bar 15mm, cyl. 37720-00		
1 Burette, 50 ml, graduations 0.1 ml 36888-00		
1 Burette clamp, roller mount, 2pl. 36888-00		
1 Funnel, 4.40 mm, f. burettes 36888-00		

**Results and Evaluation**

- click on **■** to end measurement.
- Read off the volume of silver nitrate solution added from the burette and enter the value in the computer. Transmit all measured data to "Measure".
- Save measured data with a click on "File" and "Save measurement".

The titration curve which is presented by the programme on completion of measurement is shown in Fig. 2.

- Silver iodide precipitates out first during the titration corresponding to the solubility products of silver iodide ( $1.5 \cdot 10^{-16} \text{ mol}^2/\text{l}^2$ ) and silver chloride ( $2 \cdot 10^{-10} \text{ mol}^2/\text{l}^2$ ). The potential of the solution only changes little by little, as the silver ions that are added are almost quantitatively removed from the solution by precipitation.
- On further addition of silver nitrate and in the vicinity of the first equivalence point, however, the potential suddenly jumps upwards.
- When iodide ions have been completely precipitated from solution (overstepping of the first equivalence point), the potential first returns to a slow increase as added silver ions are no longer removed by precipitation. This continues until the solubility product of silver chloride is reached and silver chloride is precipitated. A larger change in potential is only again possible when precipitation ceases, but jumps up again when the second equivalence point is reached. The following reaction takes place:

$$\text{Cl}^- + \text{Ag}^+ \longrightarrow \text{AgCl}$$

**Fig. 2:** Titration curve of a precipitation titration of 10 ml of 0.1 molar potassium chloride solution and 10 ml of 0.1 molar potassium iodide solution with 0.1 molar silver nitrate solution.

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### How to use the table of contents

Use the curricula-based content on the next pages to find your topics and our corresponding experiments. The TESS™ and Demo expert catalogue is adapted to international university curricula making it easy for you to find experiments corresponding to your desired topic. On each page you find the detailed description of one of our university level experiments. More information including the complete experiment description is available on our website [www.phywe.com](http://www.phywe.com).

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Curricular topic = main chapter of the catalogue

Curricular subtopic = sub-chapter of the catalogue

Curricular fitting PHYWE experiments

Find the overview of all experiments fitting to the international Reference Curriculum on our homepage!  
Go to [www.phywe.com](http://www.phywe.com)



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## Preparatory Course

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Sublimation of benzoic acid.

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- Complete device set for an easy realization of the experiments
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### List of topics, General Chemistry

#### 1. Properties of matter

- Hardness, colour, magnetisability, water solubility
- Combustibility, melting point
- Boiling point; Sublimation; Density determination

#### 2. Mixtures and mixture separation

- Properties of mixtures; Liquid mixtures

#### 3. Mixture separation

- Evaporation; Filtration, magnetic separation
- Extraction; Chromatography

#### 4. Chemical reactions

- Comparison of a physical process and a chemical reaction
- Reaction of copper and sulphur

#### 5. Test reactions

- the Detection of oxygen; the Detection of hydrogen; the Detection of nitrogen

#### 6. Particle model

- Degradation of water by reducing agents
- Dissolution processes in liquids
- Dissolution of salts; Crystallisation

#### 7. Chemical bonds

- Test confirming the migration of ions by means of indicator paper
- Periodic system; Dipolar properties
- Melting point lowering/ boiling point elevation
- Behaviour of salts with regard to solvents of different polarities

### Additionally required material

TESS advanced General Chemistry CH 1, consumables and chemicals for 10 groups

13300-10

TESS advanced General Chemistry CH 1, necessary accessories for 1 group

13431-88

Software interTESS Chemistry, DVD

01060-00



### 15301-88 TESS advanced Chemistry Set Inorganic Chemistry



Properties of oxygen.

#### Function and Applications

Set for the realization of 34 student experiments on the topics:

- Metals (3 experiments); Air and other gases (12 experiments)
- Water - components of water and water purification (11 experiments)
- Building material (3 experiments); Fertilizer (4 experiments)
- Glass manufacture (1 experiment)

#### Benefits

- Complete device set for an easy realization of the experiments
- Stable storage system: easy to store (stackable), fast control on completeness (foam inserts)
- Interactive executing of the experiments with help of interTESS, a software to the PC supported experimentation and evaluation
- The use of the software minimizes preparation time and facilitates individual learning-speeds

#### List of topics Inorganic Chemistry

##### 1. Metals

- Oxidation of metals; Factors determining the reaction behaviour of metals; Oxygen, causative agent of oxidation

##### 2. Air and other gases

- The importance of air for combustion processes; Air, a mixture; Properties of oxygen
- Reaction in pure oxygen; Quantitative investigation of oxides; Nitrogen, preparation and properties
- Carbon dioxide, preparation and properties; Model of a fire extinguisher
- Construction and function of a Bunsen burner
- The candle's flame; Rusting; Reduction of copper oxide

##### 3. Water – components of water and water purification

- Water content of natural substances; Dissolved compon-

ents in different waters; Solubility of gases in water; Solutions, colloids, suspensions

- Solubility of salts in water - comparison with the solubility of gases in water; Mode of operation of an aeration tank (sewage treatment plant)
- Water treatment in sewage treatment plants
- Hardness of water; Test for water; Water, an oxide
- Degradation of water by reducing agents; Synthesis of water

##### 4. Building material

- Production of cement; Processing of gypsum
- Gypsum moulds

##### 5. Fertilizer

- Mineral constituents of plants
- Absorption of mineral substances by plants
- Ammonia fertilizer; Burnt lime serving as a fertilizer

##### 6. Glass manufacture

- Soda-lime glass beads

#### Additionally required material

**TESS advanced Inorganic Chemistry, consumables and chemicals for 10 groups**

13301-10

**TESS advanced Inorganic Chemistry CH 2, necessary Accessorie for 1 group**

13433-88

**Software interTESS Chemistry, DVD**

01060-00

## TESS advanced Chemistry Set Acids, Bases, Salts

15302-88



Ammonia- comparison of gas and aqueous solutions.

**Function and Applications**

Set allowing the performance of 31 experiments about the following topics:

- Acids (16 experiments); Alkalis (8 exp.); Salts (7 exp.)

**Benefits**

- Complete equipment set: simple execution of the experiments
- The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness (foam insert)
- Experimenting literature for pupils and teachers available: minimal preparation time
- Matched with international Curriculum: all topics are covered
- Set developed by pedagogues for introduction into inorganic chemistry
- Easy teaching and efficient learning by using the interactive experimentation Software interTESS

**List of topics Acids, Bases, Salts****1. Acids**

- General safety precautions; Hazardousness of concentrated sulphuric acid; Plant pigments as indicators; The effects of acids on indicators; The effects of acids and lyes on natural and commercial; The effects of acids on metals; Acid strength; Preparation and properties of hydrochloric acid; Preparation and properties of sulphurous acid; PVC; Sulphurous acid- environmental hazards due to the combustion of fossil fuels; Oxidation of sulphurous acid; Preparation and properties of sulphuric acid; Preparation and properties of carbonic acid; Brönsted acids: conductivity comparison of molten and dissolved oxalic acid; Brönsted acids

**2. Alkalis**

- Safety precautions; Alkalis - constituents of household detergents; Aqueous solubility of ammonia; Preparation and properties of a lime water/magnesium hydroxide solution; Preparation and properties of sodium hydroxide solution; Alkali formation due to a reaction of base metals with water; Alkali formation due to a reaction of metal oxides with water; Reaction of alkalis with aluminium - alkali strength

**3. Salts**

- Salt formation due to a reaction of acids with alkalis; Salt formation due to a reaction of acids with metal oxides; Salt formation from chemical elements; Salt formation by precipitation reaction; Hydrolysis of salts; Thermal decomposition of salts; Osmosis: a "chemical garden"

**Additionally required material**

**TESS advanced Chemistry Acids, Bases, Salts, necessary Accessories for 1 group**

**13435-88**

**TESS advanced Chemistry Acids, Bases, Salts, consumables and chemicals for 10 groups**

**13436-88**

**Software interTESS Chemistry, DVD**

**01060-00**

### 15304-88 TESS advanced Chemistry Set Organic Chemistry



The cracking of petroleum.

#### Function and Applications

Set allowing the performance of more than 36 experiments about the following topics:

- Preliminary tests (7 exp.); Hydrocarbons (5 exp.); Petroleums (4 exp.); Alcohols (7 exp.); Carbonyl compounds (3 exp.); Carboxylic (alkane) acids (4 exp.); Esters (3 exp.); Soaps (3 exp.)

#### Benefits

- Complete equipment set: simple execution of the experiments; The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness
- Experimenting literature for pupils and teachers available: minimal preparation time; Matched with international Curriculum: all topics are covered
- Set developed by pedagogues for introduction into organic chemistry; Easy teaching and efficient learning by using the interactive experimentation Software interTESS

- Alcoholic fermentation; Production of methanol "wood spirit"; Alco test-tubes; Borax test; Iodoform test; Properties of homologous series; Polyhydric alcohols

#### 5. Carbonyl compounds

- Oxidation of alkanols; Schiff's test/Fehling's test; Characterisation of acetone

#### 6. Carboxylic (alkane) acids

- The use of formic acid; Characterisation of acetic acid "wood vinegar"; The acidic character of carboxylic (alkane) acids; Iron chloride test / Formation of verdigris

#### 7. Esters

- Esters of acetic acid/var. alkane acids; Splitting of esters

#### 8. Soaps

- Production of soap; Properties of soap; The action of soap

#### List of topics Organic Chemistry

##### 1. Preliminary tests

- Decomposition of organic substances; Detection of carbon with lime-water; Detection of carbon by oxidation; Detection of oxygen/nitrogen/sulphur; Beilstein test

##### 2. Hydrocarbons

- Characterisation of methane/ethylene/ethine; Homologous series of alkanes; Reactivity of the alkanes

##### 3. Petroleums

- Cracking of petroleum; Removal of paraffins by extraction/urea

##### 4. Alcohols

#### Additionally required material

TESS advanced Organic Chemistry, necessary Accessories for 1 group

13437-88

TESS advanced Organic Chemistry, consumables and chemicals for 10 groups

13438-88

Software interTESS Chemistry, DVD

01060-00

## TESS advanced Chemistry Set Chemistry of Polymers

15305-88



Production of polystyrene foam.

### Function and Applications

Equipment set allowing the performance of 26 experiments about the following topics:

- Polymer concept (2 exp.); Natural polymers (2 exp.); Initial identification of plastics (5 exp.); Preliminary exp. on the synthesis of plastics (1 exp.); Mechanism of the formation of plastics (8 exp.); Modification of plastics (4 exp.); Identification methods for plastics (2 exp.); Recycling of plastics (2 exp.)

### Benefits

- Complete equipment set: simple execution of the experiments
- The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness (foam insert)
- Experimenting literature for pupils and teachers available
- Matched with international curriculum: all topics are covered
- Developed by pedagogues for intro into chemistry of polymers
- Easy teaching and efficient learning by using the interactive experimentation software interTESS

### List of topics Chemistry of Polymers

#### 1. The polymer concept

- Constituents of polymers: The thermal decomposition/oxidation of polymers; The detection of polymer constituents

#### 2. Natural polymers

- The decomposition of naturally occurring polymers; Production of a plastic material from a protein

#### 3. The initial identification of plastics

- Properties of plastics: Mechanical properties of plastic; Determination of the densities of plastic; Flammability; Deformability on warning; Melting range

### 4. Preliminary experiments on the synthesis of plastics

- Properties of monomers

### 5. The mechanism of the formation of plastics

- Polymerisation reactions; Formation of PMMA/ Polyamide/ Nylon/ phenol resins/ PU; Aldol addition

### 6. Modification of plastics

- Modification of plastics: Production of a phenol resin foam; Production of a urea resin foam; Production of polystyrene foam; Production of a plexiglass plates

### 7. Identification methods for plastics

- Thermoplastics and thermosetting plastics; Identification scheme for thermoplastics

### 8. The re-cycling of plastics

- Re-cycling procedures: Re-melting; Pyrolysis

### Additionally required material

TESS advanced Chemistry of polymers, necessary Accessories for 1 group

13482-88

TESS advanced Chemistry of polymers, consumables and chemicals for 10 groups

13483-88

Software interTESS Chemistry, DVD

01060-00

### 15306-88 TESS advanced Chemistry Set Food Chemistry



Detection of vitamin C.

#### Function and Applications

Equipment set allowing the performance of 40 experiments about the following topics:

- Proteins (3 exp.); Fat (9 exp.); Beverage (3 exp.); Spices (1 exp.); Carbohydrate (12 exp.); Vitamines and minerals (1 exp.); Water (3 exp.); Additives (8 exp.)

#### Benefits

- Complete equipment set: simple execution of the experiments; The equipment is stored in a rugged, stackable and compact box, allowing quick control of completeness
- Experimenting literature for pupils and teachers available
- Matched with international curriculum: all topics are covered
- Easy teaching and efficient learning by using the interactive experimentation software interTESS

#### List of topics Food Chemistry

##### 1. Proteins

- The structure and composition of proteins; The coagulation of egg white changes its composition; Producing Quark; Production of curd cheese

##### 2. Fat

- Winning oils; Production of soap/margarine; Composition/ Detection/Solubility of fats; Water content of fatty prod.; Removal of grease stains; Fresh and spent deep-fry fat

##### 3. Beverage

- Detection of methanol; Tanning matter in tea; Coffee in beverages

##### 4. Spices

- Active agents in pepper

#### 5. Carbohydrate

- The term carbohydrate; The solubility of carbohydrates; The detection of glucose with Fehling's solution; Reducing properties of glucose; Fructose; Lactose; Detection of starch; Potatoe starch and paste; Composition of starch; Wheat gluten; Pectins; Cleavage of starch during digestion

#### 6. Vitamines and minerals

- Detection of vitamin C; Detection of starch

#### 7. Water

- Drinking water treatment; Compounds containing N; CO<sub>2</sub>

#### 8. Additives

- Ammonia in liquorice; Phosphate/Nitrite in meat products; Enzymatic browning; Baking powder; Emulsifying agents; Enzymatic cleavage of proteins; Catalases

#### Additionally required material

TESS advanced Food Chemistry, necessary Accessories for 1 group

13484-88

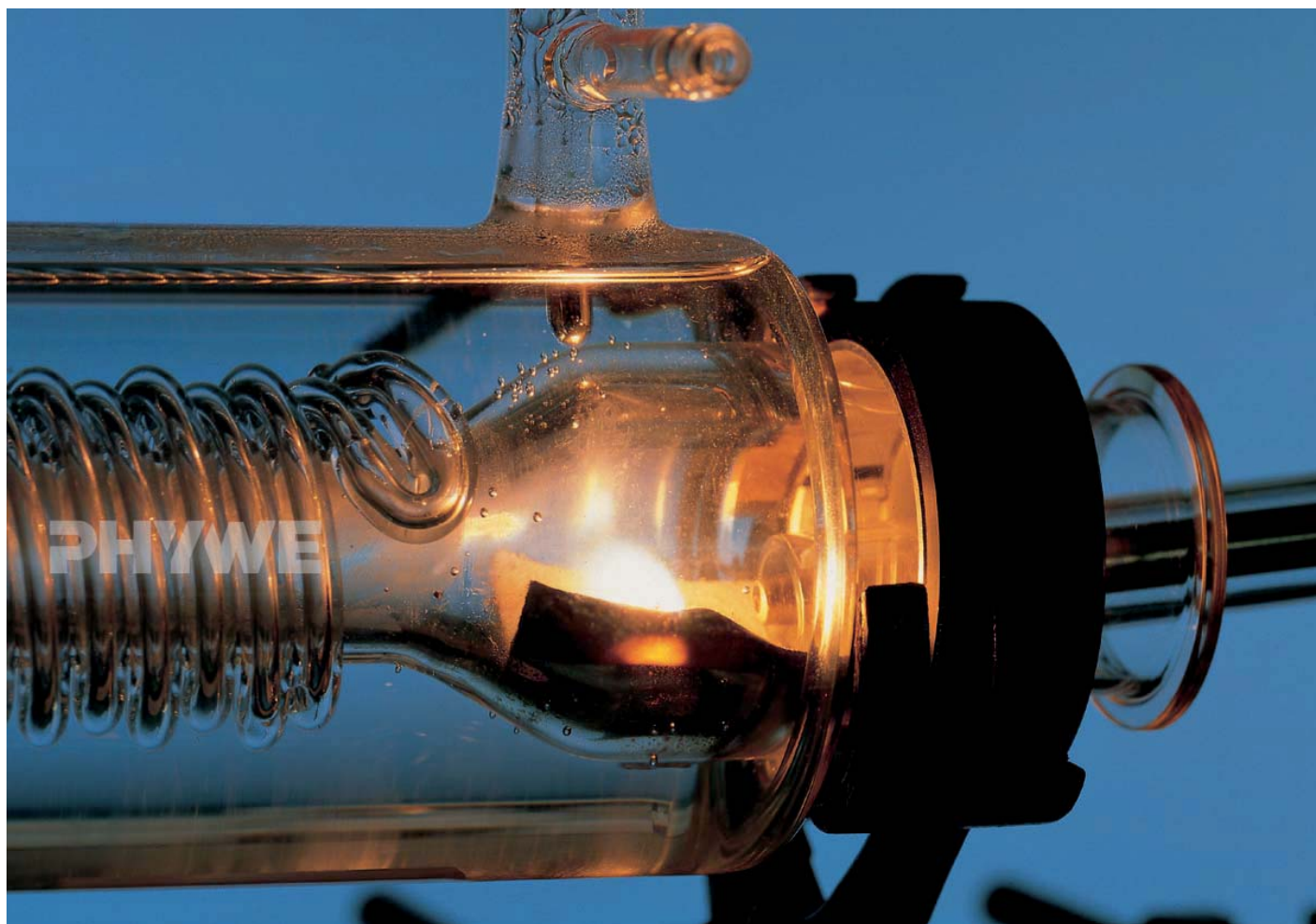
TESS advanced Food Chemistry, consumables and chemicals for 10 groups

13485-88

Software interTESS Chemistry, DVD

01060-00

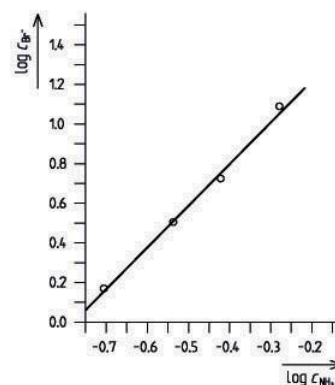




## General Chemistry

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### P3031001 Complex formation equilibrium / complex formation constant



Determination of the number of ligands bound in the complex.

#### Principle

Many metals, in particular transition elements, can form complexes with charged or neutral ligands. Complex formation reactions are equilibrium reactions. The stability of these complexes is described by the complex formation constant.

#### Task

Determine the number of ligands of the silver amine complex with a precipitation titration from a silver salt solution.

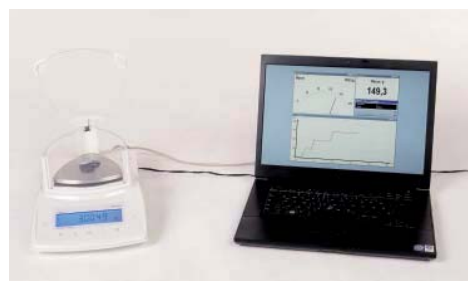
#### What you can learn about

- Complex formation
- Chemical equilibrium
- Equilibrium constant

#### Main articles

Magnetic stirrer Mini / MST	47334-93	1
Silver nitrate, cryst. 15 g	30222-00	1
Retort stand, h = 750 mm	37694-00	1
Burette, lateral stopcock, Schellbach, 25 ml	36506-01	1
Burette clamp, roller mount., 2 pl.	37720-00	1
Pipette dish	36589-00	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

#### Set of Precision Balance Sartorius CPA 623S and measure software, 230 V



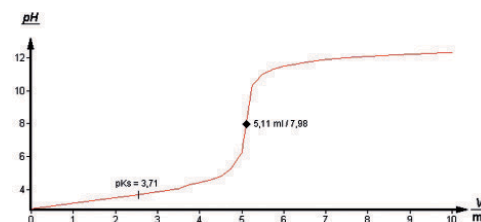
#### Function and Applications

The balances of the Sartorius CPA series convince already at first sight through an attractive, high-quality design - of the display up to the weighing pan. Onto the second look the "inner values" impress and that amazing price/power ratio. The "mechanical heart" of these balances is the patented monolithic weighing system which guarantees for confident and extremely precise weighing-results and beats in all models of the Sartorius CPA series. That ensures extremely precise weighing-results to your lab at shortest measuring times. Premium balances is also at Sartorius in any case: very best product quality with lasting reliability.

49224-88

## Dissociation equilibrium with Cobra4

P3030960



Neutralisation curve of formic acid.

### Principle

Carboxylic acids are potential electrolytes which exist in a weakly dissociated condition in aqueous solutions. The location of the dissociation equilibrium is quantitatively described by the  $K_a$  or  $pK_a$  value which can be determined with potentiometric measurements.

### Tasks

1. Measure the alteration of the pH value during a titration of approximately 0.1 molar aqueous solutions of formic acid, acetic acid, monochloroacetic acid, propionic acid, butyric acid and lactic acid with a 0.1 molar sodium hydroxide solution at constant temperature using Cobra4 system.
2. From the neutralisation curves read the  $pK_a$  values of the acids and compare them.

### What you can learn about

- True and potential electrolytes
- Strong and weak acids
- Law of mass action
- Henderson-Hasselbalch equation
- Dissociation constant and  $pK_a$  value
- Substituent effects
- Potentiometry

### Main articles

Cobra4 Wireless Manager	12600-00	1
Cobra4 Wireless-Link	12601-00	2
Cobra4 Sensor-Unit Chemistry	12630-00	1
Software Cobra4 - multi-user licence	14550-61	1
Magnetic stirrer Mini / MST	47334-93	1

### Cobra4 Sensor-Unit Drop Counter



### Function and Applications

The Cobra4 Drop Counter serves to count the number of drops that fall from a burette and so, indirectly, to quantitatively determine the volume of a liquid that flows from the burette.

The Cobra4 Sensor-Unit Drop Counter can be connected to one of the following devices to transfer the measured data: Cobra4 Wireless-Link, Cobra4 Mobile-Link, Cobra4 USB-Link or Cobra4 Junior-Link.

12636-00

### Solubility product with Cobra4

P3030862



NEW

4  
Cobra

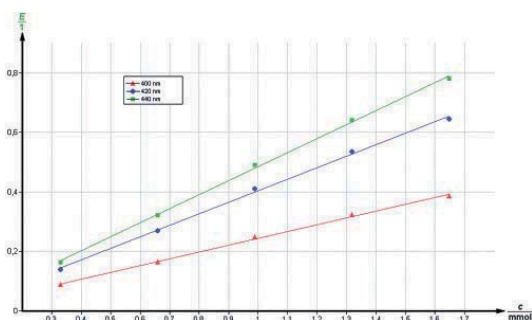
#### Principle

The solubility of poorly soluble salts is expressed as the solubility product, i.e. the product of the concentration of cations and anions in the solution which are in equilibrium with the solid salt. These concentrations can be determined via conductivity measurements.

For more details refer to page 36.

### Distribution equilibrium

P3030701



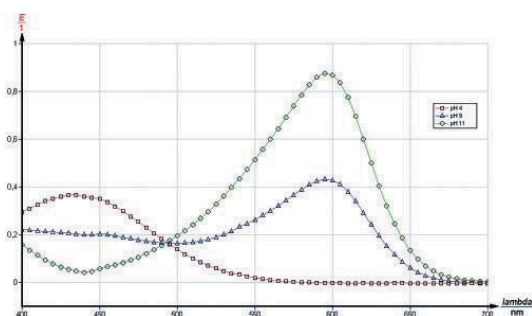
#### Principle

At constant temperature and under constant pressure, a dissolved substance distributes itself between two immiscible liquids in a constant concentration ratio. This ratio is equal to the partition coefficient (distribution coefficient) of the substance examined in the given two-phase system.

For more details refer to [www.phywe.com](http://www.phywe.com)

### Dissociation constants

P3031101



#### Principle

The coloured indicator thymol blue is a weak acid that is partially dissociated in aqueous solution, whereby non-ionized and ionized forms show absorption maximums at different wavelengths in the visible range. Photometric measurements in the visible spectral range can therefore be used to advantage to determine the position of the  $K_a$  and  $pK_a$  values of the indicator which characterize dissociation equilibrium.

For more details refer to page 38.



## Determination of molar mass using the ideal gas law

P3010401



$$M = \frac{m \cdot R \cdot T}{p \cdot V}$$

Rearranging the ideal gas equation to determine the molar mass.

**Principle**

All gases may be considered, to a first approximation, to obey the ideal gas equation which relates the pressure  $p$ , volume  $V$ , temperature  $T$  and amount of substance  $n$  of a gas. The amount of gas  $n$  is expressed as the number of moles and is equal to  $m/M$  where  $m$  is the mass of gas present and  $M$  is the mass of one mole of the gas. The volume occupied by a known mass of gas is to be measured at a given temperature and pressure, so that the ideal gas equation can be used to estimate the molar mass of the gas.

**Task**

Determine the molar masses of the gases helium, nitrogen, carbon dioxide and methane.

**What you can learn about**

- Molar mass and relative molar mass
- Properties of gases
- Ideal and ordinary gases
- Equations of state

**Main articles**

Rotary valve vacuum pump, one stage	02740-95	1
Weather monitor, 6 lines LCD	87997-10	1
Secure bottle, 500 ml, 2 x GI 18/8, 1 x 25/12	34170-01	1
Oil mist filter, DN 16 KF	02752-16	1
Glass sphere, 2 stopcocks, 100 ml	36810-00	1
Gas syringe, 100 ml, with 3-way cock	02617-00	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

**Rotary valve vacuum pump, one stage****Function and Applications**

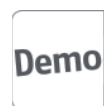
One-stage rotary vane pump suitable for the continuous operation in the rough and fine vacuum range.

**Benefits**

The pump has a high water vapour tolerance and a compact design. Due to their low weight, small dimensions and the high pumping speed, this pump is ideal to use in schools and laboratories. It is low maintenance, compact and exceptionally quiet. To prevent accidental damage the oil control glass is integrated into the housing. The casing of the pump is easy to wipe clean. Since a male ground joint ST 19 is supplied with the pump, pump plates with a ground socket ST19 can be put directly onto the pump.

02740-95

### P3010501 Determination of the molar mass of a liquid



Methanol:	$M_{\text{ideal}}$	=	32.5 g/mol
	$M_{\text{real}}$	=	32.2 g/mol
Diethyl ether:	$M_{\text{ideal}}$	=	74.6 g/mol
	$M_{\text{real}}$	=	73.5 g/mol

Measurement results of the molecular mass for methanol and diethyl ether.

#### Principle

The molar mass of a liquid is to be determined by evaporating a liquid at constant temperature and pressure, and measuring the volume of vapour formed using a calibrated gas syringe.

#### Tasks

1. Determine the molar masses of diethyl ether and methanol.
2. Discuss the results in terms of the real and ideal behaviour of vapours.

#### What you can learn about

- Ideal and ordinary gases
- Equations of state for ideal gases
- Gas volumetry
- Determination of molar masses according to the vapour density method (Victor Meyer)

#### Main articles

Set gas laws with glass jacket, 230 V	43003-88	1
Weather monitor, 6 lines LCD	87997-10	1
Power regulator	32288-93	1
Methanol 500 ml	30142-50	1
Diethyl ether 250 ml	30007-25	1
Water, distilled 5 l	31246-81	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

#### Set gas laws with glass jacket, 230 V



#### Function and Applications

With this set, experiments on the following topics can be carried out:

- Gas law of Boyle-Mariotte
- Gas law of Gay-Lussac
- Gas law of Amonton (Charles)
- Determination of molar masses according to the vapour density method

#### Benefits

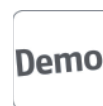
This set allows to execute the measurements in a didactical clear and easy understandable way:

- Clear setup; Easy to understand
- Completely mercury-free
- Quickly to execute; Short preparation time

43003-88

## Determination of molar masses via a measurement of the boiling point elevation (ebullioscopy)

P3021900



$$K = \frac{M \cdot \Delta T \cdot m_L}{m_S \cdot 1000}$$

Equation to demonstrate the ebullioscopic constants of solvents with known molecular weight.

### Principle

Didactic setup to train and demonstrate the determination of molar masses by way of a measurement of the boiling point elevation. The boiling point elevation of aqueous solutions of different substances is determined using. The ebullioscopic constant of water is calculated from the experimental results.

### Tasks

1. Determine the boiling point elevation of aqueous solutions of different substances.
2. Calculate the ebullioscopic constant of water from the experimental results.

### What you can learn about

- Molar mass
- Boiling point elevation
- Ebullioscopy
- Ebullioscopic constant

### Main articles

Temperature meter digital, 4-2	13617-93	1
Heating mantle f. roundbottom flask, 250ml	49542-93	1
Apparatus for elevation of boiling point	36820-00	1
Desiccator, Wertex, diam. 150 mm	34126-00	1
Power regulator	32288-93	1
Temperature probe, immersion type, Pt100	11759-01	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

### Apparatus for elevation of boiling point



### Function and Application

Apparatus for determining molar mass, boiling point method.

### Equipment and technical data:

- 2 glass vessels of DURAN glass. The outer vessel has an inlet for introduction of vapour from the solvent mixture.

A thin tube lies along the side of the inner vessel almost reaching the bottom. This also allows the circulation of the escaping vapour.

36820-00

## P3022000 Determination of molar masses via a measurement of the freezing point depression (cryoscopy)



$$M = \frac{m_s}{m_L \cdot \Delta T} \cdot K$$

Equation for the calculation of molar masses of a dissolved substance based on the measurement of the freezing-point depression of the solvent.

### Principle

In order to train and demonstrate the determination of molar masses by way of a measurement of the freezing-point depression, urea or hydroquinone are used as test substances. The cryoscopic constant of water is determined from the freezing point depression.

### Tasks

1. Determine the freezing point depression of water dissolving different amounts of hydroquinone and urea.
2. Calculate the cryoscopic constant from the experimental results.

### What you can learn about

- Cryoscopic constant
- Freezing point depression
- Molar mass

### Main articles

Temperature meter digital, 4-2	13617-93	1
Magnetic stirrer MR Hei-Standard	35750-93	1
Desiccator, Wertex, diam. 150 mm	34126-00	1
Apparatus for freezing point depression	36821-00	1
Temperature probe, immersion type, Pt100	11759-01	1
Pellet press for calorimeter	04403-04	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

### Apparatus for freezing point depression



### Function and Applications

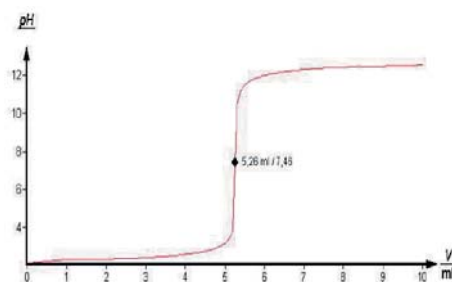
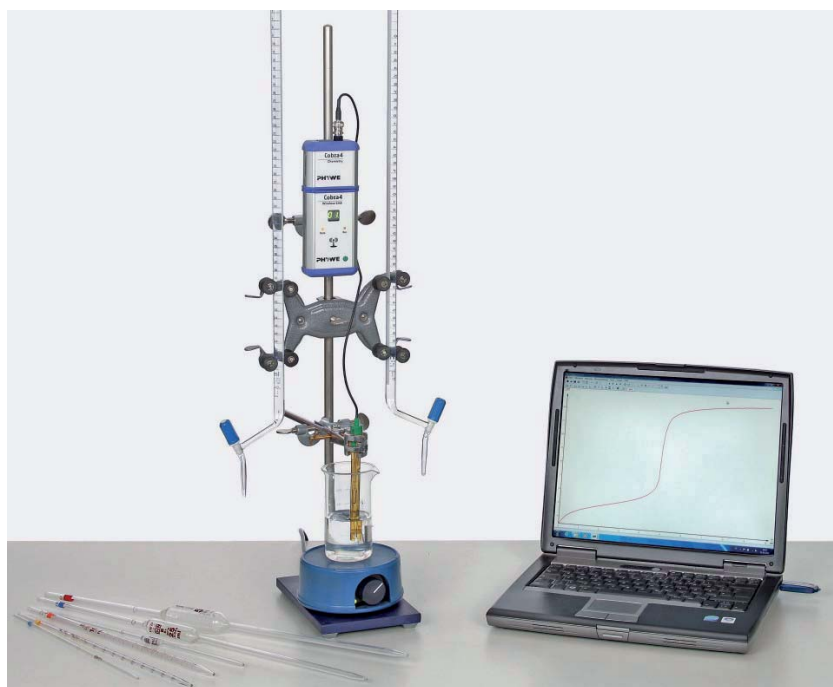
Apparatus for determining molar mass, freezing point method. The unit consists of an inner and an outer glass vessel of DURAN glass. The inner vessel has a flat bottom to accommodate magnetic stirrer bars and with lateral inlet for introduction of the substance to be tested.

36821-00



## Titration curves and buffering capacity with Cobra4

P3061660



Titration curve of acetic acid with sodium hydroxide solution.

### Principle

pH values can be measured with the aid of electrochemical measurements and proton-sensitive electrodes (e.g. glass electrodes). By combining a glass electrode with a reference electrode in one housing, a single-rod glass electrode, which is appropriate for acid-base titrations, is created. The titration curves allow an exact determination of the equivalence point in titrations of strong and weak acids and bases.

### Tasks

1. Determine the titration curves of different neutralisation reactions.
2. Determine the titration curve of an ampholyte (glycine).
3. Determine the buffering capacity of various aqueous acetic acid/sodium acetate mixtures at different total concentrations.

### What you can learn about

- Strong and weak electrolytes; Hydrolysis; Dissociation of water; Amphoteric electrolytes; Isoelectric point; Law of mass action; Indicators; Glass electrode; Activity coefficient; Buffering capacity; Henderson-Hasselbalch equation

### Main articles

Software Cobra4 - multi-user licence	14550-61	1
Cobra4 Wireless-Link	12601-00	2
Cobra4 Sensor-Unit Chemistry	12630-00	1
Cobra4 Sensor-Unit Drop Counter	12636-00	1
Cobra4 Wireless Manager	12600-00	1
Magnetic stirrer Mini / MST	47334-93	1

### Cobra4 Sensor-Unit Chemistry



### Function and Applications

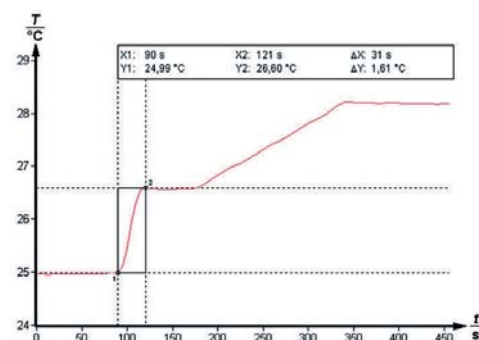
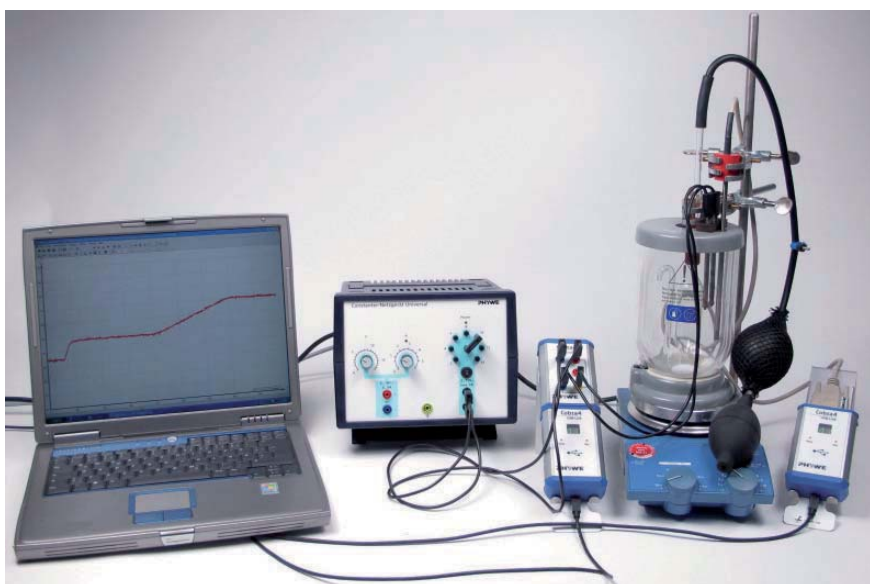
The Cobra4 Sensor-Unit pH and 2 x temperature NiCr-Ni is a measuring recorder for pH, potential and temperature measurements, which is controlled by micro-controller.

### Benefits

- It can be fitted with two NiCr-Ni thermoelements (Type K) and a pH probe or redox measuring chain
  - Measure up to two temperatures and one pH or potential value simultaneously.
  - Discover new experimental possibilities especially in thermodynamics
- Values of the calibration are saved in the sensor - no need for new calibration.
- The sensor is not restricted to the measurement of pH values: Connect the redox electrode 46267-10 to measure redox potentials.
- The unit can be connected to the Cobra4 Wireless-Link, the Cobra4 Mobile-Link or the Cobra4 USB-Link using a secure and reliable plug-in/lockable connection.

12630-00

### P3020861 Determination of the enthalpy of neutralisation with Cobra4



Temperature-time curve of neutralisation and determining the heat capacity of the system.

#### Principle

When a strong acid is neutralised with a strong base in dilute solution, the same amount of heat is always released. If the reaction takes place under isobaric conditions, this heat is known as the enthalpy of neutralisation. The chemical reaction which generates this heat is the reaction of protons and hydroxyl ions to form undissociated water. It therefore correlates to the enthalpy of formation of water from these ions.

#### Tasks

1. Measure the temperature change during the neutralisation of a dilute potassium hydroxide solution with dilute hydrochloric acid.
2. Calculate the enthalpy of neutralisation.

#### What you can learn about

- Enthalpy of neutralisation
- Calorimetry
- Heat capacity

#### Main articles

Cobra4 Sensor-Unit Energy: Current, voltage, work, power	12656-00	1
Cobra4 USB-Link	12610-00	2
Set of Precision Balance Sartorius CPA 6202S and measure software, 230 V	49226-88	1
Power supply, universal	13500-93	1
Magnetic stirrer MR Hei-Standard	35750-93	1
Software Cobra4 - multi-user licence	14550-61	1
Calorimeter, transparent, 1200 ml	04402-00	1

#### Cobra4 Sensor-Unit Energy: Current, voltage, work, power



#### Function and Applications

The Cobra4 Sensor-Unit Energy is used for the measurement and direct indication of measurement variables of the electrical power and energy in direct current and alternating current circuits (current, voltage, effective and apparent power, angular phase shift, frequency, electric work).

#### Benefits

This sensor measures directly the values for alternating current and direct current. This allows numerous basic as well as application-oriented experiments, e.g. the determination of the characteristics of alternating current resistances or the investigation of the energy demand of consumers.

12656-00

### Titration of a polyvalent acid with a strong base with Cobra4

P3121260



NEW

4  
Cobra

#### Principle

Phosphoric acid and sodium hydroxide are to be used to give an example of a titration of a polyvalent acid with a strong base.

For more details refer to page 52.

### Titration of a weak organic acid with sodium hydroxide with Cobra4

P3121360



NEW

4  
Cobra

#### Principle

Acetic acid and sodium hydroxide are to be used to give an example of a titration of a weak organic acid with sodium hydroxide.

For more details refer to page 52.

### Titration of a weak base (ammonia) with a strong acid with Cobra4

P3121460



NEW

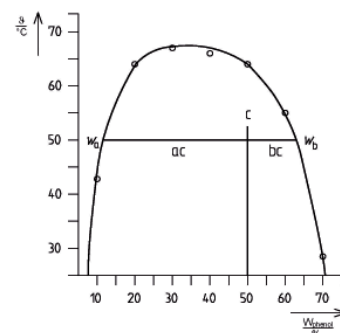
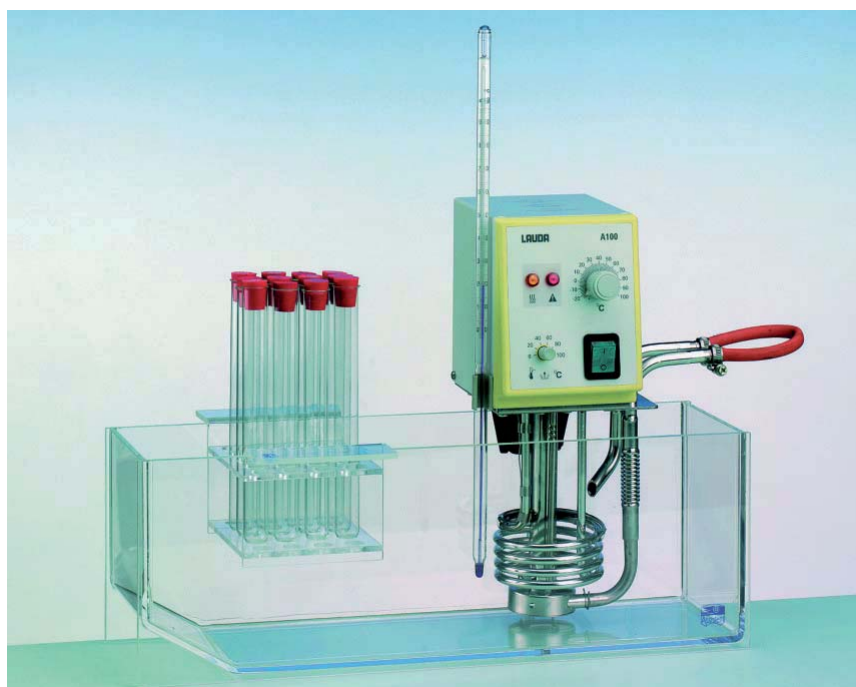
4  
Cobra

#### Principle

The titration of ammonia solution with hydrochloric acid is used here as a typical example of a titration of a weak base with a strong acid.

For more details refer to page 52.

**P3030501 Solubility diagram of two partially miscible liquids**



Solubility diagram of the phenol/water system.

**Principle**

A number of different mixtures of phenol and water are prepared and heated until complete miscibility is achieved. As the mixtures cool, two-phase systems form at certain temperatures which are recognisable by the appearance of turbidity. Plotting separation temperatures against compositions of the mixtures gives the separation curve.

**Tasks**

1. Plot the separation curve of the phenol / water binary system and prepare a temperature / mass fraction diagram.
2. Determine the critical separation point.

**What you can learn about**

- Binary system
- Miscibility gap
- Mixed phase
- Coexisting phase
- Raoult's law
- Critical dissolution temperature

**Main articles**

Immersion thermostat Alpha A, 230 V	08493-93	1
Bath for thermostat, makrolon	08487-02	1
Rack for 20 test tubes, Makrolon	08487-03	1
External circulation set f. thermostat Alpha A	08493-02	1
Retort stand, h = 750 mm	37694-00	1
Burette clamp, roller mount., 2 pl.	37720-00	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

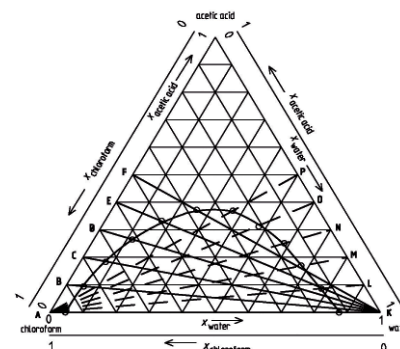


made  
in  
Germany



## Miscibility gap in a ternary system

P3030601



Triangular diagram of the system acetic acid/ chloroform/water.

### Principle

A number of completely miscible two component mixtures are prepared to investigate the three component acetic acid / chloroform / water system. These mixtures are titrated with the third component until a two phase system is formed which causes turbidity. The phase diagram for the three component system is plotted in a triangular diagram.

### Tasks

1. Titrate nine different acetic acid / chloroform mixtures with water until a two phase system is formed in each case.
2. Titrate six acetic acid / water mixtures with chloroform until phase separation is observed.
3. Plot the results of the titrations, expressed as molar fractions, in a triangular diagram.

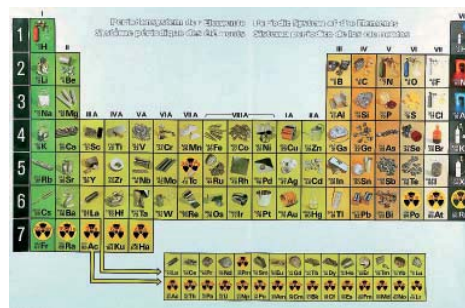
### What you can learn about

- Three component system
- Miscibility gap
- Phase diagram
- Triangular diagram
- Gibb's phase law

### Main articles

Immersion thermostat Alpha A, 230 V	08493-93	1
Bath for thermostat, Makrolon	08487-02	1
Rack for 20 test tubes, Makrolon	08487-03	1
External circulation set f. thermostat Alpha A	08493-02	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

## Periodic system with colour pictures



### Function and Applications

Wall map in multicoloured offset printing on flexible Pretex-foil with rods.

### Benefits

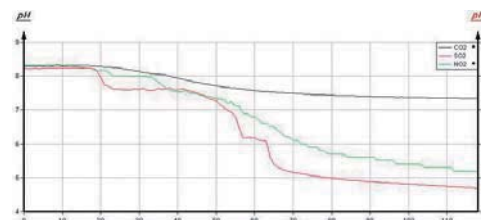
- The elements are shown with an application, the commercial form, radioactive elements with the radioactivity symbol and the half-life.
- The photos supply informations about appearance and aggregate state, metal or nonmetal character, modifications, storage and reactivity of the elements.
- Important correlations of the periodic table can be recognized immediately, basic properties of the elements are memorized.

### Equipment and technical data

- Dimensions (L x H): 195 x 138 cm

47310-02

## P4100760 Origin of acid rain with Cobra4



pH-time curve for  $\text{SO}_2$ ,  $\text{NO}_2$  and  $\text{CO}_2$ .

### Principle

Acid rain is caused by emissions from power plants, households and traffic. Gases such as sulfur dioxide, nitrogen dioxide and carbon dioxide dissolve in rainwater, the products of which form the acids (acids containing sulfur, nitrous acid, nitric acid, carbonic acid). Acid rain reduces the pH of soils and waters. Environmental damage such as forest dieback is the result.

In this experiment acid rain will be produced artificially by adding the gases  $\text{SO}_2$ ,  $\text{NO}_2$  and  $\text{CO}_2$  to water. The fall of the pH value is registered.

### Task

Add the gases  $\text{SO}_2$ ,  $\text{NO}_2$  and  $\text{CO}_2$  to water and record the fall of the pH value.

### What you can learn about

- Acid rain
- Anthropogenic air pollution
- Damage to forests
- Acidification of soil and water
- Gaseous and aerosol emissions

### Main articles

Cobra4 Wireless Manager	12600-00	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Sensor-Unit pH, BNC connector	12631-00	1
pH-electrode, plastic body, gel, BNC	46265-15	1
Software Cobra4 - multi-user licence	14550-61	1
Retort stand, h = 750 mm	37694-00	2
Separatory funnel, 100 ml pear-sh.	36883-00	1

### Cobra4 Wireless-Link



### Function and Applications

Interface module for the radio-based transmission of sensor measuring values in conjunction with the Cobra4 Wireless Manager.

### Benefits

- All Cobra4 Sensor-Units can be quickly connected using a secure and reliable plug-in / lockable connection.
- All Cobra4 measuring sensors are easy to plug in and automatically detected.
- The radio network with the Cobra4 Wireless Manager is established automatically and is extremely stable, as it uses its own radio protocol.
- Up to 99 Cobra4 Wireless-Links can be connected to one Cobra4 Wireless Manager.
- No more cable mess, thanks to radio measuring.
- With radio transmission, moving sensors offer completely new experimentation options, e.g. the measurement of acceleration of a student on a bicycle etc.

12601-00

## Concentration cells without transport: Determination of the solubility products of silver halides

P3061062



$c / \text{mol} \cdot \text{l}^{-1}$	$\text{AgNO}_3$	KCl	KBr	KI
0.001	0.945	0.965	0.965	0.965
0.01	0.897	0.902	0.903	0.905
0.1	0.734	0.770	0.772	0.778

Mean activity coefficients  $f_{\pm}$  for  $\text{AgNO}_3$ , KCl, KBr, KI at  $T = 25 \text{ }^\circ\text{C}$ .

### Principle

A concentration cell is constructed from two half-cells which are identical, except that the concentration of the ionic species to which the electrode is sensitive is different in the two sides of the cell. Such a cell may be used to measure the solubility product of a sparingly soluble salt. In one half-cell the concentration of these ions is known, in the other it is determined by the solubility product of the salt under investigation. The ratio of the two concentrations (more accurately, activities) determines the e.m.f. of the cell.

### Task

Use a concentration cell made from two  $\text{Ag(s)} \mid \text{Ag}^+(\text{aq})$  electrodes, to determine the solubility product of the three silver halides  $\text{AgCl}$ ,  $\text{AgBr}$  and  $\text{AgI}$ .

### What you can learn about

- Concentration cells without transport; Electromotive force
- Salt bridge; Liquid junction and diffusion potentials

### Main articles

Cobra4 Mobile-Link	12620-00	1
Cobra4 Sensor-Unit Chemistry	12630-00	1
Immersion probe NiCr-Ni, teflon, 300 °C	13615-05	1
Silver nitrate, cryst. 15 g	30222-00	1
Silver foil, 150 x150 x 0.1 mm, 25 g	31839-04	1
Clay pins, d = 8 mm, l = 15 mm, 2 pcs.	32486-00	1
Set of Analytical Balance Sartorius CPA 224S and measure software, 230 V	49221-88	1

### Cobra4 Mobile-Link 2



### Function and Applications

The Mobile-Link can be used in combination with all of the Cobra4 sensors. It enables measurements in the stand-alone mode without a PC.

2013 marks the launch of the new Mobile-Link generation with numerous new, extended, and improved functionalities for successful use during your classes.

12620-09

### P3030862 Solubility product with Cobra4



$c / \text{mol} \cdot \text{l}^{-1}$	$\text{AgNO}_3$	KCl	KBr	KI
0.001	0.945	0.965	0.965	0.965
0.01	0.897	0.902	0.903	0.905
0.1	0.734	0.770	0.772	0.778

Ionic conductivities at infinite dilution.

#### Principle

The solubility of poorly soluble salts is expressed as the solubility product, i.e. the product of the concentration of cations and anions in the solution which are in equilibrium with the solid salt. These concentrations can be determined via conductivity measurements.

#### Tasks

1. Measure the conductivities of saturated aqueous solutions of the salts calcium fluoride and calcium carbonate at 25 °C.
2. With the aid of tabulated ionic conductivities, calculate the solubility products of the salts from their conductivities.

#### What you can learn about

- Solubility
- Dissociation
- Electrolytic conductance
- Activity

#### Main articles

Cobra4 Mobile-Link set	12620-55	1
Cobra4 Sensor-Unit Conductivity+	12632-00	1
Conductivity temperature probe Pt1000	13701-01	1
Immersion thermostat Alpha A, 230 V	08493-93	1
Bath for thermostat, makrolon	08487-02	1
Magnetic stirrer Mini / MST	47334-93	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

#### Cobra4 Sensor-Unit Conductivity+



#### Function and Applications

The Cobra4 Sensor Unit Conductivity / Temperature (Pt1000) is a microcontroller-based measuring recorder with a 5-pin diode socket for connecting conductance measuring sensors with a cell constant of  $K = 1.00/\text{cm}$  or Pt1000 thermocouples.

#### Benefits

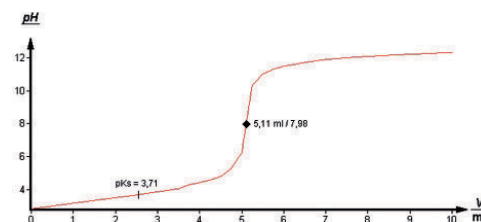
- Measure conductivity or temperature - multipurpose-sensor.
- The Cobra4 sensor may be connected directly to the Cobra4 Wireless-Link, the Cobra4 Mobile-Link, the Cobra4 USB-Link or the Cobra4 Junior-Link using a secure and reliable snap-in connection.

12632-00



## Dissociation equilibrium with Cobra4

P3030960



Neutralisation curve of formic acid.

### Principle

Carboxylic acids are potential electrolytes which exist in a weakly dissociated condition in aqueous solutions. The location of the dissociation equilibrium is quantitatively described by the  $K_a$  or  $pK_a$  value which can be determined with potentiometric measurements.

### Tasks

1. Measure the alteration of the pH value during a titration of approximately 0.1 molar aqueous solutions of formic acid, acetic acid, monochloroacetic acid, propionic acid, butyric acid and lactic acid with a 0.1 molar sodium hydroxide solution at constant temperature using Cobra4 system.
2. From the neutralisation curves read the  $pK_a$  values of the acids and compare them.

### What you can learn about

- True and potential electrolytes; Strong and weak acids; Law of mass action
- Henderson-Hasselbalch equation; Dissociation constant and  $pK_a$  value; Substituent effects; Potentiometry

### Main articles

Cobra4 Wireless Manager	12600-00	1
Cobra4 Wireless-Link	12601-00	2
Cobra4 Sensor-Unit Chemistry	12630-00	1
Cobra4 Sensor-Unit Drop Counter	12636-00	1
Software Cobra4 - multi-user licence	14550-61	1
Magnetic stirrer Mini / MST	47334-93	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

### Cobra4 Wireless Manager



### Function and Applications

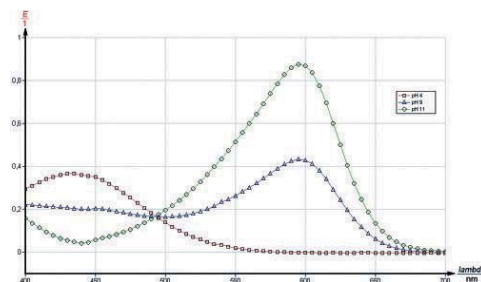
USB device for radio-based communication with the Cobra4 Wireless-Link.

### Benefits

- Simply connect the device to the computer's USB port.
- Up to 99 measuring sensors can be connected to one computer
- Automatic detection of all connected measuring sensors.

12600-00

P3031101 Dissociation constants



Absorption spectra of thymol blue at pH = 4, pH = 9 and pH = 11.

**Principle**

The coloured indicator thymol blue is a weak acid that is partially dissociated in aqueous solution, whereby non-ionized and ionized forms show absorption maximums at different wavelengths in the visible range. Photometric measurements in the visible spectral range can therefore be used to advantage to determine the position of the  $K_a$  and  $pK_a$  values of the indicator which characterize dissociation equilibrium.

**Tasks**

1. Experimentally determine the extinction (absorbance) of an aqueous solution of thymol blue (thymolsulphonephthalein) in dilute HCl, NaOH and a buffer of known pH value as a function of wavelength between 400 and 700 nm at constant concentration and constant temperature.
2. Calculate the dissociation constant (indicator constant)  $K_a$  from the measurement results.

**What you can learn about**

- True and potential electrolytes; Strong and weak acids
- Law of mass action; Dissociation constants and  $pK_a$  values
- Henderson-Hasselbalch- Equation; UV-VIS spectrometry
- Lambert-Beer's Law; Photometry

**Spectrophotometer 190-1100 nm**

**Function and Applications**

Spectrophotometer 190-1100 nm

**Benefits**

- The UV-VIS spectral photometer is characterised by its compact design and due to its wide range of possible uses.
- Operation is via a clearly set out overlay keyboard on the screen dialogue.
- Current wavelengths and measured values can be displayed in large format.
- Alternatively, all measured values can also be presented graphically or in table format on the LCD screen with background lighting.
- Strong light, high performance optics enable absorption and transmission measurements to be taken in the whole wavelength range of 200 to 1100 nm with automatic switching between the two light sources.

**35655-93**

Main articles		
Spectrophotometer 190-1100 nm	35655-93	1
Cells for spectrophotometer, opt. glass, 2 pcs.	35664-02	1
Buffer solution, pH 9 1000 ml	30289-70	1
Ethyl alcohol, absolute 500 ml	30008-50	1
Thymol blue indicator 5 g	31896-02	1
Thermometer -10...+50 °C	38034-00	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

## Boiling point elevation

P3021001



### Principle

The boiling point of a solution is always higher than that of the pure solvent. The dependence of the temperature difference (elevated boiling point) on the concentration of the solute can be determined using a suitable apparatus.

For more details refer to page 122.

## Freezing point depression

P3021101



### Principle

The freezing point of a solution is lower than that of the pure solvent. The depression of the freezing point can be determined experimentally using a suitable apparatus (cryoscopy). If the cryoscopy constants of the solvent are known, the molecular mass of the substance dissolved can be determined.

For more details refer to page 123.

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send an email to [info@phywe.com](mailto:info@phywe.com)

### P3110600 Redox reactions between metals and metal oxides (thermite process)



Demo



Experimental setup.

#### Principle

The experiments described here are highly suitable for demonstrating the different affinity of various metals in view of oxygen. The less noble a metal is the higher its affinity to oxygen and the more thermal energy is released during its oxidation. The technical importance of the thermite process for the welding of iron parts is that it is relatively easy to produce large amounts of liquid iron and, thereby, to fill wider weld grooves. This is why this process is mainly used for welding thick steel beams, rail tracks, and machine parts.

#### Tasks


1. Reduction of copper oxide with iron.
2. Reduction of iron oxide with aluminium (thermite process, aluminothermics).

#### What you can learn about

- Redox reaction; Thermite process
- Metals; Welding of iron; Aluminothermics
- Iron; Aluminium

#### Main articles

Retort stand, h = 750 mm	37694-00	1
Iron powder xtra pure 1000 g	30068-70	1
Magnet, d = 10 mm, l = 200 mm	06311-00	1
Teclu burner, DIN, natural gas	32171-05	1
Ignition sticks for thermite, 50 pcs.	31921-05	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

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 send an email to [info@phywe.com](mailto:info@phywe.com)

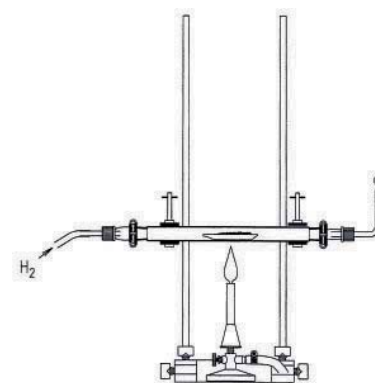


## Reduction - reducing agents - redox process

P3100300



Demo



Reduction of ferric oxide with hydrogen.

### Principle

The reduction, as the reversal of the oxidation, can be achieved thermally or with the aid of a reducing agent.

Some metal oxides can be decomposed into the metal and oxygen under the influence of thermal energy. In the case of less noble metals, a reducing agent is required for obtaining the elements. The redox processes during the preparation of lead demonstrate the relationship between oxidation and reduction.

By way of this experiment it can be shown that during the reduction of an oxide the reducing agent itself is oxidised: hydrogen to water, carbon to carbon dioxide. A reduction process is always coupled with an oxidation process, which is why this type of reaction is referred to as a redox reaction.

### Tasks

1. Reduction of lead(IV) oxide to lead(II) oxide by thermolysis.
2. Reduction of lead(II) oxide by way of charcoal to obtain elementary lead.
3. Reduction of iron oxide including the formation of hydrogen based on pyrophoric iron.

### What you can learn about

- Reduction; Oxidation; Redox reaction
- Lead; Iron; Thermolysis

### Main articles

Steel cylinder hydrogen, 2 l, full	41775-00	1
Gas bar	40466-00	1
Reducing valve for hydrogen	33484-00	1
Table stand for 2 l steel cylinders	41774-00	1
Combustion tube, 300 mm, quartz, ns	33948-01	1

### Gas bar

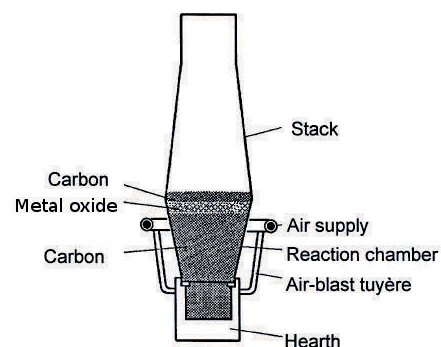


### Function and Applications

Gas bar to provide small quantities of gas ready to use, e.g. hydrogen and oxygen when using the eudiometer. The required gas quantity can be removed with a syringe through the rubber cap. Two small gasometers, capacity app. 200 ml gas. Each max. filling pressure 30 bar. With tripod and stickers for labelling.

40466-00

### P3100400 Reduction of lead oxide



The blast furnace with which iron can be obtained from iron oxide.

#### Principle

Lead oxide is reduced to lead; in the process the carbon is oxidised to carbon dioxide. In this experimental set-up and also in the blast furnace process, the reducing agent proper is not carbon, but rather the carbon monoxide generated due to the oxygen deficit.

#### Task

Demonstrate the reduction of lead oxide.

#### What you can learn about

- Lead
- Carbon monoxide
- Reduction
- Oxidation
- Redox reaction

#### Main articles

Support base variable	02001-00	1
Lead-II oxide -litharge- 500 g	31121-50	1
Bunsen burner DIN, natural gas	32165-05	1
Ring with boss head, i. d. = 10 cm	37701-01	1
Activated carbon, granular 250 g	30011-25	1
Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	1
Safety gas tubing, DVGW, sold by metre	39281-10	1



### Sulphur trioxide - the sulphuric acid contact process

P3110400



#### Principle

The contact process is currently used in the chemical industry to produce sulphuric acid in the high concentrations needed for industrial processes. In this model experiment, platinum-palladium-aluminium-oxide beads are employed as a catalyst for the reaction.

For more details refer to page 177.

### Preparation of iron from oxidic ores (blast furnace process)

P3110500



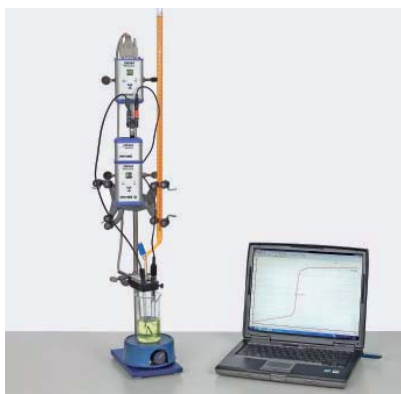
#### Principle

This is a model experiment to show the industrial blast furnace process to produce iron from iron(III) oxide. During the experiment a furnace gas flame that is approximately 10 to 20 cm high can be ignited at the stack outlet. Cavities form in the burning carbon layer. These cavities collapse over time. Apart from ash and carbon residues, metallic lumps can also be found in the frame after the end of the experiment. Samples of these lumps lead to the formation of hydrogen when they are treated with hydrochloric acid.

For more details refer to page 186.

### Volumetric redox titration: Cerimetry with Cobra4

P3121060

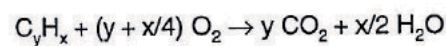
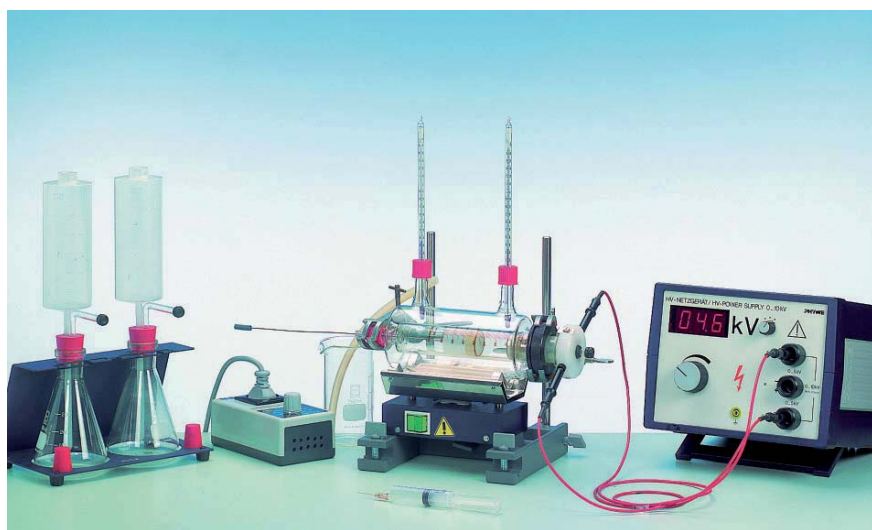


#### Principle

Potassium permanganate solutions which are used as oxidizing measuring solutions in redox titrations can in most cases be replaced by Ce(IV) solutions. These offer the advantages that they do not change on storage and that the course of the redox titration can be very conveniently followed by measuring the electrochemical potential. The equivalent point can then be found by determination of the inflection point of the potential curve which results from plotting the measured values.

For more details refer to page 50.

## P3110900 The empirical formula of methane, ethane and propane



Reaction equation of the combustion of hydrocarbons.

### Principle

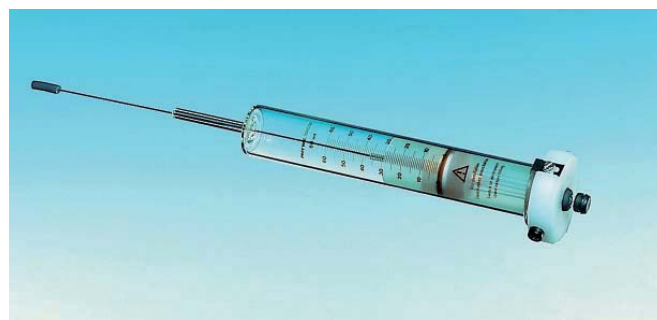
A quiescent eudiometer is inserted into the glass jacket and the glass jacket is filled with cold water. Gas mixtures composed of hydrocarbons and oxygen are injected into the eudiometer and burn there continuously at the constant sparking of the ignition spark gap. The water formed by the reaction condenses on the cool walls of the eudiometer. For this reason, the volume between the moving plunger and the fixed plunger with the ignition system after combustion is smaller than the volume of the gas mixture originally injected. In a second part of the experiment, the eudiometer in the glass jacket is heated up to over 100°C. The water formed during combustion can no longer condense on the hot eudiometer walls.

In most cases, even after conversion to standard conditions, the volume recorded then is greater than the volume of the gas that was injected. The easiest way to convert the volumes to standard conditions is with a nomogram. The measurement data obtained in this way can be used to derive the empirical formulas of gaseous hydrocarbons experimentally.

### Main articles

Cobra4 hand-held pressure and temperature measuring instrument, Cobra4 Mobile-Link	12736-00	1
High voltage supply unit, 0-10 kV, less than 2 mA	13673-93	1
Slow eudiometer	02612-00	1
Glass jacket	02615-00	1
Heating apparatus for glass jacket system	32246-93	1
Steel cylinder oxygen, 2 l, filled	41778-00	1
Support base DEMO	02007-55	1

### Slow eudiometer



### Function and Applications

Eudiometer, silent for the determination of volume ratios for continuous combustion of gas mixtures.

### Benefits

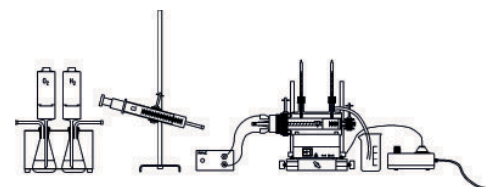
- Glass cylinder with scale, as well as fixed and movable pistons
- Ignition over a duration of sparks from a high voltage device
- The gas mixtures are simply injected into the eudiometer using an injection syringe.
- The ignition of the gas mixture then occurs easily and safely with the aid of the ignition spark generator.

02612-00



## Avogadro's law

P3111000



Schematical set-up of the experiment.

### Principle

In 1811, Avogadro stated his hypothesis that under the same conditions of pressure and temperature, equal volumes of all gases contain equal numbers of components (molecules, atoms). He derived this from the uniformity of the behaviour of (ideal) gases on increases in temperature and pressure (see the Gas Laws) and the Law of Volumes. When Avogadro's supposition is correct, then 6 parts by volume of CO and 3 parts by volume of O<sub>2</sub> must form 6 parts by volume of CO<sub>2</sub> when pressure and temperature are the same before and after the reaction. Similarly, at a temperature a little above 100 °C, a gas mixture containing 6 parts by volume of H<sub>2</sub> and 3 parts by volume of O<sub>2</sub> must give 6 parts by volume of steam, and a mixture containing 5 parts by volume of H<sub>2</sub> and 5 parts by volume of Cl<sub>2</sub> must give 10 parts by volume of HCl. In the following experiments we will carry out the reactions named above to test the correctness of the hypothesis.

### Tasks

Perform the following reactions to verify Avogadro's law:

1. Preparation of carbon monoxide and chlorine
2. The carbon monoxide/oxygen reaction
3. The hydrogen/oxygen reaction at above 100 °C
4. The hydrogen/chlorine reaction at above 100 °C

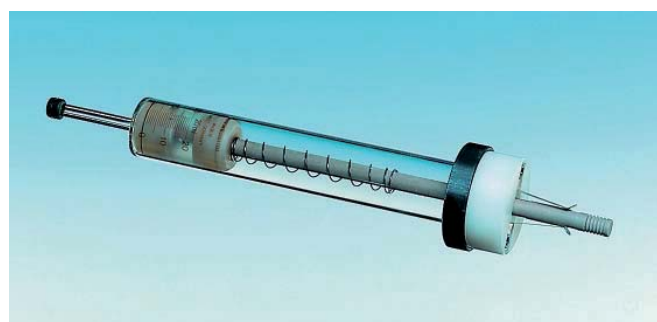
### What you can learn about

- Avogadro's law; Gas laws; Carbon monoxide
- Hydrogen; Chlorine; Oxygen

### Main articles

Plunger eudiometer	02611-00	1
Glass jacket	02615-00	1
Steel cylinder hydrogen, 2 l, full	41775-00	1
Heating apparatus for glass jacket system	32246-93	1
Steel cylinder oxygen, 2 l, filled	41778-00	1
Power regulator	32288-93	1

### Plunger eudiometer



### Function and Applications

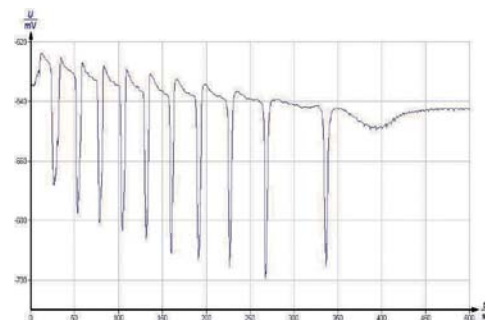
The plunger eudiometer consists of a glass cylinder with a movable plunger and is used to determine the ratio of volumes in explosive gas reactions.

### Benefits

- Two 4-mm sockets connect the ignition spark generator.
- This device can be used to cause gas mixtures to react at room temperature, which lead to gaseous reaction products or in which residual quantities of the reaction gases remain in the cylinder (e.g. mixtures of air and hydrogen, of carbon monoxide and oxygen).
- The gas mixtures are simply injected into the eudiometer using an injection syringe.
- The ignition of the gas mixture then occurs easily and safely with the aid of the ignition spark generator.
- If the plunger eudiometer is assembled in the glass jacket, the ratio of volumes of gas reactions can also be investigated at temperatures other than room temperature, such as the reaction of a stoichiometric mixture of hydrogen and oxygen at above 100°C.

02611-00

## P3121660 Briggs-Rauscher Reaction with Cobra4



Graph of measured potential against time.

**Principle**

The Briggs-Rauscher reaction is a so-called homogeneous oscillating reaction, i.e. the reaction rate of the complete process is subject to periodic fluctuations. In general, oscillating reactions can always occur when the following conditions are fulfilled: The reaction must run highly exergonic ( $\Delta G \ll 0$ ). At least one of the reaction steps must contain a positive or negative back-coupling. Such back-coupling processes occur when the result of the individual partial steps of the reaction, such as changes in temperature or concentration, act back on the rate constants of the individual partial steps of the reaction. In this way, the whole reaction becomes non-linear.

**Task**

Observe the fluctuations of the Briggs-Rauscher reaction by measuring the potential over a definite time period.

**What you can learn about**

- Oscillating reactions; Exergonic process
- Potential; Briggs-Rauscher reaction

**Main articles**

Cobra4 Wireless Manager	12600-00	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Sensor-Unit Chemistry	12630-00	1
Software Cobra4 - multi-user licence	14550-61	1
Magnetic stirrer Mini / MST	47334-93	1
Reference electrode, AgCl	18475-00	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

**Cobra4 Wireless-Link****Function and Applications**

Interface module for the radio-based transmission of sensor measuring values in conjunction with the Cobra4 Wireless Manager.

**Benefits**

- All Cobra4 Sensor-Units can be quickly connected using a secure and reliable plug-in / lockable connection.
- All Cobra4 measuring sensors are easy to plug in and automatically detected.
- The radio network with the Cobra4 Wireless-Manager is established automatically and is extremely stable, as it uses its own radio protocol.
- Up to 99 Cobra4 Wireless-Links can be connected to one Cobra4 Wireless-Manager.
- With radio transmission, moving sensors offer completely new experimentation options, e.g. the measurement of acceleration of a student on a bicycle etc. .
- The use of high performance batteries means that no external power supplies required.

12601-00

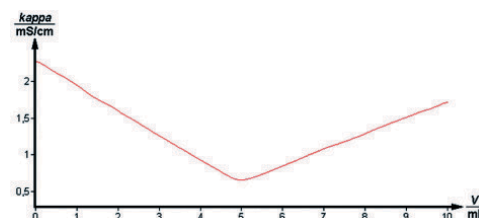


## Analytical Chemistry

<b>5.1</b>	<b>Titration</b>	<b>48</b>
<b>5.2</b>	<b>Electrogravimetry</b>	<b>53</b>
<b>5.3</b>	<b>Chromatography</b>	<b>54</b>

## P3060760

## Conductivity titration with Cobra4



Titration diagram for the neutralisation of HCl solution with NaOH solution.

**Principle**

The electric conductivity of aqueous electrolyte solutions is determined by the type and number of charge carriers at constant temperature. Characteristic changes in conductivity are connected with changes in the ionic composition of reacting systems. These can be used in the conductimetric titration as end point indicators.

**Tasks**

Using the Cobra4 system, measure the change in conductivity in the titrations of the following:

1. approximately 0.1 molar barium hydroxide solution with 0.1 molar sulphuric acid.
2. approximately 0.1 molar hydrochloric acid with 0.1 molar sodium hydroxide solution.
3. approximately 0.1 molar acetic acid with 0.1 molar sodium hydroxide solution.

Other samples can alternatively be set in advance for conductimetric determination of their concentration contents.

**What you can learn about**

- Electrolyte; Electrical conductance; Specific conductance
- Ion mobility; Ion conductivity; Conductometry; Volumetry

**Main articles**

Cobra4 Wireless Manager	12600-00	1
Cobra4 Wireless-Link	12601-00	2
Cobra4 Sensor-Unit Conductivity+	12632-00	1
Conductivity temperature probe Pt1000	13701-01	1
Software Cobra4 - multi-user licence	14550-61	1
Cobra4 Sensor-Unit Drop Counter	12636-00	1

**Conductivity temperature probe Pt1000****Function and Applications**

Conductivity temperature probe Pt1000.

**Equipment and technical data**

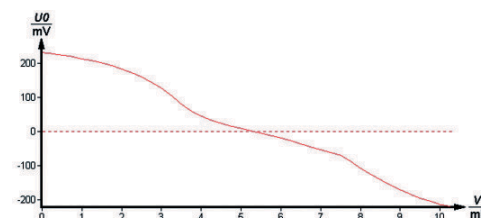
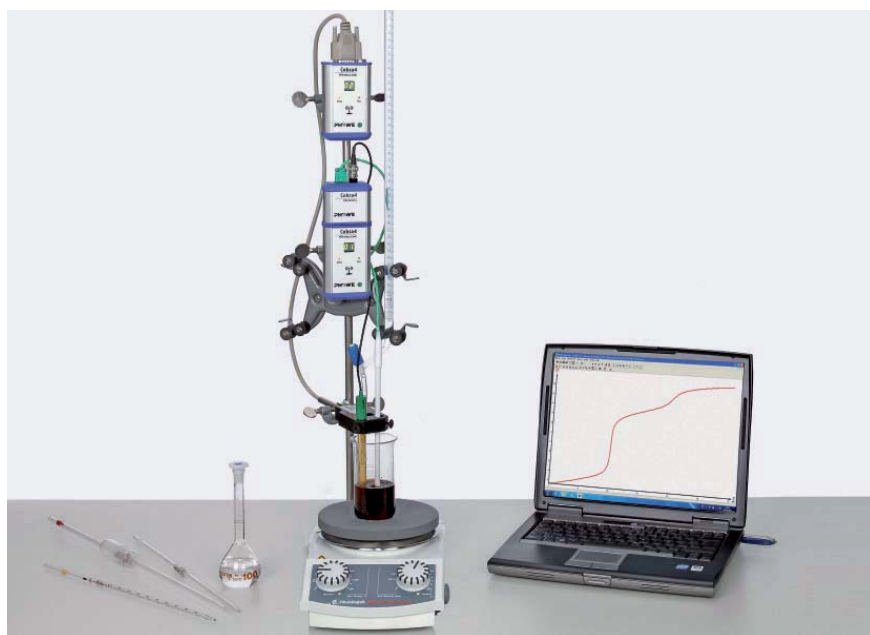
- Cell constant  $k = 1.0 / \text{cm}$
- Minimum immersion depth: 10 mm

**13701-01**



## Potentiometric pH titration (phosphoric acid in soft drinks) with Cobra4

P3061760



Titration diagram of the neutralisation of a beverage containing phosphoric acid ( $V = 50 \text{ ml}$ ) with a 0.1 molar sodium hydroxide solution.

### Principle

The cell voltage and the Galvani voltage of the electrodes of a galvanic cell are dependent upon the concentration of the ions involved in the potential forming process. Thus, conclusions can be made about the concentration of the ions to be investigated from the measured cell voltage at a constant potential of a suitable reference electrode (potentiometric titration).

### Task

Using the Cobra4-System, measure the change in the cell voltage in the titration of a sample of a carbonated beverage (Cola) containing phosphoric acid (E338) with 0.1 molar sodium hydroxide solution and calculate the beverage's phosphoric acid content from the consumption of the standard solution.

### What you can learn about

- Galvanic cell
- Types of electrodes
- Galvani voltage
- Cell voltage
- Nernst equation
- Potentiometry
- Volumetry

### Main articles

Magnetic stirrer MR Hei-Standard	35750-93	1
Software Cobra4 - multi-user licence	14550-61	1
Cobra4 Wireless-Link	12601-00	2
Cobra4 Sensor-Unit Chemistry	12630-00	1
Cobra4 Sensor-Unit Drop Counter	12636-00	1
Cobra4 Wireless Manager	12600-00	1
Immersion probe NiCr-Ni, teflon, 300 °C	13615-05	1

### Cobra4 Sensor-Unit Drop Counter



### Function and Applications

The Cobra4 Drop Counter serves to count the number of drops that fall from a burette and so, indirectly, to quantitatively determine the volume of a liquid that flows from the burette.

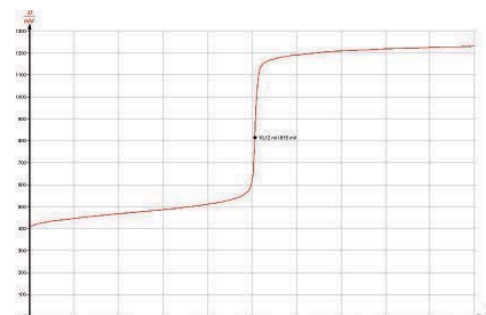
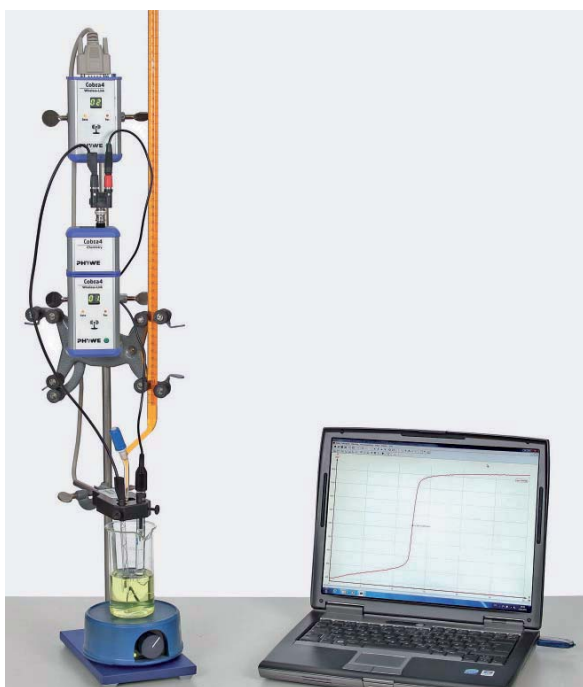
The Cobra4 Sensor-Unit Drop Counter can be connected to one of the following devices to transfer the measured data: Cobra4 Wireless-Link, Cobra4 Mobile-Link, Cobra4 USB-Link or Cobra4 Junior-Link.

### Benefits

- Automatic performance of titration measurements
- Each single drop reliably measured
- Easy calculation of the volume in the software
- Easy to mount

12636-00

### P3121060 Volumetric redox titration: Cerimetry with Cobra4



Measurement curve for the titration of 10 ml of an 0.1 molar Fe(II) sulphate solution with 10 ml of an 0.1 molar Ce(IV) sulphate solution with the equivalent point entered.

#### Principle

Potassium permanganate solutions which are used as oxidizing measuring solutions in redox titrations can in most cases be replaced by Ce(IV) solutions. These offer the advantages that they do not change on storage and that the course of the redox titration can be very conveniently followed by measuring the electrochemical potential. The equivalent point can then be found by determination of the inflection point of the potential curve which results from plotting the measured values.

#### Task

Titrate Iron(II) sulphate solution with Ce(IV) sulphate solution.

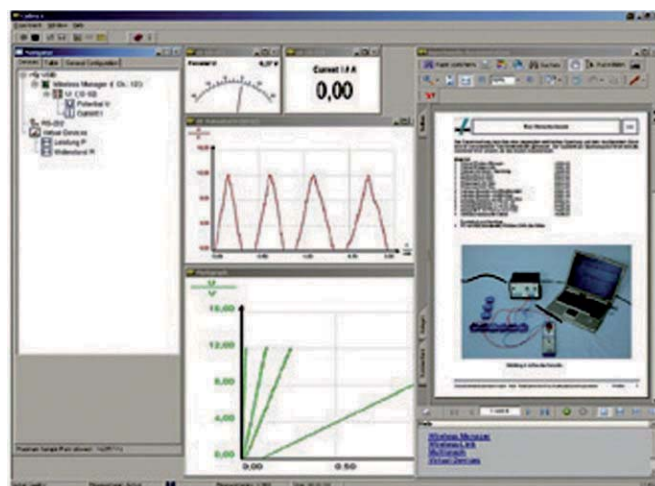
#### What you can learn about

- Redox titration; Iron(II) sulphate
- Ce(IV) sulphate; Titration
- Cerimetry

#### Main articles

Cobra4 Wireless Manager	12600-00	1
Cobra4 Wireless-Link	12601-00	2
Cobra4 Sensor-Unit Chemistry	12630-00	1
Cobra4 Sensor-Unit Drop Counter	12636-00	1
Software Cobra4 - multi-user licence	14550-61	1
Magnetic stirrer Mini / MST	47334-93	1
Set of Precision Balance Sartorius CPA 6202S and measure software, 230 V	49226-88	1

#### Software Cobra4 - multi-user licence



#### Function and Applications

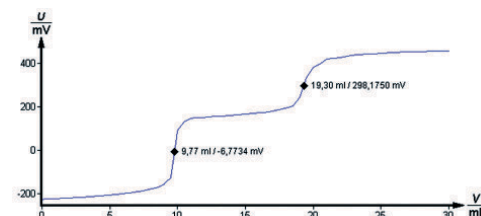
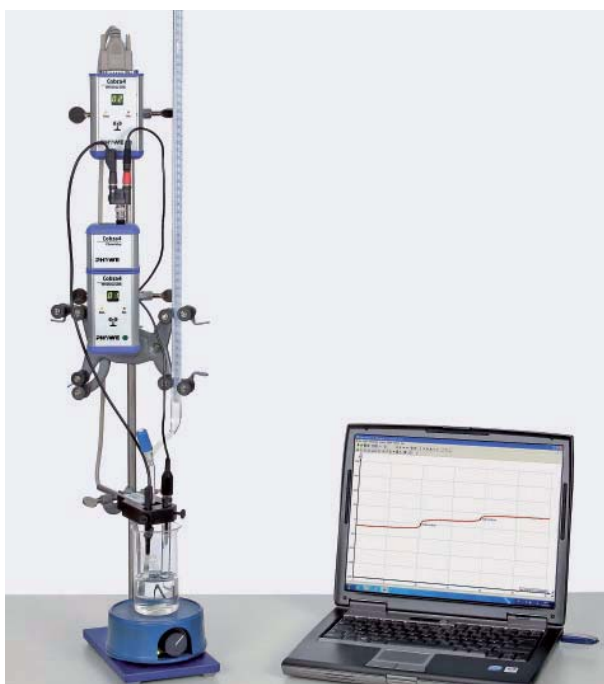
The "measure Cobra4" measuring software leaves nothing to be desired.

As soon as a Cobra4 sensor is connected to a PC, irrespective of whether by Cobra4 Wireless or Cobra4 USB Link, the "measureCobra4" software opens completely automatically and shows the connected sensors, the required measuring windows and the current measuring data.

14550-61

## Precipitation titration with Cobra4

P3061460



Course of the potential during the precipitation titration.

## Principle

Precipitation reactions which occur stoichiometrically and rapidly, and whose equilibrium lies on the side of the poorly soluble products can also be used titrimetrically. Consequently, a solution which contains both chloride and iodide ions can be titrated with a silver nitrate solution. The course of the titration is monitored potentiometrically and the equivalence points are determined from the inflection points of the potential curve.

## Tasks

1. Titrate a solution which contains 10 ml each of 0.1 molar potassium chloride and potassium iodide solutions with a 0.1 molar silver nitrate solution.
2. Plot the potential of a silver electrode measured against a silver / silver chloride reference electrode as a function of the added volumes of standard solution.
3. Determine the equivalence points from the inflection points of the potential curve.

## What you can learn about

- Electrode potential; Cell voltage
- Electrodes of the 1st and 2nd type
- Nernst equation; Argentometry; Solubility product

## Main articles

Cobra4 Wireless Manager	12600-00	1
Cobra4 Wireless-Link	12601-00	2
Cobra4 Sensor-Unit Chemistry	12630-00	1
Cobra4 Sensor-Unit Drop Counter	12636-00	1
Software Cobra4 - multi-user licence	14550-61	1

## Cobra4 Sensor-Unit Chemistry



## Function and Applications

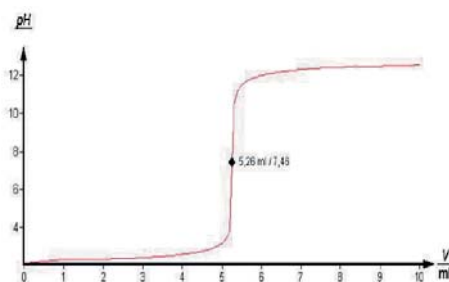
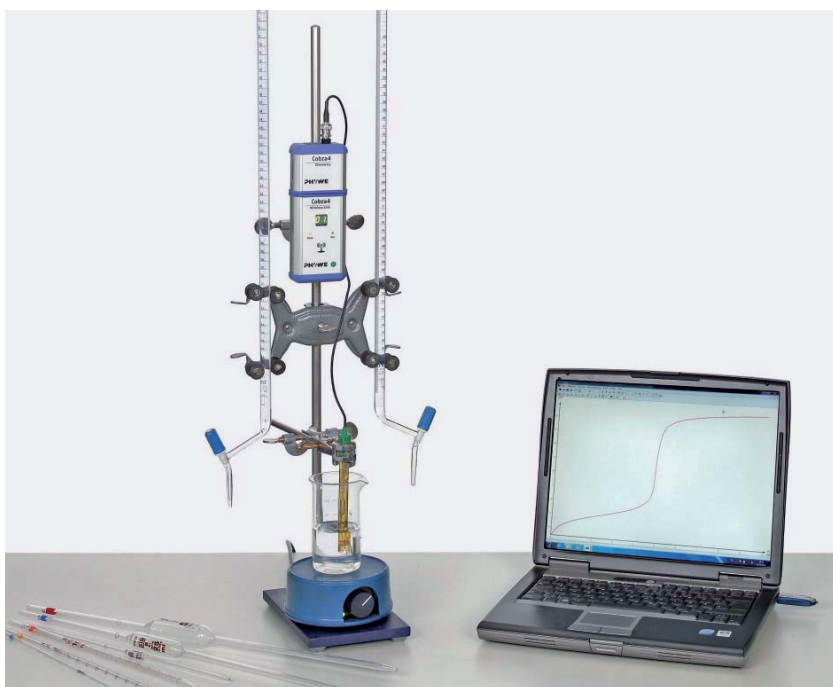
The Cobra4 Sensor-Unit pH and 2 x temperature NiCr-Ni is a measuring recorder for pH, potential and temperature measurements, which is controlled by micro-controller.

## Benefits

- It can be fitted with two NiCr-Ni thermoelements (Type K) and a pH probe or redox measuring chain
  - Measure up to two temperatures and one pH or potential value simultaneously.
  - Discover new experimental possibilities especially in thermodynamics
- Values of the calibration are saved in the sensor - no need for new calibration after changing the basic unit.

12630-00

## P3061660 Titration curves and buffering capacity with Cobra4



Titration curve of acetic acid with sodium hydroxide solution.

**Principle**

pH values can be measured with the aid of electrochemical measurements and proton-sensitive electrodes (e.g. glass electrodes). By combining a glass electrode with a reference electrode in one housing, a single-rod glass electrode, which is appropriate for acid-base titrations, is created. The titration curves allow an exact determination of the equivalence point in titrations of strong and weak acids and bases.

**Tasks**

1. Determine the titration curves of different neutralisation reactions.
2. Determine the titration curve of an ampholyte (glycine).
3. Determine the buffering capacity of various aqueous acetic acid/sodium acetate mixtures at different total concentrations.

**What you can learn about**

- Strong and weak electrolytes
- Hydrolysis
- Dissociation of water
- Amphoteric electrolytes
- Isoelectric point
- Law of mass action
- Indicators
- Glass electrode
- Activity coefficient
- Buffering capacity
- Henderson-Hasselbalch equation

**Main articles**

Set of Precision Balance Sartorius CPA 62025 and measure software, 230 V	49226-88	1
Software Cobra4 - multi-user licence	14550-61	1
Cobra4 Wireless-Link	12601-00	2
Cobra4 Sensor-Unit Chemistry	12630-00	1
Cobra4 Sensor-Unit Drop Counter	12636-00	1
Cobra4 Wireless Manager	12600-00	1
Magnetic stirrer Mini / MST	47334-93	1

**Related Experiments****Titration of a polyvalent acid with a strong base with Cobra4**

P3121260

**Titration of a weak organic acid with sodium hydroxide with Cobra4**

P3121360

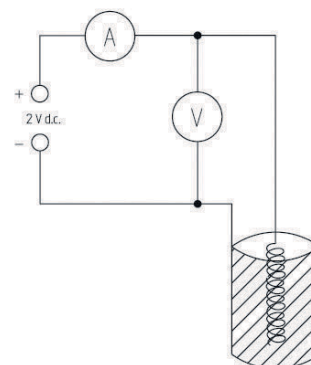
**Titration of a weak base (ammonia) with a strong acid with Cobra4**

P3121460



## Electrogravimetric determination of copper

P3062201



Electric circuit for electrolysis.

### Principle

Electrogravimetry is an important analytical method for the quantitative determination or separation of species in solution. The technique involves the quantitative electrolytic deposition of an element, usually a metal, on a suitable electrode in weighable form.

### Task

Perform an accurate electrogravimetric determination of the amount of copper in a given sample solution.

### What you can learn about

- Quantitative analysis
- Gravimetry
- Electrolysis
- Overpotential
- Electrode polarisation

### Main articles

Pt electrodes, electrogravimetry	45210-00	1
Power supply, universal	13500-93	1
Magnetic stirrer MR Hei-Standard	35750-93	1
Electronic temperature controller EKT Hei-Con	35750-01	1
Digital multimeter 2010	07128-00	2
Ethyl alcohol, absolute 500 ml	30008-50	1
Set of Analytical Balance Sartorius CPA 224S and measure software, 230 V	49221-88	1

### Power supply, universal



### Function and Applications

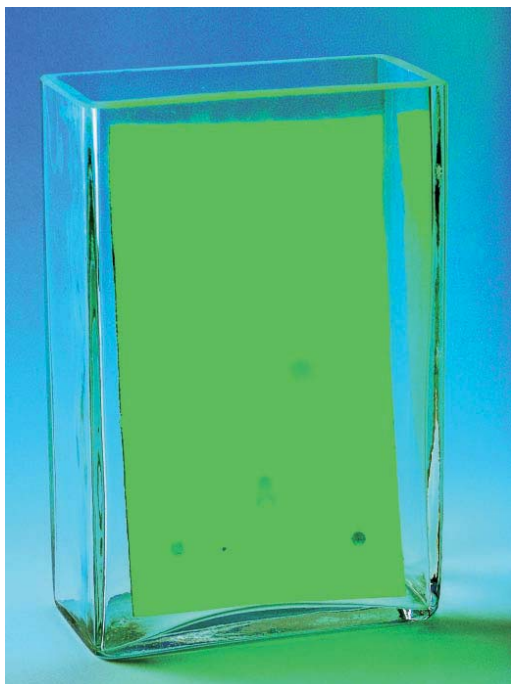
Versatile heavy duty power supply which can also be used as a constant current supply in schools, laboratories or workshops.

### Equipment and technical data

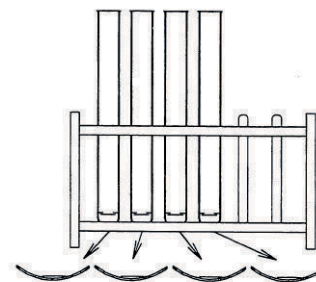
- Direct current source: Stabilised, regulated output direct voltage, continuously adjustable from 0...18 V
- Adjustable current limit between 0...5 A
- LED display for constant current operation
- Permanently short-circuit proof & protected against exterior voltages
- Alternative voltage output:
  - Multitap transformer 2...15V, outputs galvanically separated from main grid
  - Full load capacity (5 A), even if direct current is supplied simultaneously

13500-93

## P3120400 Chromatographic separation processes: thin layer chromatography



**NEW**



Part of the experimental setup.

### Principle

Chromatographic separation processes are very important for analytical chemistry. Their relatively simple technique and the possibility to separate even the smallest portions of mixtures explain the rapid development of these processes. There are numerous variations of this method.

As a result, the optimum chromatographic separation method can be found for nearly every separation task. The method that is described here can be used to demonstrate the fundamental principles and possibilities of this method with relatively simple means.

### Task

Separate a dye mixture by thin-layer chromatography.

### What you can learn about

- Thin-layer chromatography
- Separation procedure
- Adsorbent material
- Stationary phase
- Mobile phase
- Capillary action

### Main articles

Separation chamber, 180x120x50 mm	35010-06	1
TLC-foil, silica gel F254, 25 off	31503-04	1
Ethyl alcohol, absolute 500 ml	30008-50	1
Methyl red 25 g	31574-04	1
Capillary holder	35010-07	1
Micro-capillaries, 2 / 1000 ml, 100	35010-08	1
Fuchsine powder 25 g	31320-04	1

### Separation chamber, 180x120x50 mm



### Function and Application

Development vessel for thin-layer chromatography.

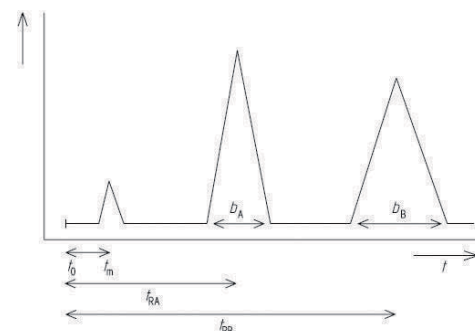
### Equipment and technical data

Dimensions: 120 mm×50 mm×180 mm

**35010-06**

## Chromatographic separation processes: Gas chromatography with Cobra4

P3031760



Gas chromatographic separation of a mixture of butane gases.

### Principle

Chromatographic procedures allow a separation of substance mixtures with the aid of a stationary separation phase and a mobile phase.

In gas chromatography the mobile phase is a gas. The mobile phase, to which the mixture to be separated is added, transports the substance mixture through the separation column at a constant flow rate. Interactions occur between the mobile phase and the stationary phase.

The establishment of equilibria between the stationary phase and the different substances (distribution equilibria, adsorption-desorption equilibria) results in different migration rates of the individual components.

At the end of the column there is a detector in the form of a thermal conductivity cell, which can detect the different substances on the basis of their differing thermal conductivities. The detector signal is recorded as a function of time.

The different thermal conductivities of the carrier gas and the substance cause temperature alterations in the electrically heated temperature sensor, which is located in a Wheatstone bridge circuit. The resulting electrical signal is recorded by a plotter as a function of time (chromatogram).

### Tasks

1. Determine the retention times of different gases and perform a chromatographic material separation of a mixture of butane gases.
2. Separate and identify the components of a two-component mixture consisting of ethanol and ethyl acetate chromatographically.

### What you can learn about

- Chromatography; Chromatogram; Multiplicative distribution
- Nernst's law of distribution (number of theoretical trays)
- Thermal conductivity detector

### Main articles

Glass jacket	02615-00	1
Cobra4 Wireless Manager	12600-00	1
Cobra4 Wireless-Link	12601-00	1
Software Cobra4 - multi-user licence	14550-61	1
Immersion thermostat Alpha A, 230 V	08493-93	1
Control unit gas chromatograph	36670-99	1
Steel cylinder helium, 2 l, filled	41776-00	1

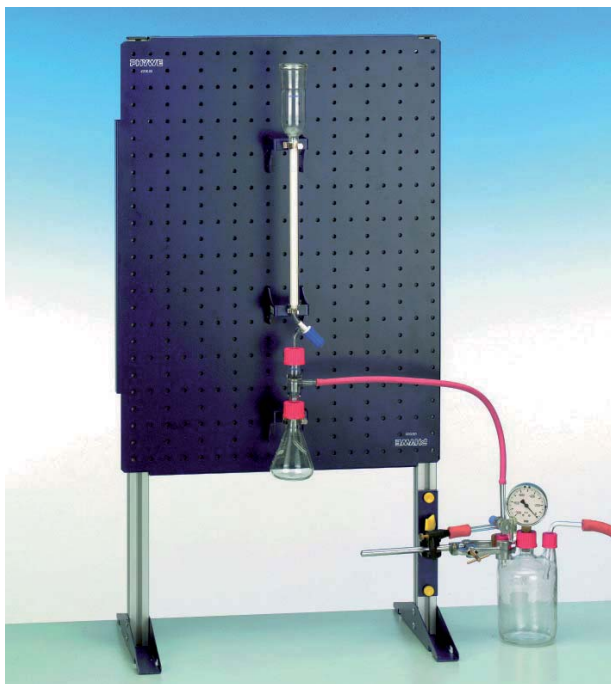


Archer J.P. Martin (left)

Richard Laurence Millington Synge (right)

1953, Nobel Prize in Chemistry

### P3120300 Column chromatography - separation of leaf pigments



**NEW**



Leaf with green pigments.

#### Principle

In this investigation, a uniformly green raw extract of fresh leaves is first separated into different fractions by means of column chromatography. To do so, the extract is added to a column filled with starch and drawn through the column under slightly reduced pressure (to increase the flow rate of the mobile phase) with ligroin as the eluent. A separation occurs in a clearly recognisable, broad, yellow area and in a narrow, green band. This means that the xanthophylls (yellow) are separated from the chlorophylls (green). If the vacuum is reduced during the separation, the separation is much better, but then separation also takes considerably longer. Each of the separation fractions can be collected individually and characterised by recording their absorption spectra, if necessary, or examined for fluorescence by radiation with UV light.

#### Task

Investigate different leaf pigments using column chromatography.

#### What you can learn about

- Chlorophyll; Column chromatography
- Leaf pigments; Xanthophyll

#### Main articles

Frame for complete experiments	45500-00	1
Secure bottle, 500 ml, 2 x GI 18/8, 1 x 25/12	34170-01	1
Column for ion-exchange chromatography	35025-01	1
Panel for complete experimental setups	45510-00	1
Vacuum adaptor, straight, GL25/12	35806-15	1
Erlenmeyer flask, GL 25/12, 100ml	35844-15	1
Spring manometer, 0...-1000 mbar	34170-02	1

#### Frame for complete experiments



#### Function and Application

Frame for complete experiments to receive up to 2 shelves or 1 panel.

#### Benefits:

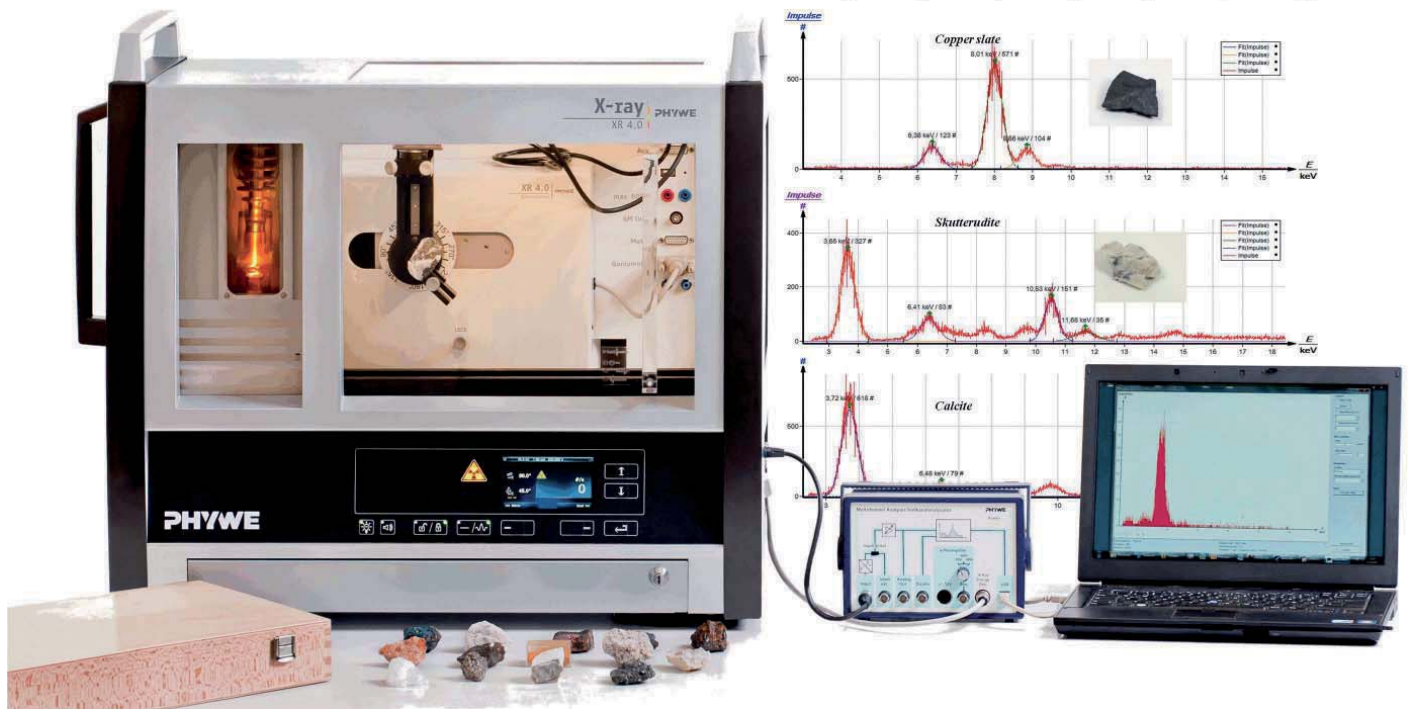
- can be fixed to a working table by G-clamps (to be ordered separately)

#### Equipment and technical data:

- aluminum frame, height 90cm,width 46.5cm
- 2 stable sheet steel bases,l=30cm

**45500-00**





## Spectroscopy

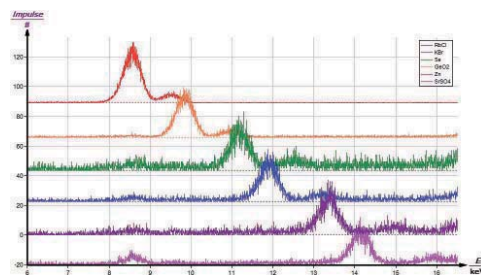
- 6.1 X-ray Fluorescence Analysis
- 6.2 Nuclear Magnetic Resonance
- 6.3 Photometry and Photochemistry

58  
61  
67

# 6 Spectroscopy

## 6.1 X-ray Fluorescence Analysis

### P2544701 Qualitative X-ray fluorescence analysis of powder samples



Total representation of the  $K\alpha$  and  $K\beta$  fluorescence lines of the elements with an atomic number of  $30 < Z < 38$ .

#### Principle

Various powder samples are subjected to polychromatic X-rays. The energy of the resulting fluorescence radiation is analysed with the aid of a semiconductor detector and a multichannel analyser. The energy of the corresponding characteristic X-ray fluorescence lines is determined. The elements of the samples are identified by comparing the line energies with the corresponding table values.

#### Tasks

1. Calibrate the semiconductor energy detector with the aid of the characteristic radiation of the tungsten X-ray tube.
2. Record the fluorescence spectra that are produced by the samples.
3. Determine the energy values of the corresponding fluorescence lines and compare the experimental energy values with the corresponding table values in order to identify the powder components.

#### What you can learn about

- Bremsstrahlung; Characteristic X-radiation
- Energy levels; Fluorescent yield
- Semiconductor energy detectors
- Multichannel analysers

#### Main articles

XR 4.0 expert unit X-ray unit, 35 kV	09057-99	1
XR 4.0 X-ray energy detector (XRED)	09058-30	1
XR 4.0 X-ray plug-in unit W tube	09057-80	1
XR 4.0 X-ray goniometer	09057-10	1
Multichannel analyser	13727-99	1
XR 4.0 X-ray Chemical set for edge absorption	09056-04	1
XR 4.0 XRED cable 50 cm	09058-32	1

#### Best fitting X-ray sets:

##### XR 4.0 X-ray expert set

09110-88

##### XR 4.0 X-ray material analysis upgrade set

09160-88

#### Multichannel analyser



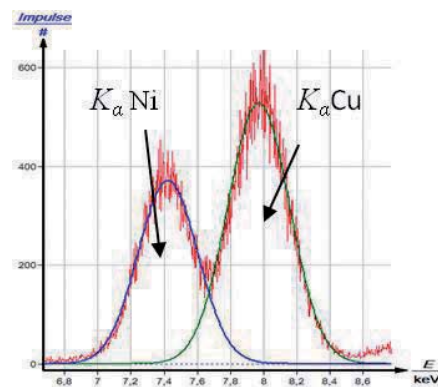
#### Function and applications

The multi channel analyser is for analysing voltage pulses which are proportional to energy and for determining pulse rates and intensities in conjunction with an X-ray detector, alpha detector or gamma detector. The analogue pulses from the detector are shaped by the analyser, digitised and summed per channel according to pulse height. This results in a frequency distribution of detected pulses dependent on the energy of the radiation.

13727-99

## Quantitative X-ray fluorescence analysis of alloyed materials

P2545001



Fluorescence spectrum of constantan,  $K_{\alpha}$ -lines.

### Principle

Various alloyed materials are subjected to polychromatic X-rays. The energy of the resulting fluorescence radiation is analysed with the aid of a semiconductor detector and a multichannel analyser. The energy of the corresponding characteristic X-ray fluorescence lines is determined. In order to determine the concentration of the alloy constituents, the intensity of their respective fluorescence signals is compared to that of the pure elements.

### Tasks

1. Calibration of the semiconductor energy detector with the aid of the characteristic radiation of the tungsten X-ray tube.
2. Recording of the fluorescence spectra that are produced by the alloyed samples.
3. Recording of the fluorescence spectra that are produced by the pure metals.
4. Determination of the energy values of the corresponding fluorescence lines.
5. Calculation of the concentration levels of the alloy constituents.

### What you can learn about

- Bremsstrahlung; Characteristic X-radiation
- Energy levels; Fluorescent yield; Auger effect
- Coherent and incoherent photon scattering
- Absorption of X-rays; Edge absorption
- Matrix effects; Semiconductor energy detectors
- Multi channel analysers

### Main articles

XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray energy detector (XRED)	09058-30	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 X-ray plug-in unit W tube	09057-80	1
Multi channel analyser	13727-99	1

XR 4.0 X-ray specimen set metals for fluorescence, set of 4	09058-34	1
XR 4.0 X-ray specimen set metals for X-ray fluorescence, set of 7	09058-31	1

### Best fitting X-ray sets:

#### XR 4.0 X-ray expert set

09110-88

#### XR 4.0 X-ray material analysis upgrade set

09160-88

### XR 4.0 X-ray energy detector (XRED)



### Function and Applications

With the new X-ray energy detector you can directly determine the energies of single x-ray quanta.

09058-30

## 6 Spectroscopy

### 6.1 X-ray Fluorescence Analysis

#### Quantitative X-ray fluorescence analysis of solutions

P2545101



##### Principle

Various solutions, with known element concentrations, are subjected to polychromatic X-rays. The energy and intensity of the resulting fluorescence radiation of the dissolved elements are analysed with the aid of a semiconductor detector and a multichannel analyser. In order to determine the unknown element concentrations in the solutions, calibration is performed. For this purpose, the known element concentrations of the calibration solution are plotted against the corresponding fluorescence intensities of the dissolved elements.

For more details refer to [www.phywe.com](http://www.phywe.com)

#### Qualitative X-ray fluorescence spectroscopy of metals - Moseley's law

P2544501



##### Principle

Various metal samples are subjected to polychromatic X-rays. The energy of the resulting fluorescence radiation is analysed with the aid of a semiconductor detector and a multi channel analyser. The energy of the corresponding characteristic X-ray lines is determined, and the resulting Moseley diagram is used to determine the Rydberg frequency and the screening constants.

For more details refer to [www.phywe.com](http://www.phywe.com)

#### Qualitative X-ray fluorescence analysis of alloyed materials

P2544601



##### Principle

The composition of various alloys is analysed with the aid of polychromatic X-rays. The energy of the characteristic fluorescence lines of the alloy constituents is analysed with the aid of a semiconductor detector and a multichannel analyser. The alloy constituents are identified by comparing the line energies with the corresponding table values.

For more details refer to [www.phywe.com](http://www.phywe.com)



### Compact MRT



#### Function and Applications

The system gives you the unique opportunity of offering training at a real magnetic resonance tomograph (MRT), which is used in almost all fields of science and medicine, directly on site. The training software and the experiment instructions cover all key aspects of the magnetic resonance technology, ranging from the basic principles of nuclear magnetic resonance (NMR) to the complex high-resolution MR imaging (MRI). Thus, students can perform some basic experiments of the MR technology as well as generate, export and analyze numerous high-resolution images in all relevant contrasts. The special option to influence experiments on runtime and to directly visualize the results gives users an unprecedented learning experience. Thereby image artifacts found in clinical MRT can be examined directly in a simple process. The system consists of a "control unit" and a "magnet unit", which differ from other magnetic resonance tomographs only in the size and the fact that they are portable.

#### Benefits

- Easy to connect and immediately operative (USB 2.0)
- New and numerous education experience
  - training with clinically relevant measuring procedures
  - high resolution MR imaging (2D, 3D)
  - live visualization of data
  - realtime control of experimental parameters
- Practice-oriented training for all fields of science and medicine
  - T1/T2 measurements
  - all MR parameters accessible
  - measure a multitude of samples with a diameter up to one centimeter
  - software perfectly fits the study purposes
  - suitable for a wide range of experiments
- Literature tailored precisely to the experiments (5 TESS expert experimental units: Basic principles in Nuclear Magnetic Resonance (NMR), Relaxation times in Nuclear Magnetic Resonance, Spatial encoding in Nuclear Magnetic Resonance, Magnetic Resonance Imaging (MRI) I, Magnetic Resonance Imaging (MRI) II)
- Possibility to select courses (Basic course, Basic principles, Relaxation, 1D spatial encoding, Imaging I, Imaging II)

#### Equipment and technical data

The system includes the following components:

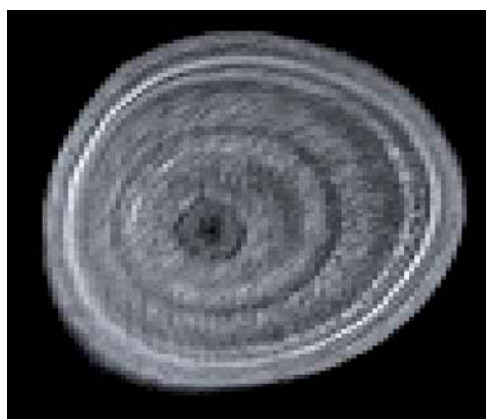
- Control unit:
  - Gradient amplifier and transmitter and receiver unit
  - PC connection USB-B
  - Connection of the imaging unit (gradient) RJ45
  - Connection of the receiver/transmitter unit BNC

- Power supply 12 V DC, 2 A
- Power supply unit (external) 100-240 VAC, 50/60 Hz, 2 A
- Dimensions (cm) 27 x 9.5 x 14
- Weight 2.3 kg
- Magnet unit:
  - High-end gradient system for 2D and 3D images
  - System frequency 22 MHz
  - Field strength 500 mT
  - Field homogeneity < 100 ppm
  - Sample diameter max. 10 mm
  - Connection of the imaging unit (gradient) RJ45
  - Connection of the receiver/transmitter unit BNC
  - Dimensions (length x width x height, cm) 27 x 25 x 14
  - Weight 17.5 kg
- Training software:
  - Languages German/English (other languages on request)
  - Product license measure MRT
  - Data formats DICOM, JPEG, CSV, TXT
  - Media types DVD
- Sample set
  - 5 different samples (water and oil samples each of with 5 and 10 mm diameter, sample with a particular structure)
  - 1 empty sample tube (10 mm)
- Soundbox for a realistic MR-noise
- Connecting cables (2 x RJ45, 1 x BNC, USB)
- Sturdy carrying case and shielded flight box for safe transport
- DVD incl. training software, comprehensive descriptions of the 5 TESS expert experimental units with detailed theoretical background, structured implementation plan, exercises, analyses and many figures clearly arranged, operating instructions, software instructions

#### Accessories

- Required for the experiments: Computer (min. processor 1.6 GHz) with Windows XP (32-Bit)/Vista (32-Bit)/7, USB 2.0 interface, min. 1 GB RAM, min. of 1 GB hard-disk space, 1024 x 758 graphics card (min. 256 MB, compatible with DirectX 9.0), 16-bit color resolution or better
- Required for MR-noise: active loudspeakers
- Options for experiments: other sample sets or own samples

#### 09500-99



Cross-sectional image of a branch.

# Compact MRT – details at a glance

The new and unique Compact MRT by PHYWE is more than just a device. It is a fascinating experience!

#### Extensive set of samples

- several example samples in a sample case
- oil and water samples to imitate fat and cerebrospinal fluid
- empty test tube for the analysis of own samples



#### MRT magnet unit

- powerful magnet with a field strength of 500 mT
- high field homogeneity < 100 ppm
- enables resolutions ~ 0.25 mm
- high level of shielding (at a distance > 1 m, hardly any magnetic field can be measured)
- lightweight ~17.5 kg
- compact design 27 cm x 25 cm x 14 cm
- sturdy transport handles



#### Clear connection

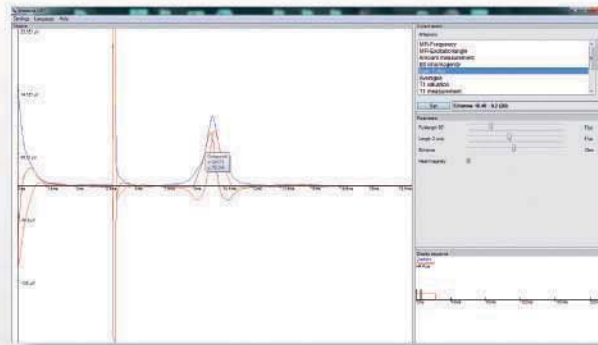
- easy to connect and immediately ready for use (BNC, RJ45, USB 2.0)
- all cables included
- optional sound box between the MRT magnet unit and MRT control unit for realistic MR sounds





### MRT control unit

- clear, central control unit
- connector for the MRT magnet unit (BNC, RJ45)
- power supply in the standard range (12 V DC, 2 A)
- USB connection to the measurement computer
- lightweight ~2.3 kg
- compact design 27 cm x 9.5 cm x 14 cm
- status LED



### measure MRT

- software package for measurements and evaluations
- easy to install
- clear structure
- selection of lessons and courses
- real-time parameter check
- export into all standard file formats (DICOM, JPEG, CSV, TXT)
- high-resolution 2D and 3D tomography
- well-structured help functions



### Transport case

- trolley case for excellent mobility and safe transport (lockable)
- board case for safe transport in planes

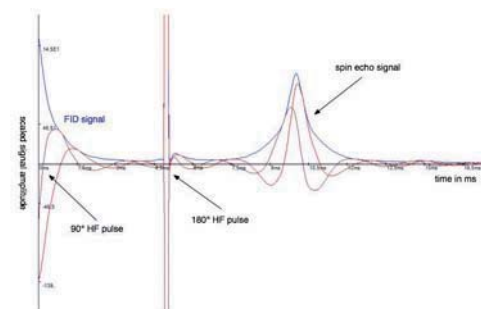
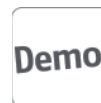


Here at PHYWE, our products must meet the highest requirements and the Compact MRT is no exception.





### P5942100 Fundamental principles of Nuclear Magnetic Resonance (NMR)



Spin echo signal of an oil sample occurring 10 ms (echo time) after a 90° HF pulse (FID signal is shown). To generate the echo signal a 180° HF pulse has to be switched after half the echo time.

#### Principle

The basic principles concerning the phenomenon of nuclear magnetic resonance (NMR) are demonstrated. Experiments are executed with a MRT training device giving the opportunity to investigate some small probes in the sample chamber. Device control is done with the provided software. Investigations comprise the tuning of the system frequency to the Larmor frequency, the determination of the flip angle of the magnetisation vector, the effects of the substance quantity, the influence of particular magnetic field inhomogeneities, the measurement of a spin echo signal and an averaging procedure to maximise the signal-to-noise ratio. The adjustment of all parameters in these experiments are inevitable to obtain an adequate MR image.

#### Tasks

1. Tuning of the system frequency to the Larmor frequency.
2. Setting of the HF (High Frequency) pulse duration to determine the flip angle of the magnetisation vector.
3. Effects of the substance quantity on the FID signal (Free Induction Decay) amplitude.
4. Minimising magnetic field inhomogeneities via a superimposed magnetic field (shim).
5. Retrieving a relaxed FID signal via a spin echo flipping nuclear spins by 180°.
6. Improving the signal-to-noise ratio (SNR) of the FID signal.

#### What you can learn about

- Nuclear spins; Atomic nuclei with a magnetic moment
- Precession of nuclear spins; Magnetisation
- Resonance condition; MR frequency; MR flip angle
- FID signal (Free Induction Decay); Spin echo
- Relaxation times (T1: longitudinal magnetisation, T2: transverse magnetisation)
- Signal-to-noise ratio

#### Main articles

Compact MRT 09500-99 1

#### Training recommended Service | PHYWE

For this experiment we recommend a seminar on equipment technology, handling and information of equipment-specific characteristics on site.

03333-02

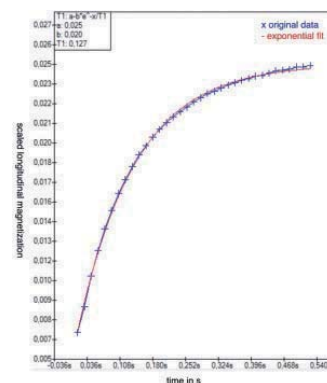


Felix Bloch (left) and Edward Mills Purcell (right)  
1952, Nobel Prize in Physics



## Relaxation times in Nuclear Magnetic Resonance

P5942200



Measurement of the T1 relaxation of an oil sample.

### Principle

The principles of relaxation processes using the MR technology are demonstrated. Experiments are executed with the MRT training device giving the opportunity to investigate some small probes in the sample chamber. Device control is done with the provided software. Investigations comprise the estimation of the relaxation time T1 which is a measure of time for reestablishing the longitudinal magnetization, the measurement of this latter time and the measurement of the relaxation time T2 which is a measure of time for the decline of the transverse magnetization. T1 and T2 are specific to the sample material and thus give important evidence for the composition of the subject of investigation.

### Tasks

1. Estimation of the relaxation time T1 via two successive 90° HF pulses.
2. Measuring the relaxation time T1 using an automatic software routine.
3. Measuring the relaxation time T2 using an automatic software routine.

### What you can learn about

- Nuclear spins; Precession of nuclear spins; Resonance condition; MR frequency; MR flip angle
- Longitudinal and transverse magnetization; FID signal (Free Induction Decay)
- T1/T2 relaxation times; Measuring T1/T2 relaxation times; Spin-lattice relaxation (T1); Spin-spin relaxation (T2); Dephasing

### Main articles

Compact MRT 09500-99 1

## Laboratory Experiments Magnetic Resonance Tomography (MRT)



16 detailed experiments regarding the magnetic resonance (MR) technology.

### Description

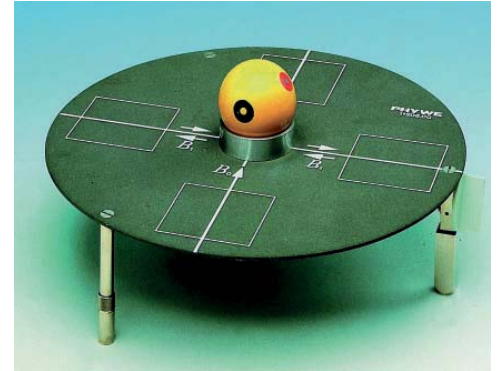
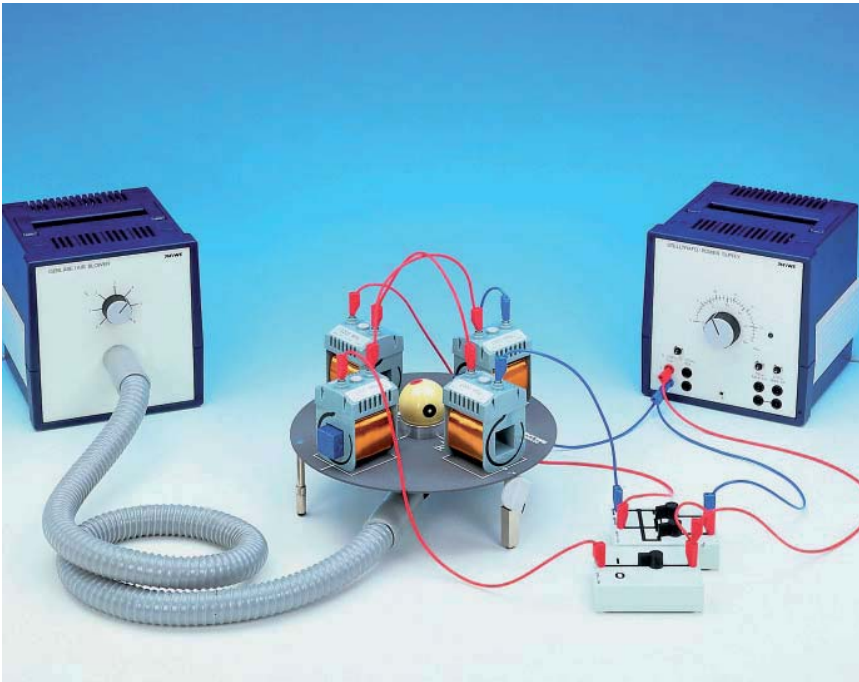
Comprehensive collection of experiments regarding the magnetic resonance (MR) technology. The manual comprises basic experiments of the MR physics as well as experiments on complex MR imaging (2D and 3D). Experiments are didactically and precisely prepared and convey all relevant information about magnetic resonance tomography.

Through questions, answers, evaluations and a comprehensive theory students are guided and are able to learn one of the most important procedures of medical diagnostics with a lot of fun and enjoyment. The software needed to perform the experiments perfectly fits the experimental literature and thus enables a unique learning and teaching experience. For example parameters can be directly varied during a measurement ("on runtime").

The manual is suitable for almost all fields of science. However, basically it is aimed at students with a deep medical background.

01233-02

### P2511205 Model experiment NMR / ESR



Gyroscope with magnetic axis, ESR model.

#### Principle

Model experiment for electron spin resonance for clear demonstration of interaction between the magnetic moment of the electron spin with a superimposed direct or alternating magnetic field.

#### What you can learn about

- Magnetic field
- Precession frequency
- Gyroscope
- Magnetic induction

#### Main articles

Gyroscope w. magn. axis, ESR model	11208-00	1
Variable transformer, 25 VAC/ 20 VDC, 12 A	13531-93	1
Blower 230V/50Hz	13770-97	1
Coil, 1200 turns	06515-01	4
Commutator switch	06034-03	1
On/off switch	06034-01	1
Iron core, short, laminated	06500-00	2

#### Variable transformer, 25 VAC/ 20 VDC, 12 A



#### Function and Application

Standard heavy duty power supply unit for low voltage.

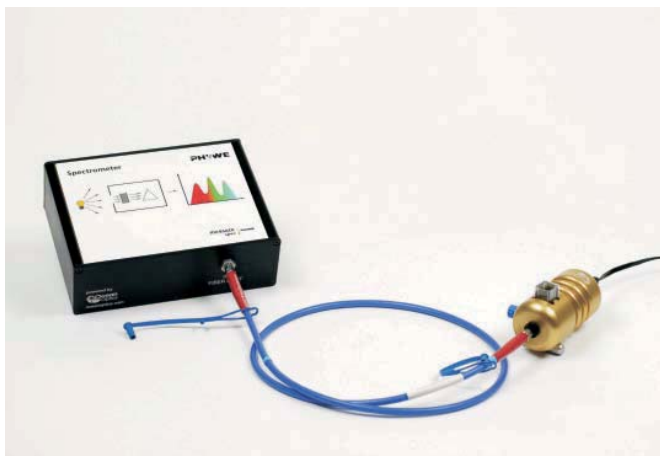
Supply unit for continuously adjustable DC and AC voltages & 2 frequently required fixed voltages.

#### Equipment and technical data

- AC output: 0...25 V/12 A
- DC output: 0...20 V/12 A
- Max. current (short term): 13 A
- Add. fixed voltages: 6 V AC / 6 A, 12 V AC / 6 A
- Max. current (short term): 10 A
- Max. power: 375 VA
- Fuses: one 13 A and two 10 A
- Supply voltage: 230 V AC
- Dimensions (mm): 230 x 236 x 234

13531-93

## Measurespec spectrometer with cuvette holder and light source



### Function and Applications

This set consisting of a Measurespec spectrometer (35610-00) and a cuvette holder and light source for the Measurespec (35610-99) makes it possible to record both emission and absorption spectra.

The light to be investigated is guided by optical fibres to a grid fixed inside the spectrometer, which disperses it into its spectral colours. The spectrum is recorded with the aid of a CCD array, which records the entire spectrum at once, making it possible to reliably record rapid changes in the spectrum itself. The spectra can be displayed and stored by means of the supplied software with its versatile functionality.

The spectrometer is connected to a PC via a USB port, which also suffices to supply power to the spectrometer, so that no additional supply is needed. The cuvette holder holds standard cuvettes measuring 1 cm x 1 cm. The built-in light source makes it possible to record absorption spectra for solutions. The rapid measuring rate of the spectrometer even allows the speed of reactions involving changes in colour to be measured (reaction kinetics).

Light having passed through the cuvette is guided into the spectrometer via optical fibre. Fibres for fluorescence measurements can also be attached at 90° to the path of the incident light.

### Benefits

Spectrometer:

- Robust aluminium case
- Rapid measurement of full spectral range
- Flexible introduction of light to be investigated by means of optical fibres
- No additional power supply required
- Measurement of emission spectra and absorption spectra
- Intuitive "measure" software for controlling the apparatus and recording spectra

Cuvette holder:

- Robust aluminium case
- Long-lived tungsten lamp
- Flexible introduction of light to be investigated by means of optical fibres

- Universal power supply via plug-in transformer
- Measurement of absorption spectra, fluorescence spectra, reaction kinetics

### Equipment and technical data

Spectrometer:

- Supplied with software and optical fibres
- Range of wavelengths: 350...850 nm
- Detector: silicon CCD array
- Resolution: 4 nm
- Connection to computer: USB
- Optical fibre connection: SMA 905
- Dimensions (mm): 170 x 126 x 55

Cuvette holder:

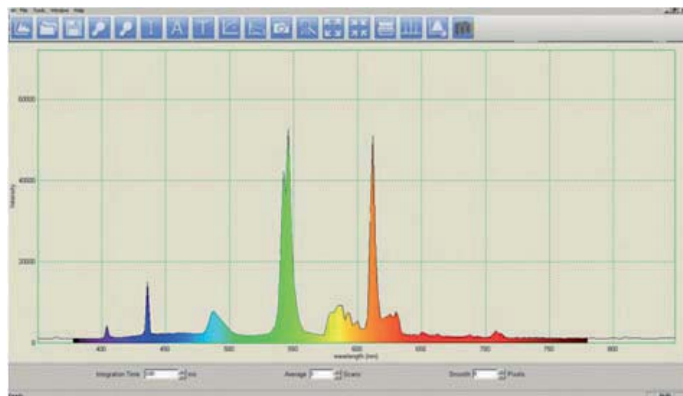
- Supplied with plug-in power supply and optical fibres
- Type of lamp: tungsten (lifetime approx. 2000 hours)
- Optical fibres: 50 µm x 2 m
- 2 optical fibre connectors: SMA 905
- Size of cuvettes: 1 cm x 1 cm
- Power supply: 100 ... 240 V / 50 ... 60 Hz
- Dimensions (mm): 95 x 51 x 46

### Accessories

Matching cuvettes:

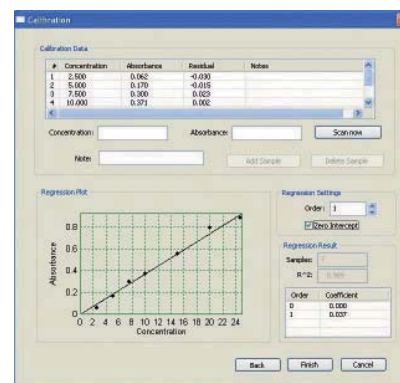
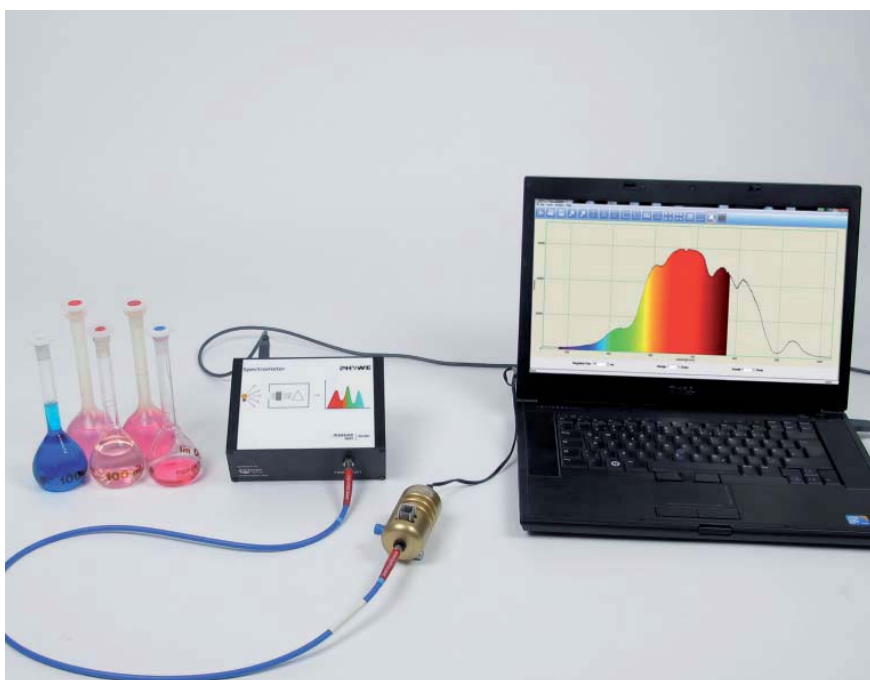
- Cuvettes for spectral photometer, optical glass, 12 x 12 x 45 mm, set of 2 (35664-02)
- Polystyrene macro-cuvette, 12 x 12 x 44 mm, 4 ml, set of 100 (35663-10)

## 35610-88



Representation of a spectrum in "measureSpec"

## P3070501 Multicomponent analysis with measureSpec (mixed colour photoetry)



Calibration curve for fuchsine acid.

### Principle

In solutions containing different-coloured substances the concentrations of the dyes can be analysed by spectrometry without prior separation of the substances.

Using measureSpec the spectra of the pure dye solutions and mixtures thereof will be recorded. Calibration curves for each substances enable us to determine the quantity of that substance in the solution.

### Task

In a mixed solution containing fuchsine acid and patent blue V, the proportion of fuchsine acid is to be determined.

### What you can learn about

- Photometry
- UV-VIS spectrometry
- Lambert-Beer's law
- Dyes
- Absorption of light

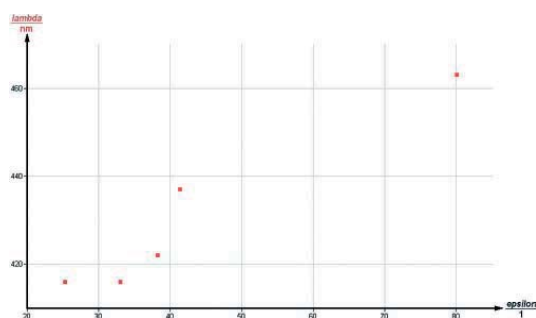
### Main articles

Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1
Measurespec spectrometer with cuvette holder and light source	35610-88	1
Fuchsine acid -rubin s-, 25 g	31813-04	1
Patent Blue V (sodium salt), 25 g	48376-04	1
Water, distilled 5 l	31246-81	1
Volumetric flask 100 ml, IGJ12/21	36548-00	9
Graduated pipette 25 ml	36602-00	1



## Absorption of light (UV-VIS spectroscopy)

P3070101



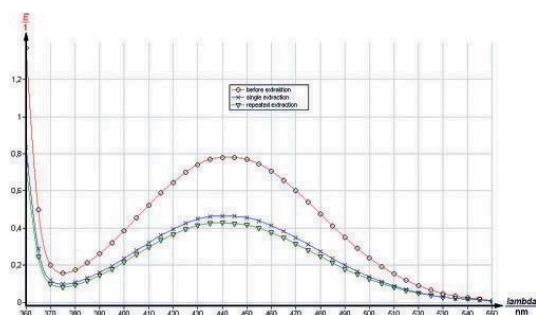
## Principle

The structures of molecules are not changed by their chemical environment in the gas phase. In contrast to this, on transition to the condensed phase, in dilute solution, the solvent changes the binding state of the dissolved substance. One of the way this influence makes itself shown is in the electron spectrum (solvatochromatic shift).

For more details refer to [www.phywe.com](http://www.phywe.com)

## Excitation of molecules

P3070301



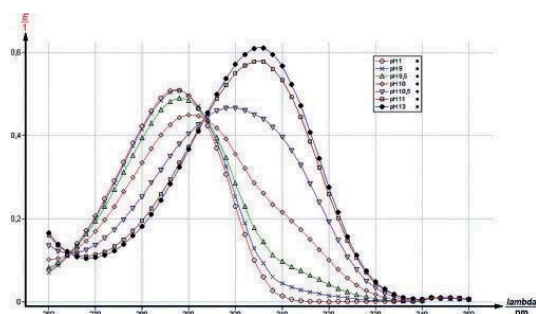
## Principle

The position of the longest wavelength  $\pi - \pi^*$ -absorption band in the UV-VIS spectrum of organic compounds which have chromophoric systems can be approximately calculated by various methods. For dyes with extended conjugated  $\pi$ -systems, the model of the electron in an unidimensional potential box (confinement region) supplies results that agree sufficiently well with experimental results.

For more details refer to [www.phywe.com](http://www.phywe.com)

## Absorption spectra and pKa values of p-methoxyphenol

P3070401



## Principle

For weak acids HA, the position of the  $K_a$  and  $pK_a$  values that characterise the dissociation equilibrium in the ground state can be determined from photometric measurements in solutions having different pH values. Further to this, the  $pK_a^*$  value for the excited state is accessible from the spectrophotometric data.

For more details refer to [www.phywe.com](http://www.phywe.com)

## 6 Spectroscopy

### 6.3 Photometry and Photochemistry

#### Spectrophotometer S800, 330...800 nm



##### Function and Applications

This visible diode array spectrophotometer has been designed to meet the routine spectroscopy needs of customers requiring a small, lightweight instrument that is easy to use. This photometer is ideal for use in educational, biotech or industrial establishments.

##### Benefits

- It measures absorbance, % transmission, absorbance ratio and concentration.
- The large backlit graphical display enables wavelength scans, kinetic assays (including slope calculation) and standard curves to be viewed.
- The instrument is delivered with "Grafico", a PC utility software package, and the requisite serial lead, providing the user with the means to capture, print and store data from the instrument on to a PC.
- The cell holder accepts standard 10 mm pathlength glass or plastic cuvettes.
- Large LCD-Display
- Splashproof touch-sensitive keyboard
- Serial interface (RS232) for transferring data to PC
- Measuring methods: absorbance; transmission; kinetic tests (absorbance and time-curves)

##### Equipment and technical data

- Optical system: single beam device with monochromator
- Lamp source: tungsten
- Wavelength range: 330...800 nm
- Wavelength accuracy:  $\pm 2$  nm
- Bandwidth: 7 nm
- Absorbance range: -0.300...2.500 Abs
- Photometric reproducibility:  $\pm 0.002$  Abs at 0...0.5 Abs and 546nm
- Photometric accuracy:  $\pm 0.01$  Abs bei 1 Abs
- Cell holder for standard cuvettes with outside dimension: 12 mm x 12 mm
- Interface: RS232 digital
- Dimension (mm): 215 x 270 x 120
- Weight: appr. 2 kg
- Mains connection: 230 V~, 50/60 Hz

35600-99

#### Spectrophotometer, SPEC 5000, 335-1000 nm



##### Function and Applications

The spectrophotometer is an easy to use device for measurement of the degree of absorption or transmission of liquid samples in the visible range (335...1000nm).

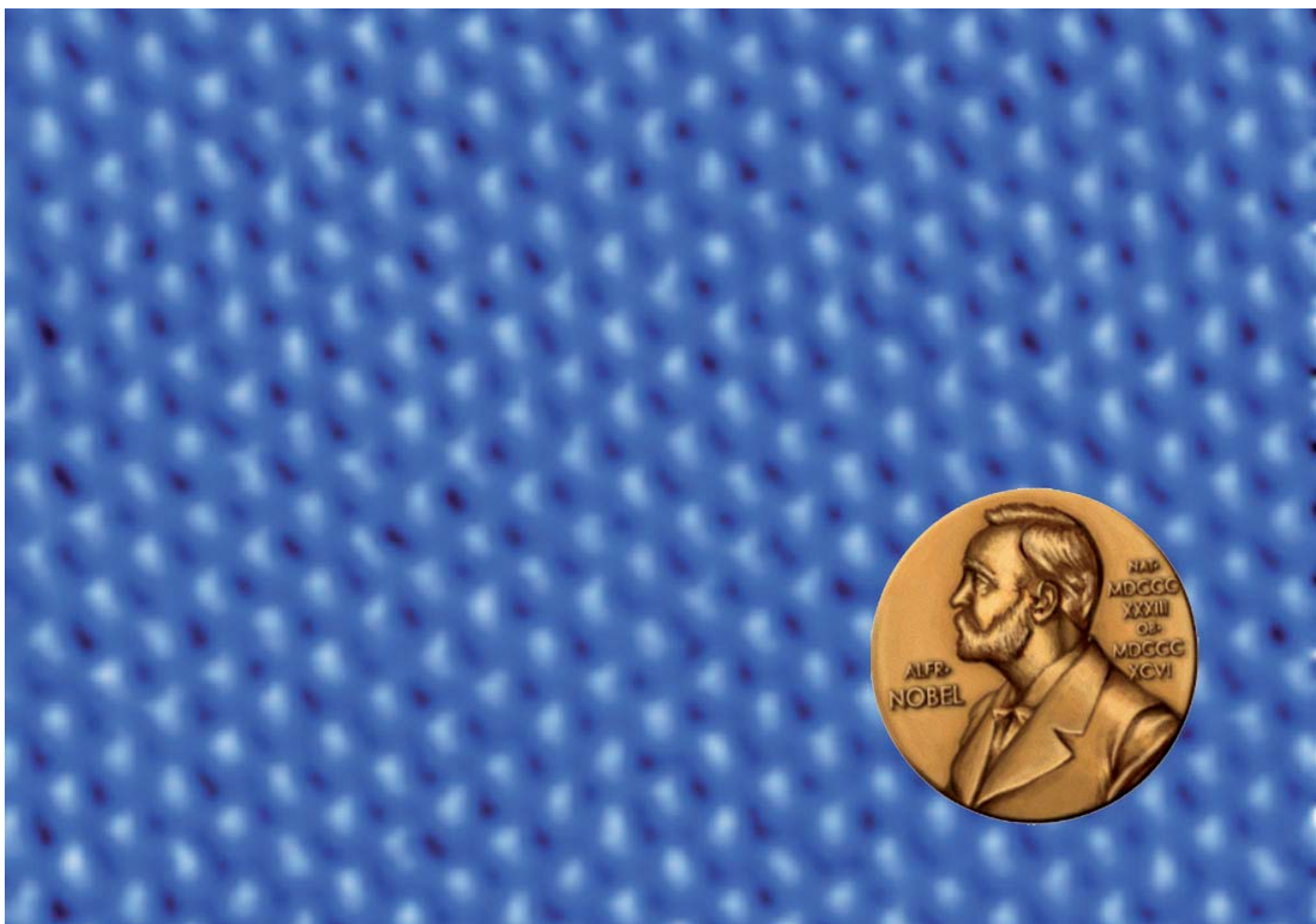
##### Benefits

- The display shows the wavelength, the degree of absorption and transmission or the concentration respectively
- it has RS232 resp. USB interfaces for connecting to a computer.

##### Equipment and technical data

- Light source: Tungsten
- Wavelength range: 335 ... 1000 nm
- Wavelength precision:  $\pm 2$  nm
- Wavelength repeatability:  $\pm 1$  nm
- Spectral bandwidth: 10 nm
- Cuvette holder: for square cuvettes with external dimensions 12 mm x 12 mm
- External dimensions (mm): 385 x 310 x 190
- Mains connection: 230 V, 50 Hz
- Included: Two square cuvettes (glass)
- Data cable for connecting to PC
- Two spare fuses (1 A)

35667-93



## Physical Chemistry

7.1	Gas Laws	72
7.2	Kinetic Theory	79
7.3	Viscosity	81
7.4	Thermochemistry / Calorimetry	84
7.5	Chemical Kinetics	97
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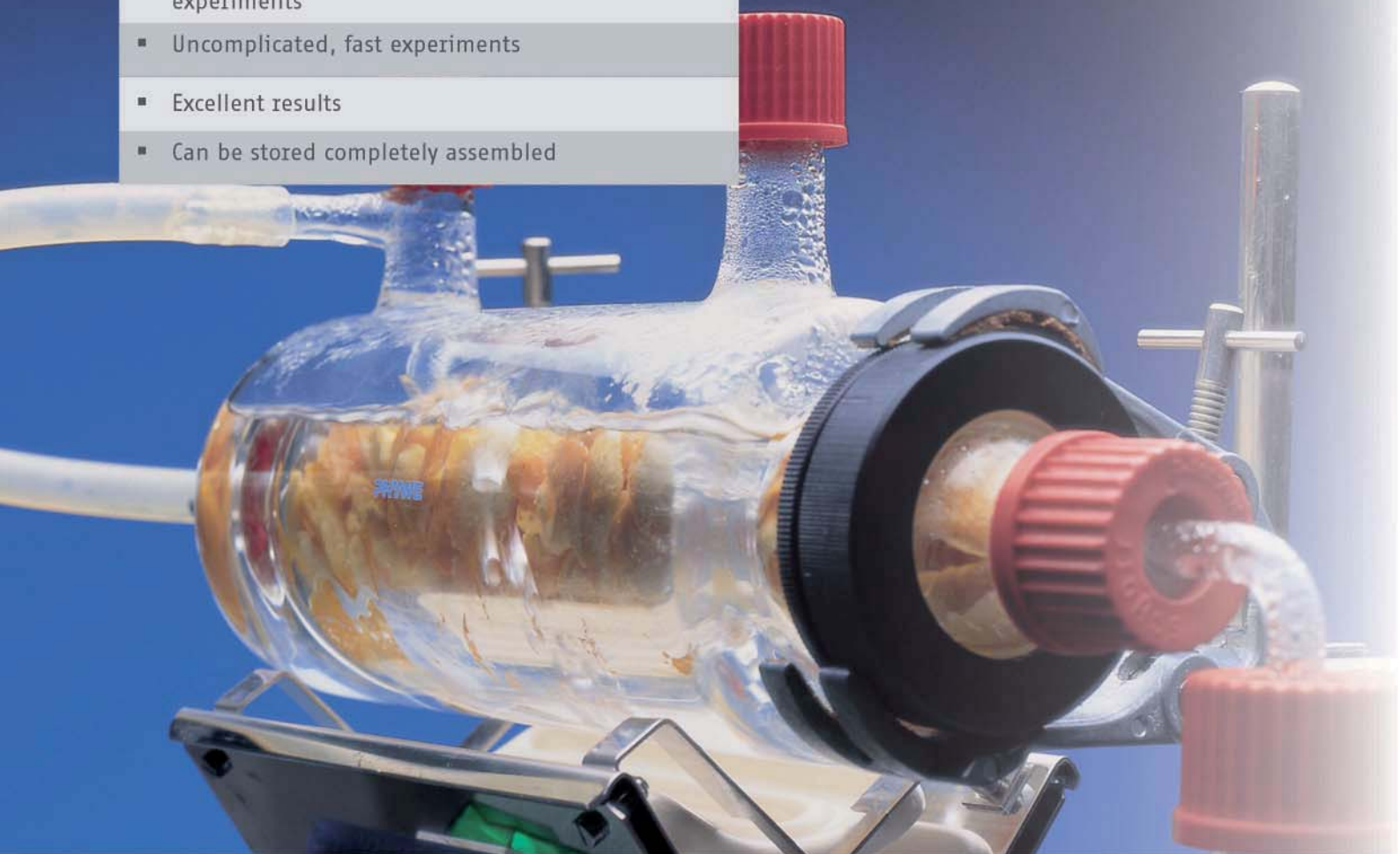
## Experiments with gases under isothermic or isobaric conditions – with the glass jacket apparatus no problem any more

The glass jacket apparatus is a multi-purpose system and finds application in numerous different fields of chemistry. It is for example used to develop the gas laws, to determine molar masses, to measure combustion enthalpies and provides easy and well-arranged set-ups for steam distillation and gas chromatography.

Working with the glass jacket system is easy – especially because of the detailed experiment descriptions.

### Your benefits

- Demonstrative and transparent
- Versatile modular system, easy to assemble
- Ideal for working with gases
- Manual with detailed instructions of experiments
- Uncomplicated, fast experiments
- Excellent results
- Can be stored completely assembled





### The Glass Jacket Apparatus System

The glass jacket apparatus system consists of the glass jacket and special inserts and accessories, allowing application in many fields of interest.

Gas Laws (e.g. P3011360)



Determination of molar masses (P3010501)



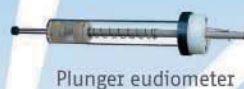
Gas reactions (e.g. The law of Avogadro, P3111000)



Gas reactions (e.g. Empirical molecular formula of methane, P3110900)



Gas syringe



Plunger eudiometer



Slow eudiometer



Steam distillation (P3031251)



Distillation insert



Glass jacket

Gas separation column



Gas chromatography (P3031760)



Calorimeter insert



Lid for the calorimeter insert

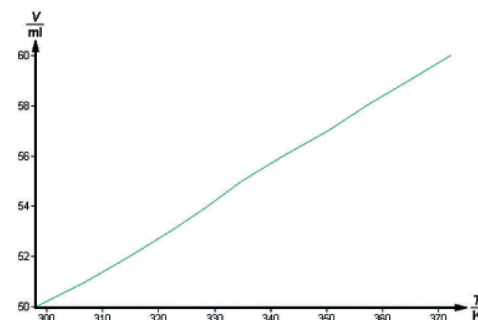


Calorimetry (e.g. Hess' law, P3021601)



Energy balances at gas reactions (P3021501)

### P3011160 Gay-Lussac's law with Cobra4



Dependence of the volume on the temperature under isobaric conditions.

#### Principle

The state of a gas is determined by temperature, pressure and amount of substance. For the limiting case of ideal gases, these state variables are linked via the ideal gas law. For a change of state under isobaric conditions this equation converts Gay-Lussac's first law.

#### Tasks

1. Experimentally investigate the validity of Gay-Lussac's law for a constant amount of gas (air).
2. Calculate the universal gas constant and the thermal coefficient of expansion from the relationship obtained.

#### What you can learn about

- Pressure
- Temperature
- Volume
- Coefficient of thermal expansion
- Ideal gas law
- Universal gas constant
- Gay-Lussac's law

#### Main articles

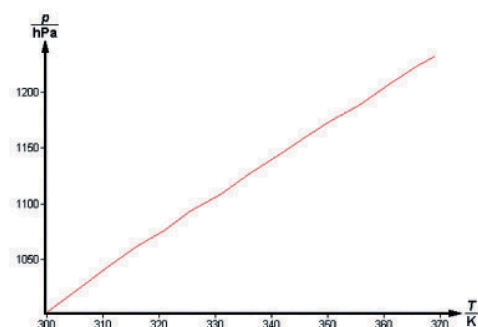
Set Gas laws w. glass jacket & Cobra4	43020-00	1
Cobra4 Remote-Link	12602-00	1



**Johannes Diderik van der Waals**  
1910, Nobel Prize in Physics

## Amontons' law with Cobra4

P3011260



Dependence of the pressure on the temperature under isochoric conditions.

**Principle**

The state of a gas is determined by temperature, pressure and amount of substance. For the limiting case of ideal gases, these state variables are linked via the ideal gas law. For a change of state under isochoric conditions this equation becomes Amontons' law.

**Tasks**

1. Experimentally investigate whether Amontons' law is valid for a constant amount of gas (air).
2. From the resulting relationship calculate the universal gas constant and thermal coefficient of tension.

**What you can learn about**

- Pressure
- Temperature
- Volume
- Thermal tension coefficient
- Ideal gas law
- Universal gas constant
- Charles's (Amontons') law

**Main articles**

Set Gas laws w. glass jacket & Cobra4	43020-00	1
Cobra4 Remote-Link	12602-00	1

**Cobra4 Remote-Link****Function and Applications**

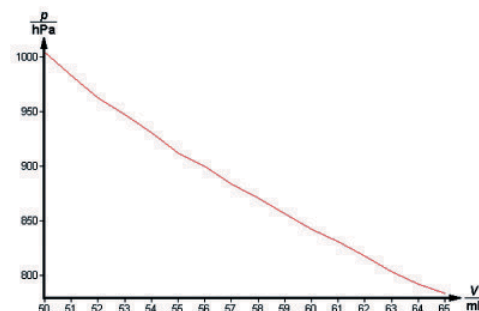
The Cobra4 Remote-Link is used to control the measuring value recording of an experiment constructed using a radiobased Cobra4 network.

**Benefits**

- The measuring value recording start and stop command is transmitted by radio to the Cobra4 Wireless Manager on the PC.
- Optimum application, e.g. in student experiments, free fall with an acceleration sensor etc. .

12602-00

### P3011360 Boyle's law with Cobra4



Correlation between volume and pressure under isothermal conditions.

#### Principle

The state of a gas is determined by temperature, pressure and amount of substance. For the limiting case of ideal gases, these state variables are linked via the ideal gas law. In the case of isothermal process control this equation converts Boyle and Mariotte's law.

#### Tasks

1. Experimentally investigate the validity of Boyle and Mariotte's law for a constant amount of gas (air).
2. From the resulting relationship calculate the universal gas constant.

#### What you can learn about

- Pressure
- Temperature
- Volume
- Cubic compressibility coefficient
- Ideal gas law
- Universal gas constant
- Boyle and Mariotte's law

#### Main articles

Set Gas laws w. glass jacket & Cobra4	43020-00	1
Cobra4 Remote-Link	12602-00	1

### Set Gas laws w. glass jacket & Cobra4



#### Function and Applications

Complete device compilation for a comfortable way to derive the ideal gas laws experimentally with help of the Cobra4 Sensor-Unit Thermodynamics and the glass jacket system.

#### Equipment and technical data

The set consists of:

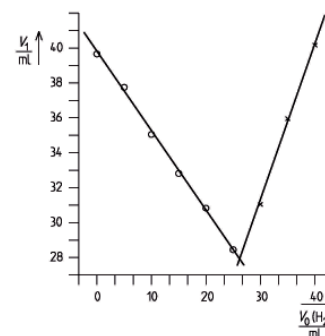
- 1 Cobra4 Wireless Manager; 1 Cobra4 Wireless-Link.
- 1 Cobra4 Sensor-Unit Thermodynamics, pressure absolute 2 bar and 2 x temperature.
- 1 Software measure Cobra4, single user and school licence.
- 1 Glass jacket; 1 Gas syringe 100 ml; 1 Heater for Glass jacket.
- 1 Immersion probe NiCr-Ni, -50...1000 °C.
- All necessary support materials and all the other small hardware items to be able to carry out the measurements for the gas laws.

43020-00



## Law of integer ratio of volumes according to Gay-Lussac's law of chemical volumes

P3031401



Dependence of the final volume reduced to room temperature from the initial volume of hydrogen-oxygen mixtures of different composition.

### Principle

According to Gay-Lussac's law of chemical volumes, gases react in volume ratios which are whole numbers. These values can be volumetrically determined.

### Task

Determine the volume ratio for the conversion of hydrogen and oxygen to water experimentally by burning gas mixtures of different compositions and measuring the resulting gas volume.

### What you can learn about

- Law of constant proportions
- Avogadro's law
- Gay-Lussac's law of chemical volumes
- General equation of state for ideal gases
- Gay-Lussac's first law

### Main articles

High voltage supply unit, 0-10 kV	13670-93	1
Slow eudiometer	02612-00	1
Glass jacket	02615-00	1
Steel cylinder hydrogen, 2 l, full	41775-00	1
Heating apparatus for glass jacket system	32246-93	1
Steel cylinder oxygen, 2 l, filled	41778-00	1
Power regulator	32288-93	1

### Related Experiment

Thermal equation of state and critical point

P2320400

### High voltage supply unit, 0-10 kV



### Function and Applications

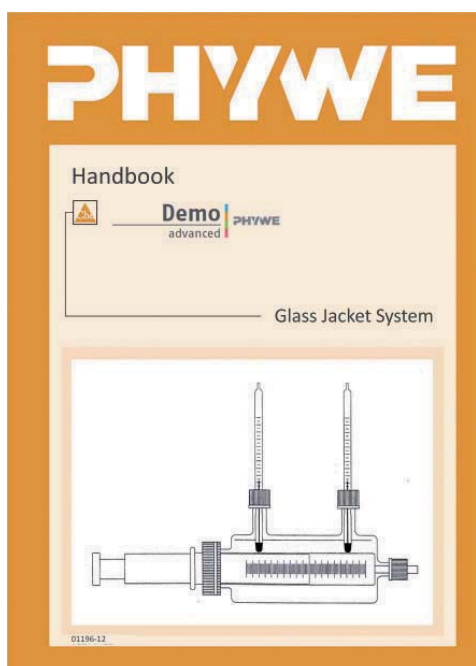
For electrostatic experiments and for operation of spectral and gas discharge tubes.

### Equipment and technical data

- It supplies 3 continuously variable DC voltages isolated from earth and ground.
- Two of the voltages are connected in series 0-5 kV DC = total of 0 -10 kV DC.

13670-93

### Handbook Glass Jacket System



**Article no. 01196-12**

#### Description

Comprehensive set of 17 experiments using the glass jacket set for various uses.

#### Topics

- Gas laws
- Gas reactions
- Determining molecular mass
- Calorimetry
- Gas chromatography
- Distillation of steam

This system consists of a glass jacket, special inserts and accessories. It was mainly developed for experiments with gases and can be used at school for teaching physics, chemistry and biology.

- Demonstrative and transparent
- Versatile and easily assembled
- Water bath for accurate measurements

#### This documentation contains the following experiments:

Gay-Lussac's law

**P1222900**

Charles's (Amontons') law

**P1223000**

The Boyle-Mariotte law

**P1223100**

The gas laws of Boyle-Mariotte, Gay-Lussac and Charles (Amontons)

**P1223200**

Determination of molar masses with the vapour density method

**P1223301**

Law of integer ratio of volumes

**P1223400**

Gay-Lussac's law of volumes

**P1223551**

Avogadro's law

**P1223651**

The empirical formula of methane, ethane and propane

**P1223751**

Determination of the heat of formation of water

**P1223800**

Determination of the heat of formation of CO<sub>2</sub> and CO and Hess's law

**P1223900**

Determination of the heating values of solid and gaseous fuels in a horizontal calorimeter

**P1224051**

Determination of the calorific value of food stuffs

**P1224100**

Determination of the heating values of liquids in a vertical calorimeter

**P1224251**

Determination of the heating value of fuel oil and of the calorific value of olive oil

**P1224300**

Chromatographic separation processes: Gas chromatography

**P1224451**

Steam distillation

**P1224551**

**01196-12**



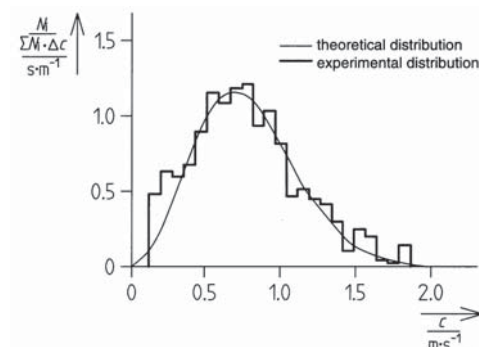
**Steam distillation - P3031251**

## Maxwellian velocity distribution

P2320300



Demo



Experimental and theoretical velocity distribution in the model experiment.

## Principle

By means of the model apparatus for kinetic theory of gases the motion of gas molecules is simulated and the velocities determined by registration of the throw distance of the glass balls. This velocity distribution is compared to the theoretical Maxwell-Boltzmann equation.

## Tasks

1. Measure the velocity distribution of the "model gas".
2. Compare the result to theoretical behaviour as described by the Maxwell-Boltzmann distribution.
3. Discuss the results.

## What you can learn about

- Kinetic theory of gases
- Temperature
- Gas-molecules
- Model kinetic energy
- Average velocity
- Velocity distribution

## Main articles

Kinetic gas theory apparatus	09060-00	1
Digital stroboscope	21809-93	1
Receiver with recording chamber	09061-00	1
Power supply variable 15 VAC/ 12 VDC/ 5 A	13530-93	1
Tripod base PHYWE	02002-55	2
Stopwatch, digital, 1/100 s	03071-01	1

## measure Dynamics experiment - available 2014

## Maxwellian velocity distribution with measure Dynamics

P2320380

## Kinetic gas theory apparatus



## Function and Applications

Kinetic gas theory apparatus with vertical chamber and built in motor.

## Equipment and technical data

- Chamber (mm) 60 x 20 x 180
- Motor supply 12 VDC /20 W

09060-00

## P3010301 Diffusion in gases: The diffusion coefficient of bromine in air



$$D = - \frac{\Delta m \cdot l \cdot R \cdot T}{M \cdot A \cdot p_0 \cdot \Delta t}$$

Diffusion coefficient of Fick's first law.

### Principle

Diffusion arises from the flow of matter down a concentration gradient. In the evaporation method, a stationary concentration gradient is achieved in which the concentration decreases linearly with distance. Under these conditions the diffusion coefficient of the diffusing substance may be calculated by a direct application of Fick's first law of diffusion.

### Task

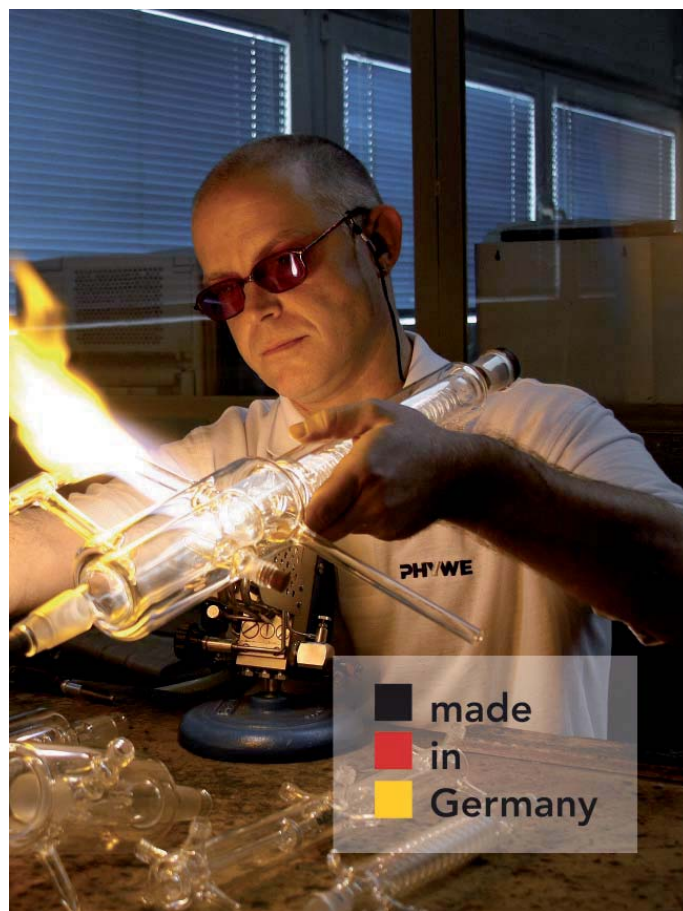
Measure the diffusion coefficient of bromine in air using an evaporation method.

### What you can learn about

- Kinetic theory of gases
- Transport properties
- Fick's laws of diffusion
- Self and mutual diffusion coefficients
- Alternative techniques e.g. Loschmidt's method

### Main articles

Sec. bottle 500ml, 2xGl18/8, 1x25/12	34170-01	1
Tube connector, T-shaped, IGJ29	35859-00	1
Spring manometer, 0...-1000 mbar	34170-02	1
Bromine 100 ml	30046-10	1
Gas-wash. bottle w. frit, IGJ.29/32	36691-01	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

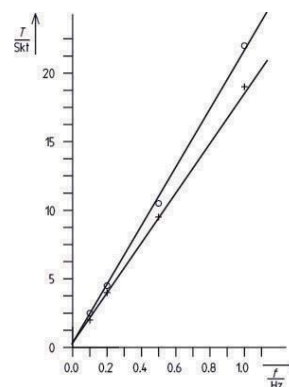


made  
 in  
 Germany



## Viscosity of Newtonian and non-Newtonian liquids (rotary viscometer)

P2140300



Moment of rotation as a function of the frequency for a Newtonian liquid glycerol (+), liquid paraffin (o).

### Principle

The viscosity of liquids can be determined with a rotation viscometer, in which a motor with variable rotation speed drives a cylinder immersed in the liquid to be investigated with a spiral spring. The viscosity of the liquid generates a moment of rotation at the cylinder which can be measured with the aid of the torsion of the spiral spring and read on a scale.

### Tasks

1. Determine the gradient of the rotational velocity as a function of the torsional shearing stress for two Newtonian liquids (glycerine, liquid paraffin).
2. Investigate the temperature dependence of the viscosity of Castor oil and glycerine.
3. Determine the flow curve for a non Newtonian liquid (chocolate).

### What you can learn about

- Shear stress; Velocity gradient; Internal friction
- Viscosity; Plasticity

### Main articles

Rotary viscometer, 15 - 2,000,000 mPas	18223-99	1
Magnetic stirrer MR Hei-Standard	35750-93	1
Electronic temperature controller EKT Hei-Con	35750-01	1
Glycerol 250 ml	30084-25	2
Separator for magnetic bars	35680-03	1
Supp.rod stainl.st.,50cm,M10-thr.	02022-20	1
Acetone, chem.pure 250 ml	30004-25	3

### Rotary viscometer, 15 - 2,000,000 mPas

#### Function and Applications

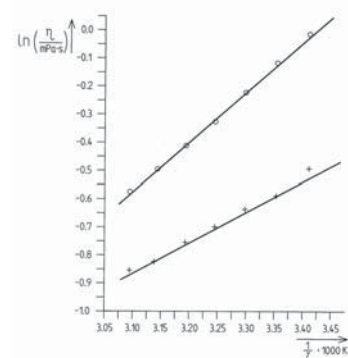
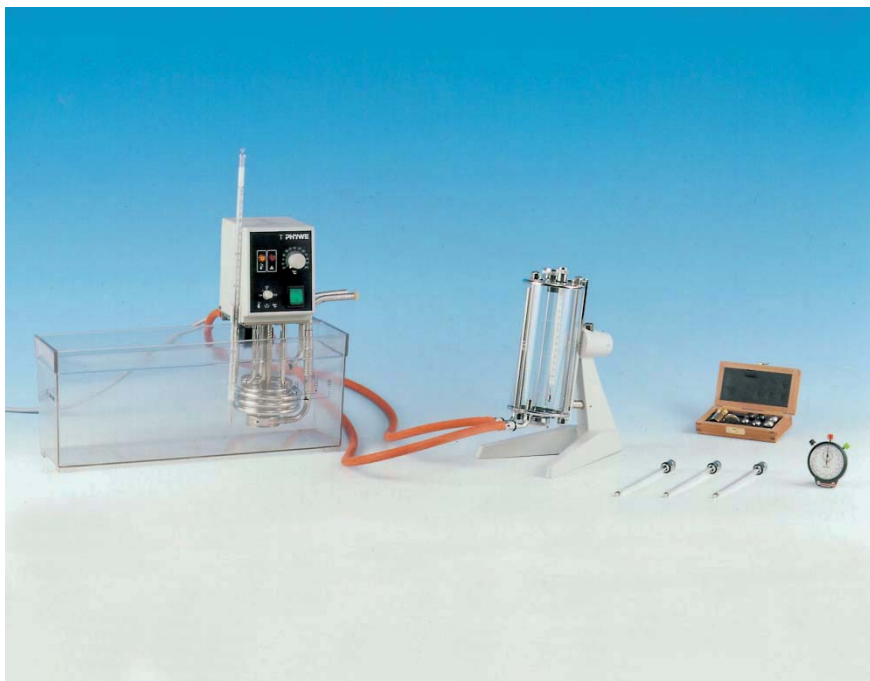
Classic rotational viscometer for the viscosity determination according to ISO2555 ("Brookfield method") and many ASTM standards.

#### Benefits

- The results are 100% compatible to the Brookfield method.
- All results (viscosity, torque in %, speed, spindle) are displayed on the built-in display.
- Multilanguage display: English, French, German, Spanish, Italian, Japanese, Portuguese, Dutch, Polish, Catalan.
- Visual and acoustic signals at critical measuring conditions.
- Warning, if the device is used outside of the permissible measuring ranges.
- Digital speed control with "built-in" accuracy through stepping motor.
- Touchless, optoelectronic torque measuring system with high accuracy and without wear.
- It is supplied as a complete measuring unit consisting of the basic instrument with stand, set of spindles with a storage rack in a stable case.

18223-99

## P2140400 Viscosity measurement with the falling ball viscometer



Temperature dependence of the dynamic viscosity of water (o) and methanol (+), respectively.

### Principle

Due to internal friction among their particles, liquids and gases have different viscosities. The viscosity, a function of the substance's structure and its temperature, can be experimentally determined, for example, by measuring the rate of fall of a ball in a tube filled with the liquid to be investigated.

### Tasks

Measure the viscosity

1. of methanol-water mixtures of various composition at a constant temperature,
2. of water as a function of the temperature and
3. of methanol as a function of temperature.

From the temperature dependence of the viscosity, calculate the energy barriers for the displacement of water and methanol.

### What you can learn about

- Newtonian liquid
- Stokes law; Fluidity
- Dynamic and kinematic viscosity
- Viscosity measurements

### Main articles

Falling ball viscometer	18220-00	1
Immersion thermostat Alpha A, 230 V	08493-93	1
Thermometer, 24...+ 51 °C, for 18220.00	18220-02	1
Bath for thermostat, makrolon	08487-02	1
External circulation set f. thermostat Alpha A	08493-02	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

### Falling ball viscometer



### Function and Applications

Falling ball viscometer.

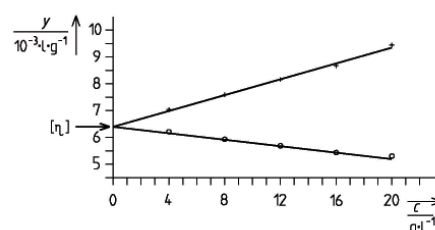
### Equipment and technical data

- Thermometer
- Diameter of the fall tube: 15.95 mm
- Initiabile fall times: 25...300 s
- Fall distance: 100 mm
- 6 balls

**18220-00**

## Determining the molecular weight of a polymer from intrinsic viscosity measurements

P3010601



Plot used to determine the intrinsic viscosity  $h$ .  
Data for polystyrene in toluene at 25.0°C.

**Principle**

The viscosity of a liquid is effectively determined by the strength of the intermolecular attractive forces. In the case of solutions, the viscosity of the solvent can alter significantly depending on the type and concentration of the solute. Due to their size, macromolecules have a very considerable impact on the viscosity of the solvent. Viscosity measurements can be used to estimate the mean molecular mass of a macromolecule if something is known about its conformation.

**Tasks**

1. Use a thermostatted capillary viscometer to measure the viscosities of solutions of polystyrene in toluene over a range of five polymer concentrations.
2. Determine the intrinsic viscosity and from that estimate the molecular weight (relative molecular mass) of the polymer in this solution.

**What you can learn about**

- Viscosity of liquids
- Ostwald capillary viscometer
- Poiseuille's equation
- Macromolecules
- Mass average and number average molecular weights
- The Mark-Houwink equation
- Alternative techniques e.g. osmosis
- Sedimentation (ultracentrifuge methods)
- Light scattering

**Main articles**

Immersion thermostat Alpha A, 230 V	08493-93	1
Ubbelohde viscosimeter, 0.4 mm	03102-03	1
Bath for thermostat, makrolon	08487-02	1
External circulation set f. thermostat Alpha A	08493-02	1
Retort stand, h = 750 mm	37694-00	1
Water jet pump, plastic	02728-00	1
Set of Analytical Balance Sartorius CPA 224S and measure software, 230 V	49221-88	1

## P2320500 Adiabatic coefficient of gases - Flammersfeld oscillator



Argon	$\chi = 1.62 \pm 0.09$
Nitrogen	$\chi = 1.39 \pm 0.07$
Carbon dioxide	$\chi = 1.28 \pm 0.08$
Air	$\chi = 1.38 \pm 0.08$

Sample results for the adiabatic coefficients. Experimental conditions: ten measurements, each of about  $n = 300$  oscillations.

### Principle

A mass oscillates on a volume of gas in a precision glass tube. The oscillation is maintained by leading escaping gas back into the system. The adiabatic coefficient of various gases is determined from the periodic time of the oscillation.

### Tasks

Determine the adiabatic coefficient of air, nitrogen and carbon dioxide (and also of argon, if available) from the periodic time of the oscillation  $T$  of the mass  $m$  on the volume  $V$  of gas.

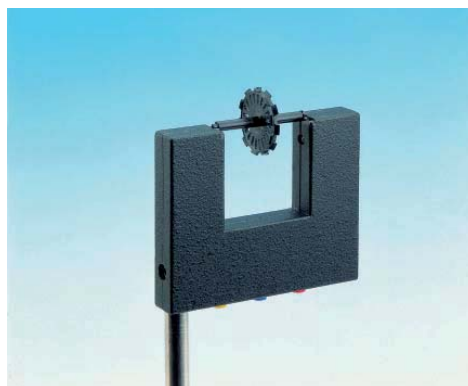
### What you can learn about

- Equation of adiabatic change of state
- Polytropic equation
- Rüchardt's experiment
- Thermal capacity of gases

### Main articles

Steel cylinder, CO <sub>2</sub> , 10l, full	41761-00	1
Steel cylinder, nitrogen, 10l, full	41763-00	1
Light barrier with counter	11207-30	1
Gas oscillator, Flammersfeld	04368-00	1
Sliding weight balance, 101 g / 0.01 g	44012-01	1
Reducing valve for CO <sub>2</sub> / He	33481-00	1
Reducing valve f. nitrogen	33483-00	1

### Light barrier, compact



### Function and Applications

Universal fork-type light barrier to measure short and long shadowing periods.

### Benefits

- An incremental wheel with a string groove which can be attached to the fork of the light barrier allows to measure paths by counting the ribs of the incremental wheel.
- Areas of application: track experiments, freefall, pendulum experiments, leaf spring oscillations, drop counters, volumetric measurements concerning the gas laws.

### Equipment and technical data

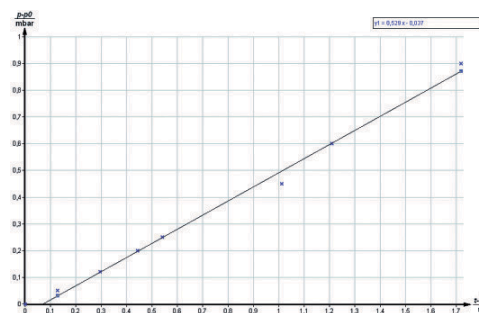
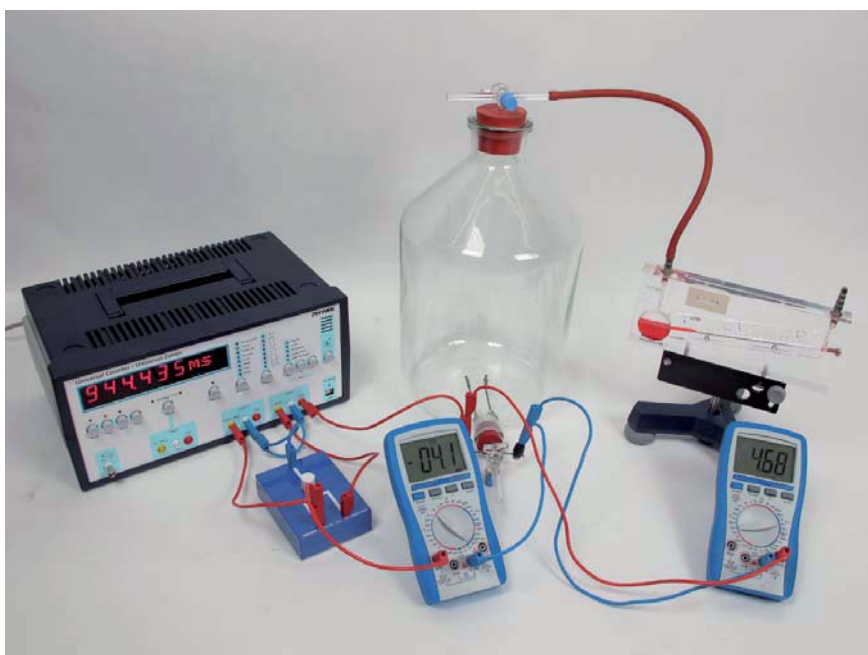
- Dimensions: 40 x 40 mm
- Supply voltage: 5 V

11207-20



## Heat capacity of gases

P2320201



Pressure change  $\rho$  as a function of the heat-up time  $t$ .  $U = 4.59 \text{ V}$ ,  $I = 0.43 \text{ A}$ .

### Principle

Heat is added to a gas in a glass vessel by an electric heater which is switched on briefly. The temperature increase results in a pressure increase, which is measured with a manometer. Under isobaric conditions a temperature increase results in a volume dilatation, which can be read from a gas syringe. The molar heat capacities  $C_V$  and  $C_p$  are calculated from the pressure or volume change.

### Task

Determine the molar heat capacities of air at constant volume  $C_V$  and at constant pressure  $C_p$ .

### What you can learn about

- Equation of state for ideal gases
- First law of thermodynamics
- Universal gas constant
- Degree of freedom
- Mole volumes
- Isobars
- Isotherms
- Isochores and adiabatic changes of state

### Main articles

Universal Counter	13601-99	1
Precision manometer	03091-00	1
Weather station, wireless	04854-00	1
Mariotte flask, 10 l	02629-00	1
Tripod base PHYWE	02002-55	1
Digital multimeter 2010	07128-00	2
Two-way switch, single pole	06030-00	1

## Universal Counter



### Function and Applications

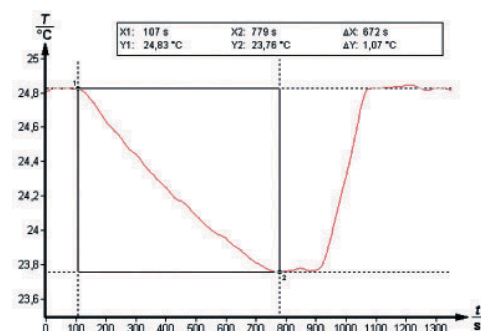
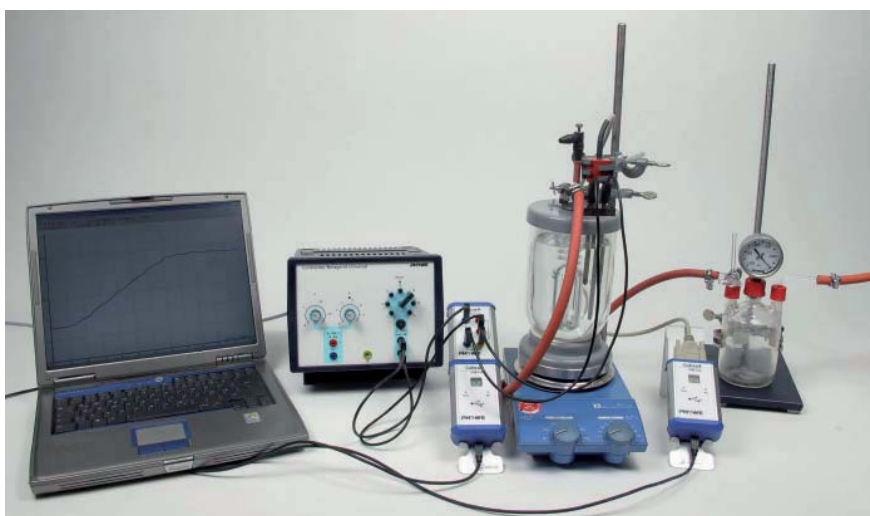
The universal counter is used for measuring time, frequency, pulse rates, pulse counting, periodic times, speeds and velocities.

### Benefits

- The device has all the qualities that are expected of a modern universal counter and is also equipped with a number of technical specifics of how it specifically arise from the requirements of science teaching practice.
- For the scientifically correct representation of each measurement is shown in principle with the associated unit. With the overflow of the display is automatically switched into the next area.
- Before the measurement starts it can be manually adjusted to a maximum of 6 decades defined range, e.g. to suppress is not physically meaningful digits on the display.
- A special jack for direct connection of a GM counter tube is available for radioactivity experiments. The required voltage can be changed manually to determine the characteristics of a counter tube too.

13601-99

## P3020461 Determination of the enthalpy of vaporisation of liquids with Cobra4



Temperature-time curve of the vaporisation of diethyl ether and determining the heat capacity of the system.

### Principle

The vaporisation of a liquid occurs with heat absorption. To determine the enthalpy of vaporisation, a known mass of the liquid which is to be investigated is vaporised in a special vaporisation vessel in a current of air. The quantity of heat absorbed, which corresponds to the enthalpy of vaporisation, can be calorimetrically determined.

### Tasks

1. Determine the molar enthalpy of vaporisation of diethyl ether and methanol.
2. Calculate the molar entropies of vaporisation and discuss the results under consideration of Trouton's rule.

### What you can learn about

- Enthalpy of vaporisation
- Enthalpy of condensation
- Enthalpy of sublimation
- Vapour pressure
- Entropy of vaporization
- Clausius-Clapeyron equation
- Trouton's rule
- Law of thermodynamics; Calorimetry

### Main articles

Cobra4 Sensor-Unit Energy: Current, voltage, work, power	12656-00	1
Set of Precision Balance Sartorius CPA 6202S and measure software, 230 V	49226-88	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1
Power supply, universal	13500-93	1
Magnetic stirrer MR Hei-Standard	35750-93	1
Software Cobra4 - multi-user licence	14550-61	1
Calorimeter, transparent, 1200 ml	04402-00	1

### Evaporation vessel for calorim.

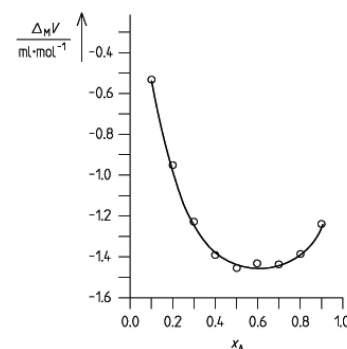


Insert for transparent calorimeter to determine the evaporation heat of liquids. The liquid is evaporated in an air flow and the required energy is drawn from the water bath of the calorimeter. The evaporation chamber is covered with a glass filter plate. Spiral shaped heat exchanger.

04405-00

## Partial molar volumes

P3020501



Dependence of the mean molar mixing volumes on the composition of different ethanol/water mixtures.

### Principle

Due to intermolecular interactions, the total volume measured when two real liquids (e.g. ethanol and water) are mixed deviates from the total volume calculated from the individual volumes of the two liquids (volume contraction). To describe this non-ideal behaviour in the mixing phase, one defines partial molar quantities which are dependent on the composition of the system. The values of these can be experimentally determined.

### Tasks

1. Measure the densities of different ethanol-water mixtures of specified composition at 20 °C with pycnometers.
2. Calculate the real volumes and the mean molar mixing volumes of the investigated ethanol-water mixtures and also the partial molar volumes of each liquid for selected compositions.
3. Compare them with the molar volumes of the pure substances at 20 °C.

### What you can learn about

- Principles of thermodynamics
- Ideal and non-ideal behaviour of gases and liquids
- Volume contraction
- Molar and partial molar quantities

### Main articles

Immersion thermostat Alpha A, 230 V	08493-93	1
Bath for thermostat, Makrolon	08487-02	1
External circulation set f. thermostat Alpha A	08493-02	1
Pycnometer, calibrated, 25 ml	03023-00	9
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

### Immersion thermostat Alpha A, 230 V



### Function and Applications

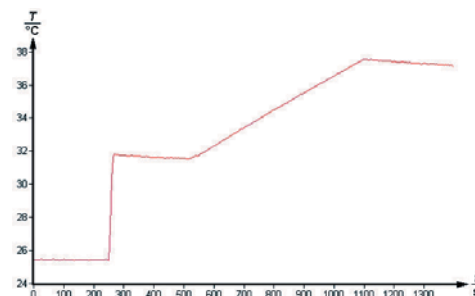
Immersion circulator with simple, reliable options for obtaining consistent results. Compact unit can be combined with any existing baths up to 25 mm wall thickness.

### Benefits

- Wide temperature range to meet application needs.
- Digital settings for simple operation.
- Strong pump for high temperature conformity.
- To be used with water as heat transfer liquid.
- Screw clamp for bath walls up to 25 mm.
- Robust design using high grade stainless steel and temperature resistant polymer.
- Wear-free; integrated overload protection.

08493-93

## P3020661 Determination of the mixing enthalpy of binary fluid mixtures with Cobra4



Temperature-time curve of the mixing of two miscible fluids and determining the heat capacity of the system.

### Principle

When two miscible liquids are mixed, a positive or negative heat effect occurs, which is caused by the interactions between the molecules. This heat effect is dependent on the mixing ratio. The integral mixing enthalpy and the differential molar mixing enthalpy can be determined by calorimetric measurements of the heat of reaction.

### Tasks

1. Measure the integral mixing enthalpy of seven different water-acetone mixtures.
2. Plot the molar integral mixing enthalpy versus the quantity of substance (mole fraction) and determine the molar mixing enthalpy.
3. Discuss the results on the basis of the interactions in the mixture.

### What you can learn about

- Differential molar mixing enthalpy; Real and ideal behaviour
- Integral molar mixing enthalpy; Fundamental principles of thermodynamics; Calorimetry

### Main articles

Set of Precision Balance Sartorius CPA 6202S and measure software, 230 V	49226-88	1
Immersion thermostat Alpha A, 230 V	08493-93	1
Power supply, universal	13500-93	1
Magnetic stirrer MR Hei-Standard	35750-93	1
Software Cobra4 - multi-user licence	14550-61	1
Cobra4 Sensor-Unit Energy: Current, voltage, work, power	12656-00	1
Calorimeter, transparent, 1200 ml	04402-00	1

### Set calorimetry, 230 V



### Function and Applications

With this setup a great number of measurements to heat capacities, reaction enthalpies, solution enthalpies, neutralisation enthalpies, melting enthalpies and enthalpies of mixtures can be carried out.

### Advantages

This set allows to execute the measurements in a didactical clear and easy way:

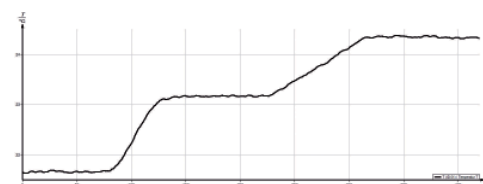
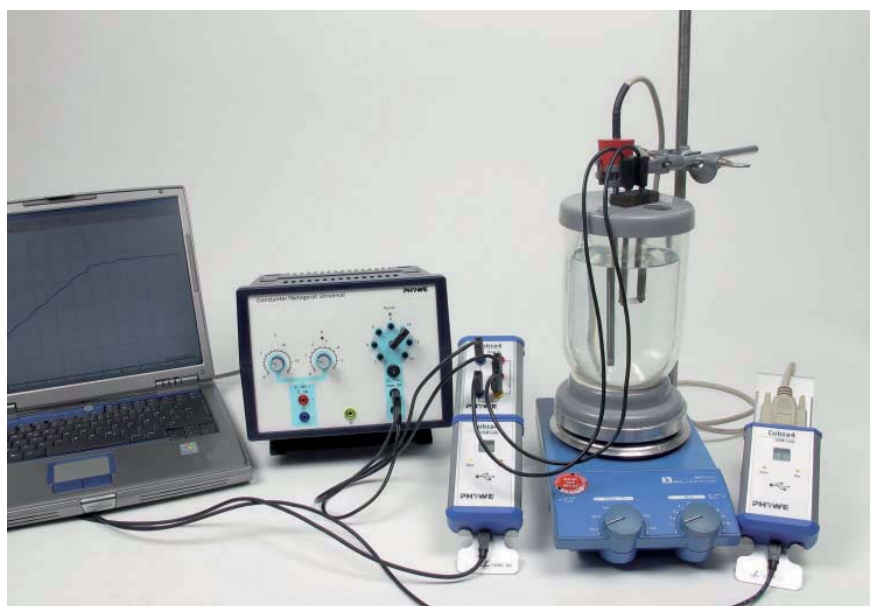
- the transparent calorimetric vessel allows at every time a free insight into the system
- the heat capacity of the calorimetric system itself is determined especially conveniently by supplying an exactly known amount of electric heating energy to the system

43030-88



## Determination of the hydration enthalpy of an electrolyte (solution enthalpy) with Cobra4

P3020761



Example measurement.

### Principle

When a solid electrolyte dissolves in water, a positive or negative heat effect occurs as a result of the destruction of the crystal lattice and the formation of hydrated ions. The enthalpy of hydration of copper sulphate can be calculated from the different heats of reaction measured when anhydrous and hydrated copper sulphate are separately dissolved in water.

### Tasks

1. Record temperature-time curves for the dissolution of anhydrous copper sulphate and hydrated copper sulphate in water.
2. Calculate the hydration enthalpy of anhydrous copper(II)sulphate.

### What you can learn about

- Integral enthalpy of solution
- Hess's law
- Lattice energy
- Ion solvation
- Calorimetry

### Main articles

Cobra4 Sensor-Unit Energy: Current, voltage, work, power	12656-00	1
Cobra4 USB-Link	12610-00	2
Calorimeter, transparent, 1200 ml	04402-00	1
Set of Precision Balance Sartorius CPA 6202S and measure software, 230 V	49226-88	1
Power supply, universal	13500-93	1
Magnetic stirrer MR Hei-Standard	35750-93	1
Software Cobra4 - multi-user licence	14550-61	1

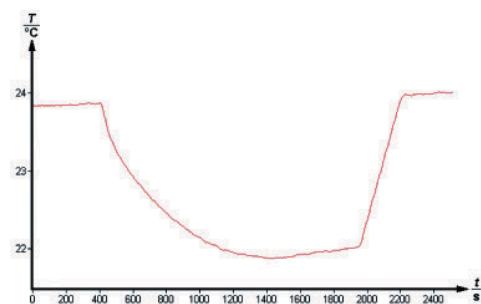
### Related Experiment

#### Determination of the enthalpy of neutralisation with Cobra4

P3020861

You need more information about Cobra4? Go to chapter „Computer Assisted Measurement“.

**P3020961**      **Determination of the melting enthalpy of a pure substance mit Cobra4**



Temperature-time curve for the melting process of dioxan and determining the heat capacity of the system.

**Principle**

When a solid melts, energy is required for the destruction of the crystal lattice. A substance whose melting point lies slightly below room temperature is first cooled until it solidifies and then melted in a calorimeter. The melting enthalpy is calculated from the decrease in temperature due to the melting process which is measured in the calorimeter.

**Tasks**

1. Take a temperature-time-diagram for the melting process of dioxan.
2. Calculate the melting enthalpy and entropy of 1,4-dioxan.

**What you can learn about**

- Heat capacity
- Melting point
- Latent heat
- Calorimetry
- Gibbs' phase rule
- Enthalpy of sublimation
- Enthalpy of vaporisation

Main articles			
Set of Precision Balance Sartorius CPA 6202S and measure software, 230 V	49226-88	1	
Power supply, universal	13500-93	1	
Magnetic stirrer MR Hei-Standard	35750-93	1	
Software Cobra4 - multi-user licence	14550-61	1	
Cobra4 Sensor-Unit Energy: Current, voltage, work, power	12656-00	1	
Calorimeter, transparent, 1200 ml	04402-00	1	
Cobra4 USB-Link	12610-00	2	



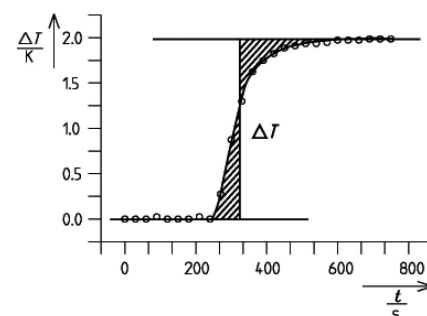
made in Germany

## Determination of the enthalpy of combustion with a calorimetric bomb

P3021401



Demo



Determining the corrected temperature difference.

## Principle

The bomb calorimeter is used to completely burn substances in an excess of oxygen. The heat of combustion released is absorbed by the calorimetric vessel in which the bomb is immersed, and results in a temperature increase  $\Delta T$ . The heat capacity of the system is first determined by adding a defined amount of heat from the combustion of benzoic acid. The combustion of the naphthalene is subsequently performed under the same conditions.

## Tasks

1. Determine the enthalpy of combustion of naphthalene using a bomb calorimeter.
2. Calculate the enthalpy of formation of naphthalene from the enthalpy of combustion using Hess' law.

## What you can learn about

- First law of thermodynamics
- Hess' law of constant heat summation
- Enthalpy of combustion
- Enthalpy of formation
- Heat capacity

## Main articles

Calorimetric bomb	04403-00	1
Temperature meter digital, 4-2	13617-93	1
Power supply, universal	13500-93	1
Magnetic stirrer MR Hei-Standard	35750-93	1
Calorimeter, transparent, 1200 ml	04402-00	1
Set of Precision Balance Sartorius CPA 6202S and measure software, 230 V	49226-88	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

## Calorimetric bomb



## Function and Applications

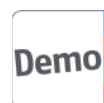
Calorimetric bomb for the quantitative determination of combustion heat of liquid and solid organic substances under high oxygen pressure.

## Equipment and technical data

- Stainless steel body
- Contents approx. 120 ml
- Stainless steel lid with valve
- Oxygen filling connection
- Max. oxygen pressure 25 bar
- Ignition wire

04403-00

## P3021501 Determination of the heat of formation of water



$$\Delta n (H_2) = \frac{pV}{RT}$$

General equation of state for ideal gases.

### Principle

Standard molar enthalpies of formation  $\Delta_f H^\ominus$  are important compiled thermodynamics tabulation quantities for calculating standard enthalpies of reaction for any arbitrary reaction. They are defined as the heat of reaction occurring in the direct formation of one mole of the pertinent pure substance from the stable pure elements at constant pressure. For spontaneous and quantitative formation reactions, e.g. the conversion of hydrogen and oxygen to water, standard enthalpies of formation can be measured directly using calorimetry.

### Task

Determine the enthalpy of formation of water by burning 100 ml  $H_2$  in a closed glass jacket calorimeter.

### What you can learn about

- First law of thermodynamics
- Thermochemistry
- Calorimetry
- Enthalpy of formation
- Enthalpy of reaction

### Main articles

High voltage supply unit, 0-10 kV	13670-93	1
Glass jacket	02615-00	1
Steel cylinder hydrogen, 2 l, full	41775-00	1
Lid for calorimeter insert	02615-02	1
Steel cylinder oxygen, 2 l, filled	41778-00	1
Calorimeter insert for glass jacket	02615-01	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

### Glass jacket



### Function and Applications

Glass jacket, used as cooling or heating mantle.

### Benefits

The cylinder is made of DURAN 50®, which gave him an extreme heat resistance, high thermal shock resistance, mechanical strength and excellent chemical resistance.

### Equipment and technical data

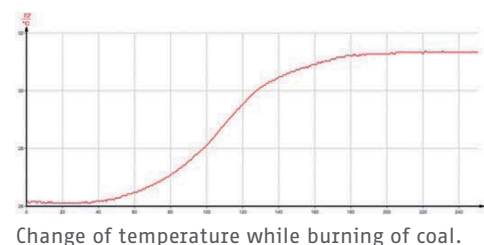
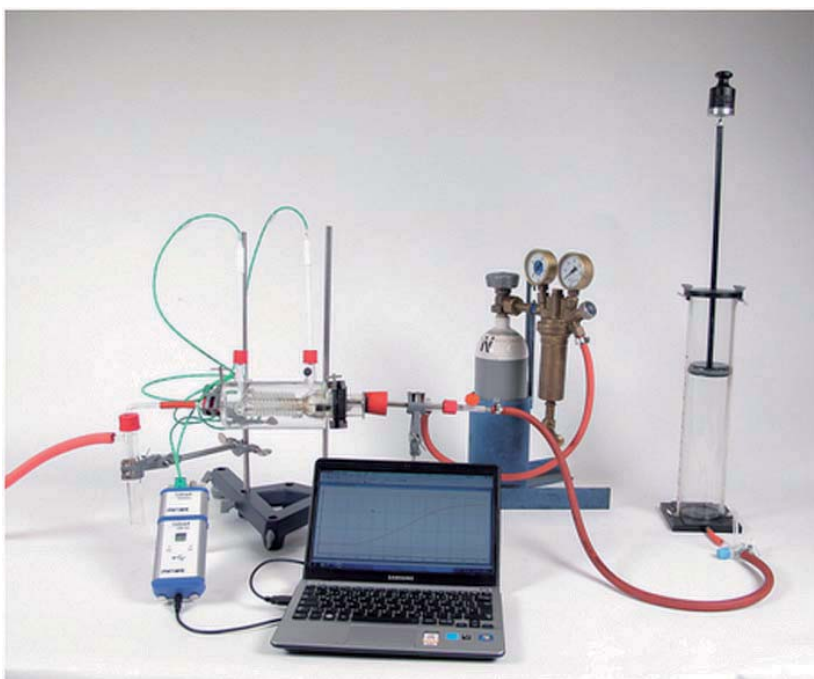
- Cylindrical glasstube with screw closures for different inserts
- Length: 205 mm
- Outer diameter: 75 mm
- Connecting nut and gasket for flanging cylindrical inserts with an outer diameter of 36 mm watertight and airtight
- 1 Flange with ring nut

**02615-00**



## Hess's law with Cobra4

P3021661



### Principle

The standard molar enthalpies of formation  $\Delta_B H^\Phi$  are important compiled thermodynamic tabulation quantities for calculating standard enthalpies of reaction for any arbitrary reaction. They are defined as the heat of reaction occurring in the direct formation of one mole of the pertinent pure substance from the stable pure elements at constant pressure. For spontaneous and quantitative formation reactions, e.g. the conversion of carbon and oxygen to  $\text{CO}_2$ , standard enthalpies of formation can be measured directly using calorimetry. Alternatively, they can be calculated from known enthalpies of reaction using Hess's law.

### Tasks

1. Determine the enthalpies of reaction for the combustion of carbon and carbon monoxide calorimetrically.
2. Use the experimentally determined enthalpies and Hess's law to calculate the enthalpies of formation of CO and  $\text{CO}_2$ .

### What you can learn about

- First law of thermodynamics; Thermochemistry; Calorimetry; Enthalpy of formation; Enthalpy of reaction; Hess's law

### Main articles

Cobra4 USB-Link	12610-00	1
Cobra4 Sensor-Unit Conductivity+	12632-00	1
Software Cobra4 - multi-user licence	14550-61	1
Gasometer 1000 ml	40461-00	1
Glass jacket	02615-00	1
Steel cylinder oxygen, 2 l, filled	41778-00	1

### Related Experiment

**Determination of the heat of formation for  $\text{CO}_2$  and CO (Hess' law)**

P3021601

### Gasometer 1000 ml

#### Function and Applications

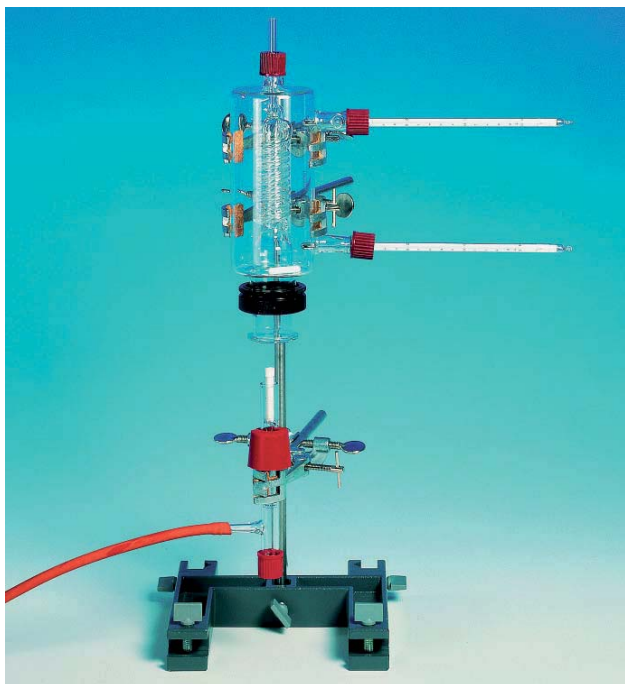
Gasometer.

#### Equipment and technical data

- Content 1000 ml
- Adjustable outer scale
- Readability 10 ml

40461-00

## P3021701 Determination of the heating value of fuel oil and of the calorific value of olive oil



### Principle

The heat of reaction generated during the complete combustion of 1000 g of solid or liquid fuel is known as the calorific value  $H$ . In the case of complete combustion of nutritional fats, the gross calorific value can also be determined. In order to ensure complete combustion, the reaction takes place under oxygen. The heat generated during the combustion of a specific amount of fuel is absorbed by a glass jacket calorimeter of known heat capacity. The calorific value of the test substance can be calculated from the temperature increase in the calorimeter.

### Task

Determine the calorific value of heating oil and the gross calorific value of olive oil.

### What you can learn about

- Heat of reaction
- Heat of combustion
- Enthalpy of combustion
- First law of thermodynamics

### Main articles

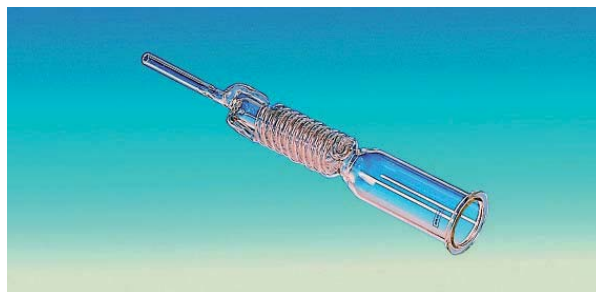
Glass jacket	02615-00	1
Steel cylinder oxygen, 2 l, filled	41778-00	1
Calorimeter insert for glass jacket	02615-01	1
Reducing valve for oxygen	33482-00	1
Table stand for 2 l steel cylinders	41774-00	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1



$$H = \frac{(m_w \cdot c_w + C_{\text{cal}}) \cdot \Delta T}{m}$$

Equation to calculate the calorific value (of fuels) and the gross calorific value (of food-stuffs).

### Calorimeter insert for glass jacket



### Function and Applications

Calorimeter insert for glass jacket.

### Benefits

- It can determine calorific values, heat of combustion and enthalpies of gaseous, liquid and solid substances.
- Combustion chamber with a circular cross section, rotating double helix as a heat exchanger

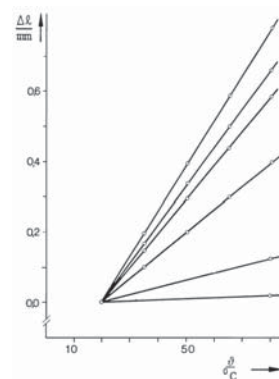
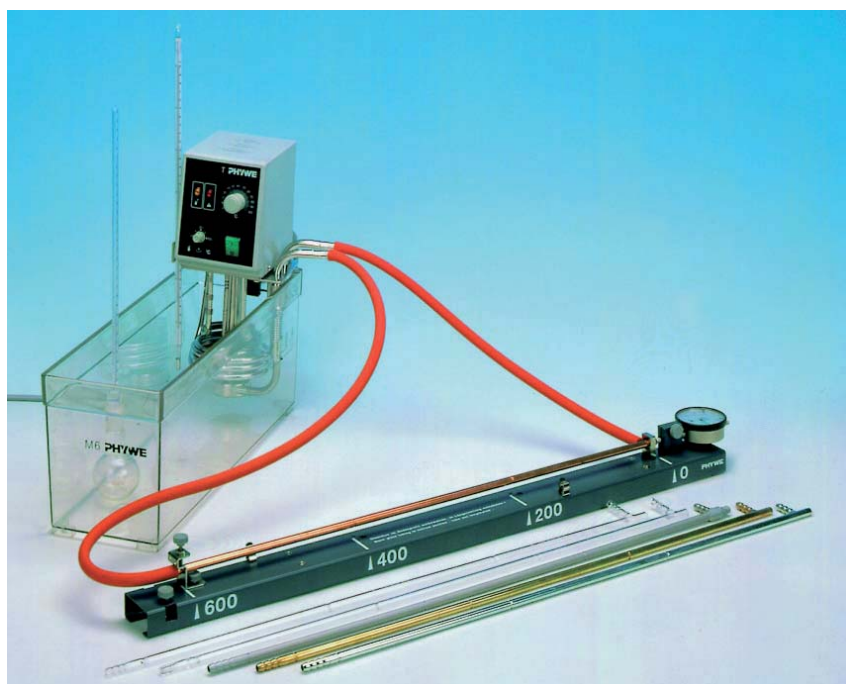
### Equipment and technical data

- Total length: 280 mm
- Combustion chamber length: 90 mm
- Outer combustion chamber: 36 mm
- Length of the approach pipe: 70 mm
- OD approach pipe: 8 mm

**02615-01**

## Thermal expansion in solids and liquids

P2310100



Relationship between length  $l$  and temperature, for a) aluminium, b) brass, c) copper, d) steel, e) duran glass, f) quartz glass ( $l_0 = 600$  mm).

### Principle

The volume expansion of liquids and the linear expansion various materials is determined as a function of temperature.

### Tasks

1. To determine the volume expansion of ethyl acetate (C<sub>4</sub>H<sub>8</sub>O<sub>2</sub>), methylated spirit, olive oil, glycerol and water as a function of temperature, using the pycnometer.
2. To determine the linear expansion of brass, iron, copper, aluminium, duran glass and quartz glass as a function of temperature using a dilatometer.
3. To investigate the relationship between change in length and overall length in the case of aluminium.

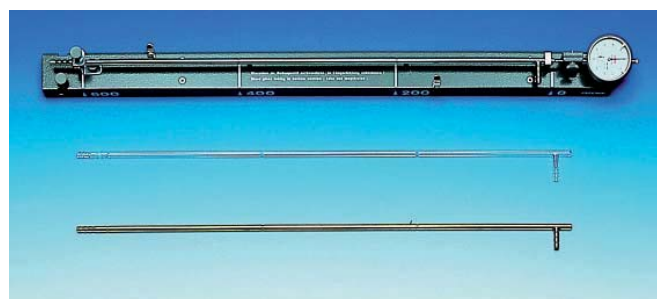
### What you can learn about

- Linear expansion
- Volume expansion of liquids
- Thermal capacity
- Lattice potential
- Equilibrium spacing
- Grüneisen equation

### Main articles

Immersion thermostat Alpha A, 230 V	08493-93	1
Dilatometer with clock gauge	04233-00	1
Bath for thermostat, makrolon	08487-02	1
Tube, quartz for 04231-01	04231-07	1
Measuring tube, $l = 300$ mm, IGJ 19/26	03024-00	2
Aluminium tube for 04231-01	04231-06	1
Set of Precision Balance Sartorius CPA 423S and measure software, 230 V	49223-88	1

### Dilatometer with clock gauge



### Function and Applications

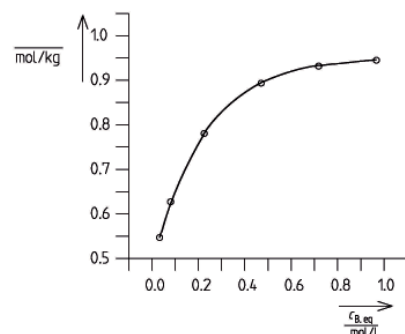
Dilatometer with clock gauge on baseplate 730x50x25 mm for the quantitative measurement of the linear expansion of solid bodies depending on material, length and temperature.

### Benefits

- Metal tubes are fixed on the base plate and heated by hot water or steam flowing through them.
- Base plate with fixing holder, leading bearing and measuring unit.
- Transmission of linear expansion to a pointer by means of toothed rod and wheel.

04233-00

## P3040801 Adsorption isotherms



Investigation of the adsorption isotherm for the citric acid/active carbon system.

**Principle**

In general, the term adsorption is used to describe the attachment of gases or dissolved substances to the surface of a solid or liquid. At constant temperature, the quantity of adsorbed substances is a function of the type of system investigated and the partial pressure and / or concentration of the substance concerned. The correlation is described by a number of adsorption isotherms. The validity is to be investigated experimentally.

**Tasks**

1. Determine the residual equilibrium concentrations of citric acid after stirring solutions of differing initial concentrations with a constant mass of activated carbon.
2. Use the measurement results to determine which of the adsorption isotherms is valid for the given system.

**What you can learn about**

- Adsorbent and adsorbate
- Henry Freundlich and Langmuir adsorption isotherms
- Volumetry

**Main articles**

Magnetic stirrer Mini / MST	47334-93	2
Filtration stand for 2 funnels	33401-88	1
Retort stand, h = 750 mm	37694-00	2
Burette 50ml, lat. stopc. Schellbach	36513-01	1
Burette clamp, roller mount., 2 pl.	37720-00	1
Activated carbon, granular 500 g	30011-50	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1



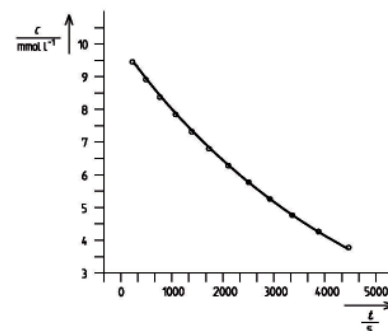
Irving Langmuir

1932, Nobel Prize in Chemistry



## Saponification rate of tertbutyl chloride

P3050101



Concentration-time diagram for the saponification of *tert*-butyl chloride in acetone/water.

## Principle

Tertiary butylhalogenides are saponified in aqueous and aqueous basic solutions according to an  $S_N1$  mechanism to tertiary butanol. The kinetics of the reaction can be followed via the temporal consumption of hydroxide ions and evaluated accordingly.

## Tasks

1. Determine the concentration-time diagram for the saponification of *tert*-butyl chloride with sodium hydroxide solution.
2. Based on the experimental data, establish the valid reaction order, and calculate the reaction rate constant and the half-life of the reaction.

## What you can learn about

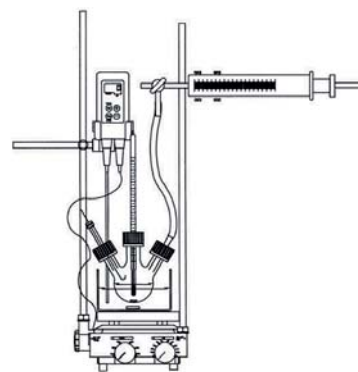
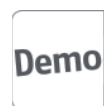
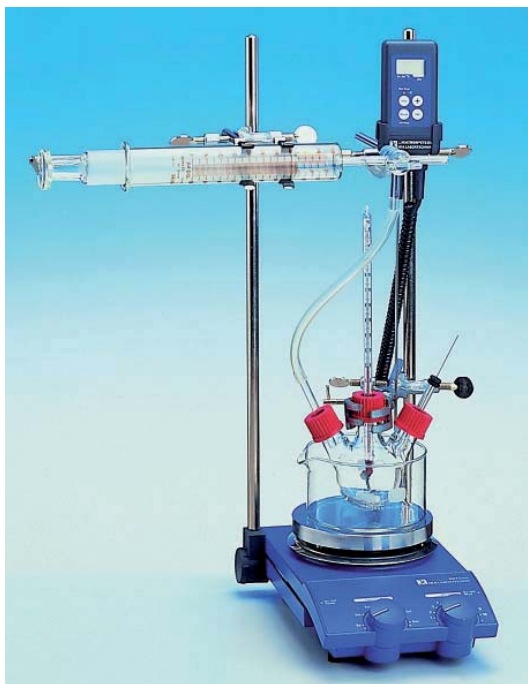
- Reaction rate
- Reaction rate constant
- Molecularity of reaction
- Reaction order
- Rate law for first and second order reactions
- Half-life

## Main articles

Magnetic stirrer MR Hei-Standard	35750-93	1
Digital thermometer, NiCr-Ni, -50...+1300 °C	07050-00	1
Immersion probe NiCr-Ni, steel, -50...400 °C	13615-03	1
<i>tert</i> -Butyl chloride, 250 ml	30045-25	1
Burette clamp, roller mount., 2 pl.	37720-00	1
Caustic soda sol., 1.0 M 1000 ml	48329-70	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1



## P3051101 Dependence of the reaction velocity on the temperature (acetic acid - magnesium)



Schematical setup.

### Principle

The reaction velocity is highly dependent on the temperature. In this experiment magnesium reacts with acetic acid. Comparing the velocity at the beginning of the reaction shows that the velocity doubles when the temperature increases 10 K.

### Task

Investigate the reaction of magnesium with acetic acid at different temperatures.

### What you can learn about

- Reaction kinetics
- First order reaction
- Magnesium
- Acid

### Main articles

Magnetic stirrer MR Hei-Standard	35750-93	1
Electronic temperature controller EKT Hei-Con	35750-01	1
Stop clock, demo.; diam. 13 cm	03075-00	1
Round flask, 100 ml, 3-n., 3 x GL25	35677-15	1
Gas syringe, 100 ml, with 3-way cock	02617-00	1
Magnesium, ribbon, roll, 25 g	30132-00	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

### Magnetic stirrer MR Hei-Standard



### Function and Applications

Modern magnetic hot plate stirrer with a flat and hermetically sealed housing as protection against chemicals.

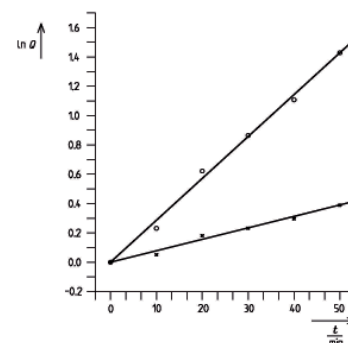
### Benefits

- Separate switchers with LEDs for heating and stirring
- Hot plate made of Silumin (aluminiumalloys) with ceramic coating
- Excellent heat conduction and distribution
- Extremely resistant against scratches and chemicals

**35750-93**

## Reaction rate and activation energy of the acid hydrolysis of ethyl acetate

P3050201



Graphic determination of the reaction rate constant for the acid hydrolysis of ethyl acetate at  $T_X = 299.15 \text{ K}$  and  $T_0 = 314.15 \text{ K}$ .

**Principle**

In acid solution, ethyl acetate is hydrolysed to equivalent quantities of ethanol and acetic acid according to a pseudo-first order rate law. The alkalimetric determination of the acetic acid formed enables conclusions to be drawn on the temporal concentration of ester.

**Tasks**



1. Determine the reaction rate constant for the acidolysis of ethyl acetate at two (or more) temperatures.
2. Calculate the activation energy of the reaction from the temperature dependence of the measured rate constants.

**What you can learn about**

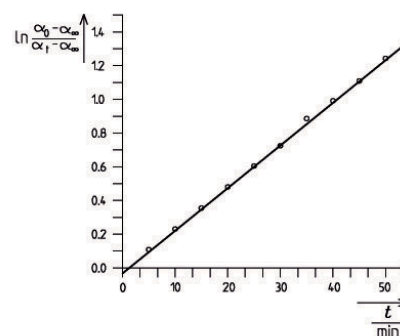
- Reaction rate
- Reaction rate constant
- Rate law for first and second order reactions
- Reactions with pseudo order
- Arrhenius equation
- Activation energy

**Main articles**

Immersion thermostat Alpha A, 230 V	08493-93	1
Magnetic stirrer MR Hei-Standard	35750-93	1
Digital thermometer, NiCr-Ni, -50...+1300 °C	07050-00	1
Bath for thermostat, makrolon	08487-02	1
External circulation set f. thermostat Alpha A	08493-02	1
Retort stand, h = 750 mm	37694-00	2
Immersion probe NiCr-Ni, steel, -50...400 °C	13615-03	1

You need more information? **WEB@**   
Go to [www.phywe.com](http://www.phywe.com) or  
 send an email to [info@phywe.com](mailto:info@phywe.com)

## P3050301 Kinetics of the inversion of saccharose



Floating point representation of saccharose inversion as a function of time.

### Principle

The inversion reaction of saccharose, which is catalysed by protons, produces invert sugar, which is a mixture of glucose and fructose. The reaction is accompanied by a change in the optical rotation of the system. Glucose rotates the polarisation plane of linearly polarised light to the right, while inverted sugar rotates it to the left. A half-shade polarimeter is used for the measurement of the change in the angle of rotation of polarised light during the inversion reaction of saccharose over time.

### Tasks

1. Determine the specific rotation of saccharose and lactose by measuring the rotation angle of solutions of various concentrations.
2. Determine the rate constant of the inversion of saccharose.

### What you can learn about

- Reaction rate
- First order reaction
- Polarimetry
- Optical rotation

### Main articles

Half-shade polarimeter, 230 V AC	35906-93	1
Immersion thermostat Alpha A, 230 V	08493-93	1
Magnetic stirrer MR Hei-Standard	35750-93	1
Bath for thermostat, makrolon	08487-02	1
External circulation set f. thermostat Alpha A	08493-02	1
Retort stand, 210 × 130 mm, h = 500 mm	37692-00	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

### Half-shade polarimeter, 230 V AC



### Function and Application

Half-shade polarimeter for concentration measurement of optical active solutions.

### Equipment and technical data

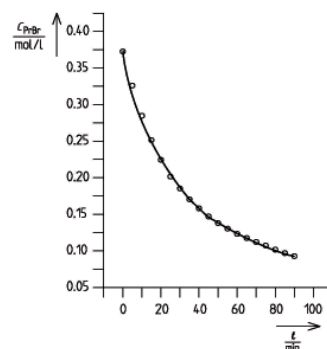
- Polarimeter support with built-in light source and filters
- Polarimeter tube length 100 and 200 mm
- 2 scales 0-180 degrees
- Division 1 degree
- Vernier reading 0.05 degrees with nonius
- Light source sodium lamp 589 nm
- Power supply 230 V / 50 Hz

**35906-93**



## Halogen exchange rate with Cobra4

P3050762



Concentration-time diagram ( $c_{\text{PrBr}} = c_{\text{I}^-} = c_{\text{NaI}}$ ) for the Finkelstein reaction between propyl bromide and iodide ions ( $T = 303 \text{ K}$ ).

## Principle

Alkyl halides experience rapid halogen exchange reactions in appropriate solvents. These substitution reactions occur according to an  $\text{S}_{\text{N}}2$  mechanism. Their velocity can be advantageously monitored via conductivity measurements if the ion mobilities in question clearly differ, or the number of charge carriers changes in the course of the reaction.

## Tasks

Measure the specific conductivities of solutions of various concentrations of sodium iodide in acetone. Subsequently determine the temporal concentrations of the co-reactants for the reaction of propyl bromide with sodium iodide (Finkelstein reaction) in acetone at  $30^\circ \text{C}$ . Based on the experimental data, establish the valid order of reaction and determine the rate constant.

## What you can learn about

- Reaction rate
- Rate laws for first and higher order reactions
- Conductometry

## Main articles

Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1
Magnetic stirrer MR Hei-Standard	35750-93	1
Cobra4 Mobile-Link set	12620-55	1
Electronic temperature controller EKT Hei-Con	35750-01	1
Cobra4 Sensor-Unit Conductivity+	12632-00	1
Conductivity temperature probe Pt1000	13701-01	1
Condenser, Dimroth type GL25/12	35815-15	1

## Cobra4 Sensor-Unit Conductivity+



## Function and Applications

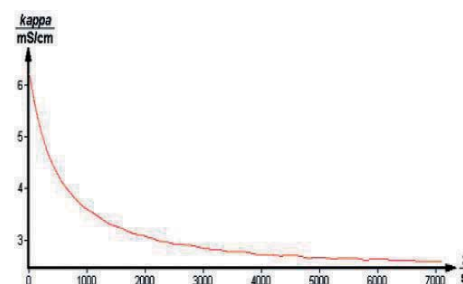
The Cobra4 Sensor Unit Conductivity / Temperature (Pt1000) is a microcontroller-based measuring recorder with a 5-pin diode socket for connecting conductance measuring sensors with a cell constant of  $K = 1.00/\text{cm}$  or Pt1000 thermocouples.

## Benefits

- Measure conductivity or temperature - multipurpose-sensor.
- The Cobra4 sensor may be connected directly to the Cobra4 Wireless-Link, the Cobra4 Mobile-Link, the Cobra4 USB-Link or the Cobra4 Junior-Link using a secure and reliable snap-in connection.

12632-00

## P3050860 Conductometric measurement of the saponification of esters with Cobra4



Change in the specific conductivity  $k$  during the saponification of ethyl butyrate in ethanol/water at an approximate ratio of 50:50 ( $T=323.15$  K).

### Principle

Carboxylic acid esters are saponified in an alkaline medium according to the second order reaction rate (law). In the process, hydroxide ions with a high ion mobility are consumed in reaction with an ester. The temporal course of reaction can thus be advantageously monitored by using the measurements of the changing conductance.

### Tasks

Determine the reaction rate constant for the saponification of ethyl butyrate in an ethanol-water mixture at 50 °C via the conductance measurements.

### What you can learn about

- Reaction rate
- Reaction rate constant
- Reaction molecularity
- Reaction order
- First and second order reaction rates (laws)
- Conductance and conductance measurements (conductometry)

### Main articles

Magnetic stirrer MR Hei-Standard	35750-93	1
Software Cobra4 - multi-user licence	14550-61	1
Electronic temperature controller EKT Hei-Con	35750-01	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Sensor-Unit Conductivity+	12632-00	1
Conductivity temperature probe Pt1000	13701-01	1
Cobra4 Wireless Manager	12600-00	1

### Cobra4 Wireless Manager



### Function and Applications

USB device for radio-based communication with the Cobra4 Wireless-Link.

### Benefits:

Simply connect the device to the computer's USB port.

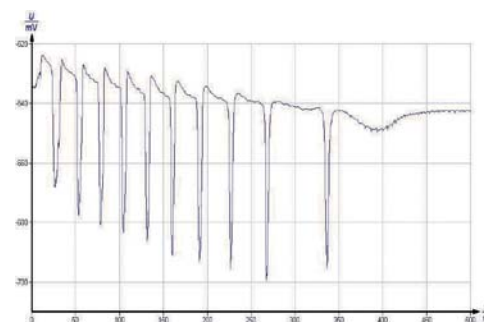
Up to 99 measuring sensors can be connected to one computer

Automatic detection of all connected measuring sensors.

12600-00

## Briggs-Rauscher Reaction with Cobra4

P3121660



Graph of measured potential against time.

**Principle**

The Briggs-Rauscher reaction is a so-called homogeneous oscillating reaction, i.e. the reaction rate of the complete process is subject to periodic fluctuations. In general, oscillating reactions can always occur when the following conditions are fulfilled: The reaction must run highly exergonic ( $\Delta G \ll 0$ ). At least one of the reaction steps must contain a positive or negative back-coupling. Such back-coupling processes occur when the result of the individual partial steps of the reaction, such as changes in temperature or concentration, act back on the rate constants of the individual partial steps of the reaction. In this way, the whole reaction becomes non-linear.

**Task**

Observe the fluctuations of the Briggs-Rauscher reaction by measuring the potential over a definite time period.

**What you can learn about**

- Oscillating reactions; Exergonic process
- Potential; Briggs-Rauscher reaction

**Main articles**

Cobra4 Wireless Manager	12600-00	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Sensor-Unit Chemistry	12630-00	1
Software Cobra4 - multi-user licence	14550-61	1
Magnetic stirrer Mini / MST	47334-93	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

**Cobra4 Sensor-Unit Chemistry****Function and Applications**

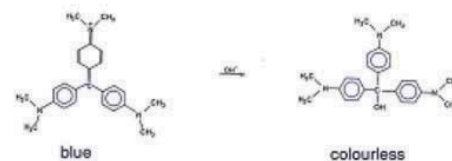
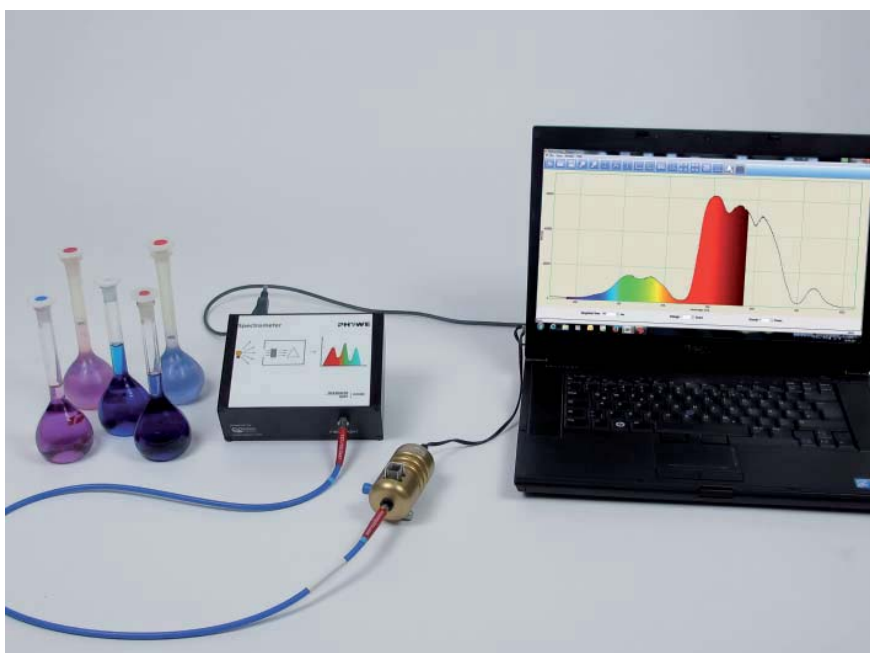
The Cobra4 Sensor-Unit Chemistry is a measuring recorder for pH, potential and temperature measurements, which is controlled by micro-controller.

**Benefits**

- It can be fitted with two NiCr-Ni thermoelements (Type K) and a pH probe or redox measuring chain
- Values of the calibration are saved in the sensor - no need for new calibration.
- The sensor is not restricted to the measurement of pH values: Connect the redox electrode 46267-10 to measure redox potentials.

12630-00

## P3070601 Reaction kinetics with measureSpec



Decolorisation of crystal violet.

**Principle**

The organic dye crystal violet is decolorised in an alkaline medium. This reaction takes place according to a velocity-time law, hence it is a reaction of the first order.

Using measureSpec, the change in concentration of the dye can be traced by measuring the extinction at the wavelength of the absorption maximum. The computer program plots the kinetic data in graphical form.

**Task**

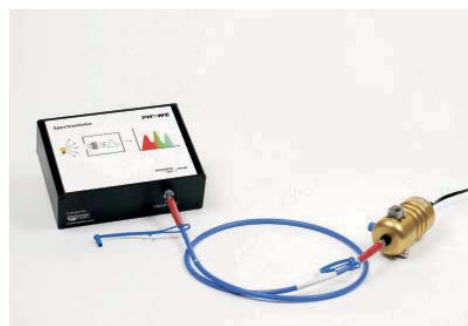
The order of reaction during decolorisation of crystal violet is to be determined.

**What you can learn about**

- Reaction kinetics
- First order reaction
- Photometry
- Reaction rate

**Main articles**

Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1
Measurespec spectrometer with cuvette holder and light source	35610-88	1
Crystal violet f.bacteriology,25g	31488-04	1
Caustic soda sol.,0.1M 1000 ml	48328-70	1
Volumetric flask 1000ml, IGJ24/29	36552-00	2
Water, distilled 5 l	31246-81	1
Pipettor	36592-00	1

**Measurespec spectrometer with cuvette holder and light source****Benefits****Spectrometer:**

- Robust aluminium case
- Rapid measurement of full spectral range
- Flexible introduction of light to be investigated by means of optical fibres
- No additional power supply required
- Intuitive "measure" software for controlling the apparatus and recording spectra

**Cuvette holder:**

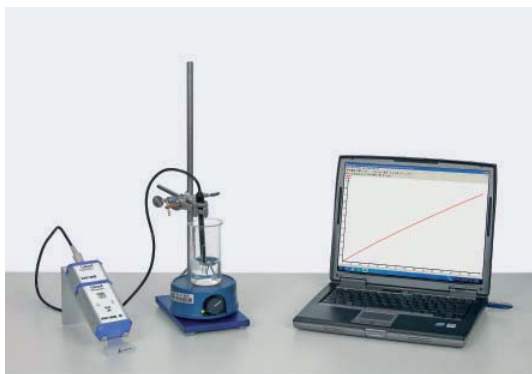
- Robust aluminium case; Long-lived tungsten lamp
- Universal power supply via plug-in transformer
- Measurement of absorption spectra, fluorescence spectra, reaction kinetics

**35610-88**



### Determination of the Michaelis constant with Cobra4

P4120360



NEW

4  
Cobra

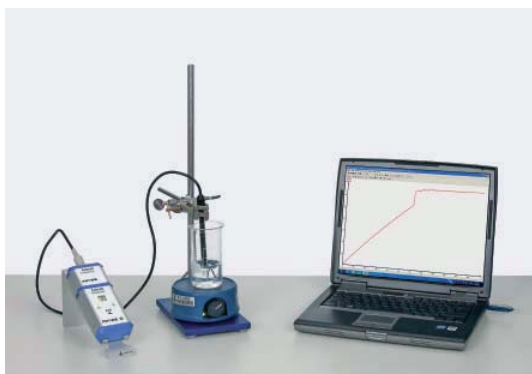
#### Principle

The enzymatic hydrolysis of urea in aqueous solution liberates carbon dioxide and ammonia. The ions of these compounds increase the conductivity of the solution. Conductivity measurements can so be made to determine the rate of hydrolysis of urea by the enzyme urease at various substrate concentrations.

For more details refer to page 189.

### Enzyme inhibition (poisoning of enzymes) with Cobra4

P4120560



NEW

4  
Cobra

#### Principle

The enzymatic hydrolysis of urea in aqueous solutions liberates carbon dioxide and ammonia. The ions of these compounds increase the conductivity of the solution.

For more details refer to [www.phywe.com](http://www.phywe.com)

You need more information?

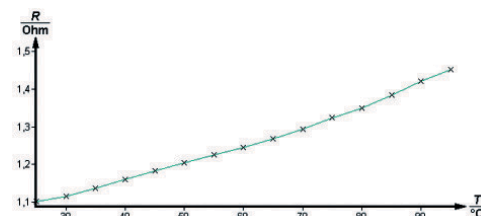
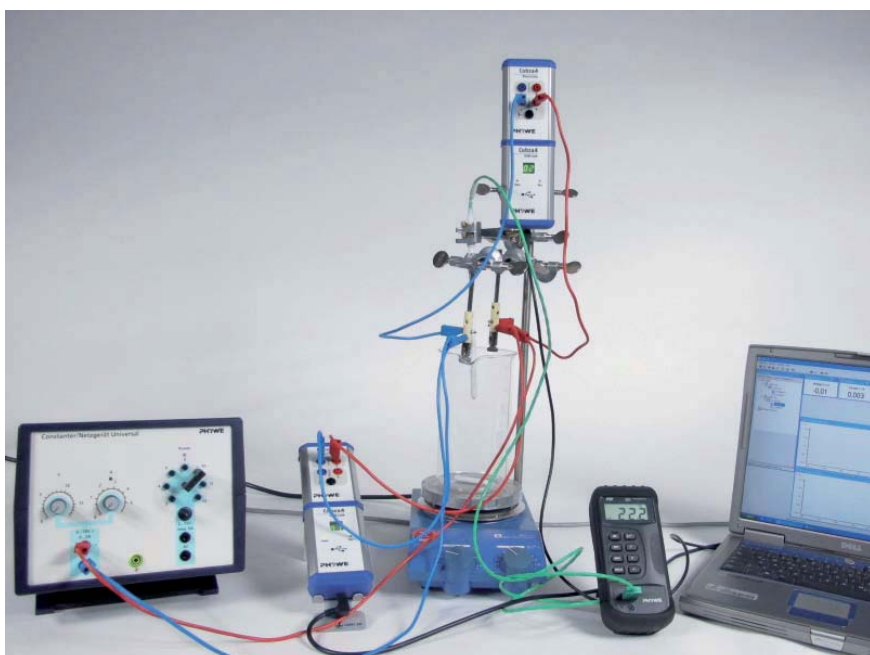
WEB @ PHYWE

Go to [www.phywe.com](http://www.phywe.com) or



send an email to [info@phywe.com](mailto:info@phywe.com)

## P3060161 Charge transport in solids with Cobra4



Dependence of resistance versus temperature (iron wire).

**Principle**

Measuring the temperature dependence of the resistivity of solids provides information on the mechanism of conduction and charge transport in solids.

**Task**

Determine the temperature coefficient of iron wire, copper wire and constantan wire in the range of room temperature to 95 °C.

**What you can learn about**

- Electron conductivity
- Ion conductivity

**Main articles**

Power supply, universal	13500-93	1
Magnetic stirrer MR Hei-Standard	35750-93	1
Software Cobra4 - multi-user licence	14550-61	1
Cobra4 USB-Link	12610-00	2
Cobra4 Sensor-Unit Electricity	12644-00	2
Digital thermometer, NiCr-Ni, -50...+1300 °C	07050-00	1
Immersion probe NiCr-Ni, teflon, 300 °C	13615-05	1

**Power supply, universal****Function and Applications**

Versatile heavy duty power supply which can also be used as a constant current supply in schools, laboratories or workshops.

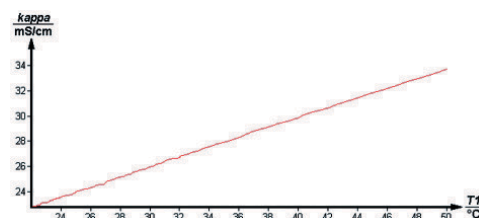
**Equipment and technical data**

- Direct current source: Stabilised, regulated output direct voltage, continuously adjustable from 0...18 V; Adjustable current limit between 0...5 A
- LED display for constant current operation
- Permanently short-circuit proof & protected against exterior voltages
- Alternative voltage output:
  - Multitap transformer 2...15V, outputs galvanically separated from mains grid
  - Full load capacity (5A), even if direct current is supplied simultaneously
  - Short-circuit protection through overcurrent circuit breaker
- All output voltages available at 4 mm safety plug sockets.

13500-93

## Charge transport in liquids with Cobra4

P3060260



Conductivity of an aqueous potassium chloride solution at different temperatures.

**Principle**

A potential difference between two electrodes in a liquid causes the flow of a current in the liquid. This current depends on the potential drop across the liquid and its conductivity. The measurement of the conductivity of electrolyte solutions yields knowledge about charge transport in liquids. (Drying oven required!)

**Tasks**

1. Measure the change in conductivity caused by diluting a 0.1 molar potassium chloride solution with distilled water.
2. Measure the conductivity of an aqueous potassium chloride solution at different temperatures.
3. Explain the observed effects.

**What you can learn about**

- Electrolyte solutions
- Conductivity
- Ionic migration

**Main articles**

Cobra4 Wireless Manager	12600-00	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Sensor-Unit Conductivity+, Conductivity/ Temperature (Pt1000)	12632-00	1
Software Cobra4 - multi-user licence	14550-61	1
Hotplate Magnetic Stirrer, 5 ltr., 230 V	35730-93	1
Desiccator, wertex, diam. 150 mm	34126-00	1
Conductivity temperature probe Pt1000	13701-01	1

**Cobra4 Wireless-Link****Function and Applications**

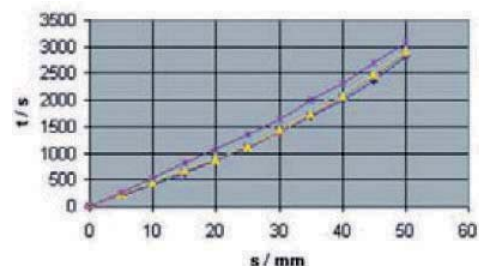
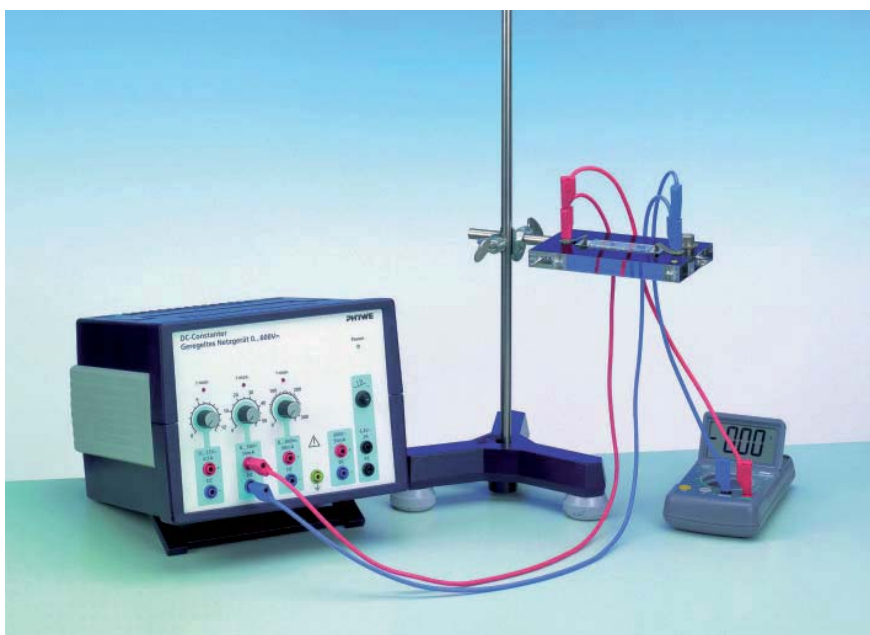
Interface module for the radio-based transmission of sensor measuring values in conjunction with the Cobra4 Wireless Manager.

**Benefits**

- All Cobra4 Sensor-Units can be quickly connected using a secure and reliable plug-in / lockable connection.
- All Cobra4 measuring sensors are easy to plug in and automatically detected.
- The radio network with the Cobra4 Wireless Manager is established automatically and is extremely stable, as it uses its own radio protocol.
- Up to 99 Cobra4 Wireless-Links can be connected to one Cobra4 Wireless Manager.

12601-00

## P3060301 Ion migration velocity



Location of colour interface versus time.

**Principle**

The movement of ions is responsible for current flow in solutions of electrolytes. The migration of coloured ions can be easily observed by the migration of the colour front in an electric field.

**Task**

Demonstrate the migration of the permanganate anion in an electric field and measure the ionic velocity at five different concentrations.

**What you can learn about**

- Charge transport in liquids
- Ion mobility
- Conductivity

**Main articles**

Power supply, 0...600 V DC	13672-93	1
Flat chamber for ionic migration	06605-00	1
Tripod base PHYWE	02002-55	1
Digital multimeter 2010	07128-00	1
Stopwatch, digital, 1/100 s	03071-01	1
Set of Analytical Balance Sartorius CPA 224S and measure software, 230 V	49221-88	1

**Flat chamber for ionic migration****Function and Applications**

For demonstrating the migration of coloured ions in an electrolyte and for the determination of the absolute mobility of ions.

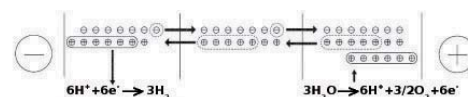
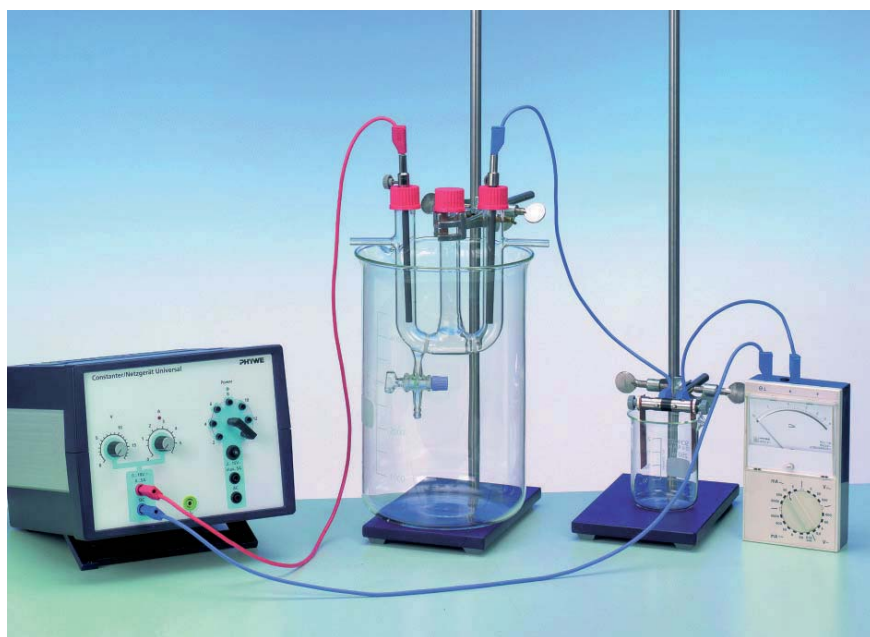
Transparent plastic plate with engraved groove; upper face of the plastic plate blackened, except the groove. At each end face of the groove there is a nickel electrode with a 4 mm socket; the longitudinal sides of the groove have a scale with 5 mm divisions. The upper face of the plastic plate has a water level for horizontal adjustment of the flat chamber. The process of ionic migration can be especially well observed in projections using an overhead projector.

06605-00



## Transference numbers

P3060401



Transport and electrode processes during electrolysis of diluted nitric acid.

### Principle

Cations and anions contribute to charge transport in electrolytic processes in accordance with their different mobilities in an electric field. Hittorf transport numbers characterise the fraction of the total charge transported by a particular ion during electrolysis. They enable the calculation of ionic conductivities, the values of which are important in electrochemical practice. Transport numbers are to be experimentally determined from the characteristic concentration changes which take place at the cathode and the anode during electrolysis.

### Task

Determine the Hittorf transport numbers for hydronium and nitrate ions from measurements resulting from the electrolysis of an 0.1 molar nitric acid solution.

### What you can learn about

- Electrolysis
- Faraday's laws of electrolysis
- Charge transport
- Ion mobility
- Hittorf numbers

### Main articles

Power supply, universal	13500-93	1
Multi-range meter w.overl.prot.	07021-01	1
Digital thermometer, NiCr-Ni, -50...+1300°C	07050-00	1
Double U-tube w.frits+cock, GL25	44451-00	1
Glass beaker, short, 5000 ml	36272-00	1
Retort stand, h = 750 mm	37694-00	3
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

### Power supply, universal



### Function and Applications

Versatile heavy duty power supply which can also be used as a constant current supply in schools, laboratories or workshops.

### Equipment and technical data

- Direct current source: Stabilised, regulated output direct voltage, continuously adjustable from 0...18 V
- Adjustable current limit between 0...5 A
- LED display for constant current operation
- Permanently short-circuit proof & protected against exterior voltages
- Alternative voltage output: Multitap transformer 2...15V, outputs galvanically separated from mains grid

13500-93

## P3060560 Temperature dependence of conductivity with Cobra4

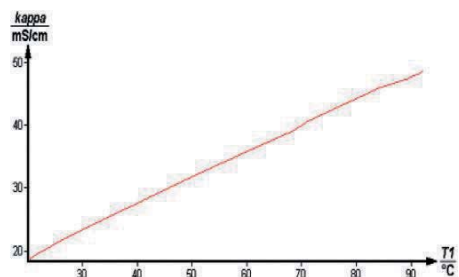


Diagram of the conductivity as a function of the temperature.

### Principle

The electrical conductivity of an electrolytic solution is dependent not only upon the type and concentration of the electrolytes, but also other state values. Thus, an increase in conductivity is generally observed with an increase in temperature. This is fundamentally due to the exponential decrease of the solutions's viscosity. In aqueous solutions a limit is reached at approximately 90°C. Above this temperature the conductivity again decreases.

### Task

Determine the temperature dependence of the conductivity of a 10% sodium chloride solution from 20 °C to approximately 60 °C.

### What you can learn about

- Electrolytic resistance
- Conductance
- Specific and molar conductivity
- Ion mobility
- Equivalent conductance at infinite dilution
- Kohlrausch's law
- Ostwald's law of dilution
- Transference numbers
- Viscosity

### Main articles

Cobra4 Wireless Manager	12600-00	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Sensor-Unit Conductivity+	12632-00	1
Software Cobra4 - multi-user licence	14550-61	1
Electronic temperature controller EKT Hei-Con	35750-01	1
Magnetic stirrer MR Hei-Standard	35750-93	1
Conductivity temperature probe Pt1000	13701-01	1

### Cobra4 Sensor-Unit Conductivity+

#### Function and Applications

The Cobra4 Sensor Unit Conductivity / Temperature (Pt1000) is a microcontroller-based measuring recorder with a 5-pin diode socket for connecting conductance measuring sensors with a cell constant of  $K = 1.00/\text{cm}$  or Pt1000 thermocouples.

#### Benefit

- Measure conductivity or temperature - multipurpose-sensor.

12632-00

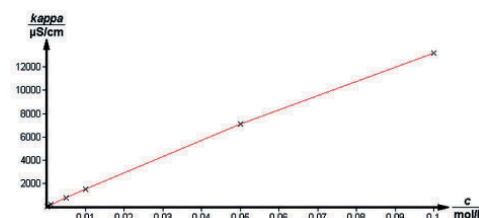


Wilhelm Ostwald

1909, Nobel Prize in Chemistry

## Conductivity of strong and weak electrolytes with Cobra4

P3060660



Conductivity of a strong electrolyte as a function of the concentration.

**Principle**

It is possible to differentiate between strong and weak electrolytes by measuring their electrical conductance. Strong electrolytes follow Kohlrausch's law, whereas weak electrolytes are described by Ostwald's dilution law. The examination of the concentration dependence of the conductivity allows the molar conductivities of infinitely diluted electrolytes to be determined, and facilitates the calculation of degree of dissociation and the dissociation constants of weak electrolytes.

**Tasks**

1. Determine the concentration dependence of the electrical conductivity of potassium chloride and acetic acid solutions.
2. Calculate the molar conductivity using data from the measurements taken and determine the molar conductivity at infinite dilution by extrapolation.
3. Determine the dissociation constant of acetic acid.

**What you can learn about**

- Kohlrausch's law
- Equivalent conductivity
- Temperature-dependence of conductivity
- Ostwald's dilution law

**Main articles**

Cobra4 Wireless Manager	12600-00	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Sensor-Unit Conductivity+	12632-00	1
Software Cobra4 - multi-user licence	14550-61	1
Desiccator, wertex, diam. 150 mm	34126-00	1
Magnetic stirrer Mini / MST	47334-93	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

**Magnetic stirrer Mini / MST****Function and Applications**

Magnetic stirrer without heating for mixing smaller quantities.

**Benefits**

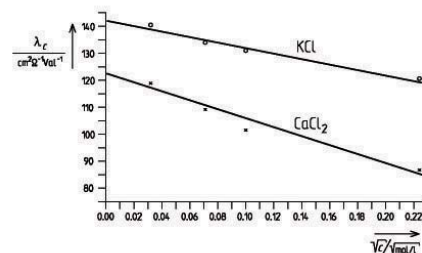
- All housing parts are made of a sturdy, reinforced ABS plastic material that is resistant to many chemicals
- Electronic speed control to protect the engine against uncontrolled acceleration
- The speed is infinitely adjustable
- Delivery includes a magnetic stirring bar

**Equipment and technical data**

- Stirring capacity: max. 1l water
- Speed: 100 .. 1000 rpm
- Without heating
- Diameter: 137 mm
- Height: 51 mm; Weight: 0.6 kg

47334-93

## P3060862 Determination of the activity coefficient by a conductivity measurement with Cobra4



Curves for potassium chloride and calcium chloride.

### Principle

The equivalent conductivity of strong electrolytes depends on their concentration. The quotient of the equivalent conductivity at a certain concentration and the equivalent conductivity at infinite dilution is called the conductivity coefficient, which is the result of interionic action.

### Tasks

1. Measure the specific conductivities of various potassium chloride and calcium chloride solutions and calculate the equivalent conductivities.
2. Determine the equivalent conductivities at infinite dilution using the Kohlrausch equation and calculate the conductivity coefficients.

### What you can learn about

- Equivalent conductivity
- Ion mobility
- Conductivity
- Interionic action

### Main articles

Cobra4 Mobile-Link set	12620-55	1
Cobra4 Sensor-Unit Conductivity+	12632-00	1
Desiccator, Wertex, diam. 150 mm	34126-00	1
Conductivity temperature probe Pt1000	13701-01	1
Magnetic stirrer Mini / MST	47334-93	1
Retort stand, h = 750 mm	37694-00	1
Set of Analytical Balance Sartorius CPA 224S and measure software, 230 V	49221-88	1

### Conductivity temperature probe Pt1000



### Function and Applications

Conductivity temperature probe Pt1000

### Equipment and technical data

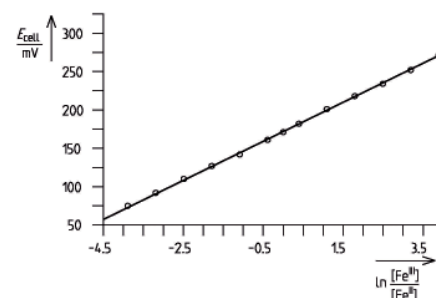
- Cell constant  $k = 1.0 / \text{cm}$
- Minimum immersion depth: 10 mm

13701-01



## Nernst equation with Cobra4

P3060962



Verification of the Nernst equation for the  $\text{Fe}(\text{CN})_6^{4-}$ ,  $\text{Fe}(\text{CN})_6^{3-}$  Pt redox electrode.

## Principle

The Nernst equation expresses how the electrical potential of an electrode in contact with a solution of ions depends upon the concentrations (more accurately, activities) of those ions. The equation may be experimentally verified using an electrochemical cell formed from an inert indicator electrode coupled with a convenient reference electrode. The potential of the indicator electrode, and hence the e.m.f. of the cell, is monitored as the ionic composition of the electrolyte solution is changed.

## Tasks

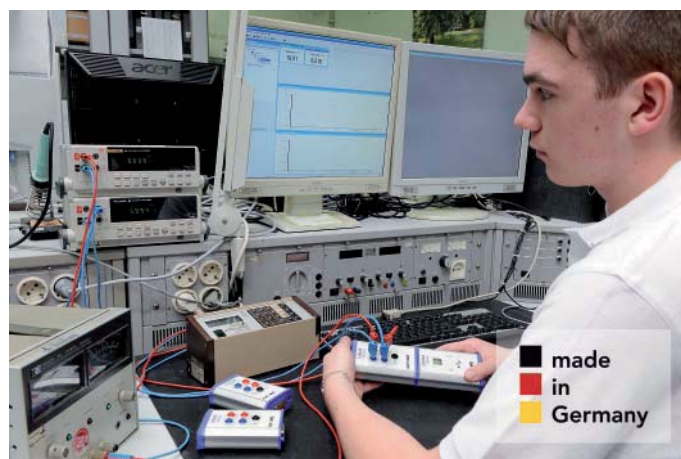
Using an  $\text{Ag}(\text{S}) \mid \text{AgCl}(\text{S}) \mid \text{Cl}^-$  reference electrode, measure the potential of a platinum electrode in contact with solutions containing known concentration of the iron(II) and iron(III) complex ions  $[\text{Fe}(\text{CN})_6]^{4-}$  and  $[\text{Fe}(\text{CN})_6]^{3-}$ .

## What you can learn about

- Electrode potentials and their concentration dependence
- Redox electrodes
- Electrochemical cells

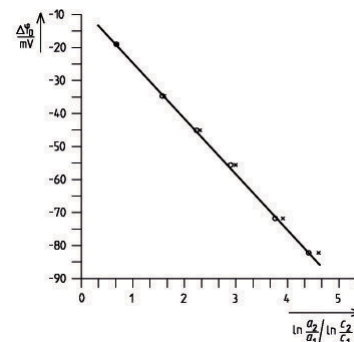
## Main articles

Cobra4 Mobile-Link	12620-00	1
Cobra4 Sensor-Unit Chemistry	12630-00	1
Immersion probe NiCr-Ni, teflon, 300 °C	13615-05	1
Magnetic stirrer Mini / MST	47334-93	1
Reference electrode, AgCl	18475-00	1
Retort stand, h = 750 mm	37694-00	2
Set of Analytical Balance Sartorius CPA 224S and measure software, 230 V	49221-88	1



made  
in  
Germany

## P3061101 Determination of diffusion potentials



Diffusion potential  $\Delta\phi_D$  for HCl as a function of  $\ln a_2/a_1$  (o) and  $\ln c_2/c_1$  (x) (for cellophane).

**Principle**

An electrochemical potential establishes itself at the interface between two solutions of different ion concentrations. The magnitude of this is determined by the concentration ratio and the transference numbers of the ions involved. This potential difference can be measured as a function of the concentration at semi-permeable and ion-selective membranes.

**Tasks**

1. Measure the diffusion potential as a function of the concentration gradient at a cellophane membrane and at a cation-selective membrane.
2. Determine the transference numbers of the ions in HCl, NaCl and KCl.

**What you can learn about**

- Concentration cells with transport
- Transference numbers
- Semi-permeable membrane
- Selectively permeable membrane
- Nernst equation

**Main articles**

Osmosis and electrochemistry chamber	35821-00	1
Digital thermometer, NiCr-Ni, -50...+1300 °C	07050-00	1
Magnetic stirrer Mini / MST	47334-93	1
Digital multimeter 2010	07128-00	1
Gasket for GL25, 12mm hole, 10pcs	41243-03	1
Retort stand, h = 750 mm	37694-00	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

**Osmosis and electrochemistry chamber****Function and Applications**

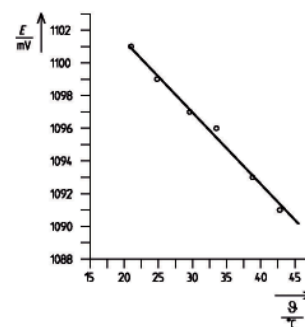
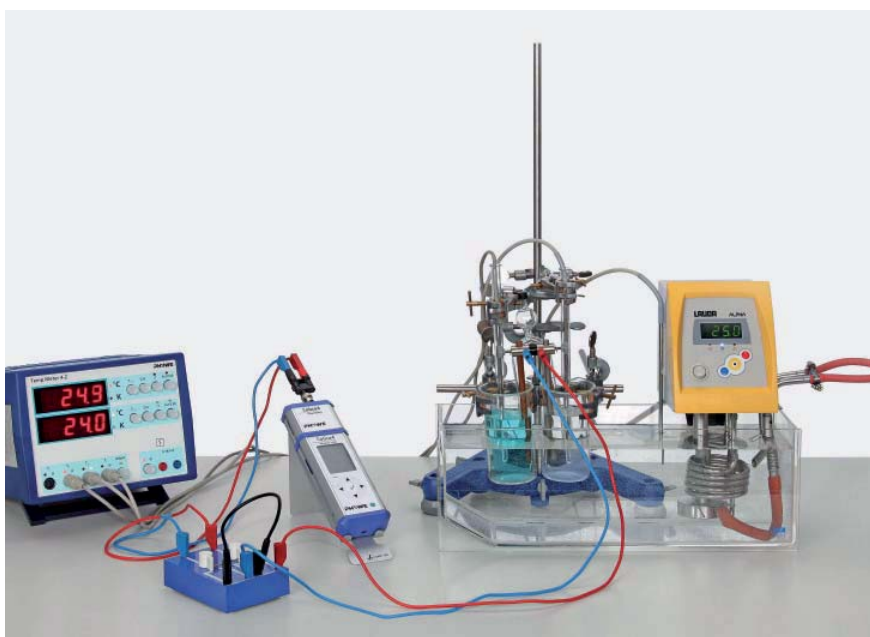
Osmosis and electrochemistry chamber for the demonstration and observation of osmotic processes.

The chamber can be built up and cleaned without problems. Between two sealing rings arbitrary semipermeable membranes can be fixed. A measurable rise is achieved by the big boundary surface of differently concentrated solutions very quickly in the capillary tube. For the readout of the altitude a scale can be put on the capillary tube.

**35821-00**

## Temperature dependence of the electromotive force with Cobra4

P3061262



Electromotive force versus temperature.

### Principle

Thermodynamic data of the gross reaction in a galvanic cell can be determined by measuring the e.m.f. at different temperatures.

### Task

Determine the usable reaction equivalent work of the Daniell cell by measuring the dependence of the electromotive force on temperature.

### What you can learn about

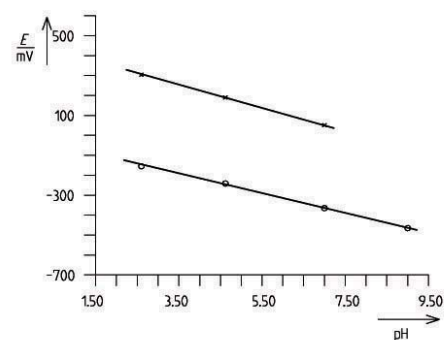
- Electromotive force
- Electrode reactions
- Electrochemical potential
- Nernst equation

### Main articles

Cobra4 Sensor-Unit Chemistry	12630-00	1
Temperature meter digital, 4-2	13617-93	1
Immersion thermostat Alpha A, 230 V	08493-93	1
Cobra4 Mobile-Link	12620-00	1
Temperature probe, immersion type, Pt100	11759-01	3
Bath for thermostat, makrolon	08487-02	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1



## P3061562 pH measurement with Cobra4



Calibration curves for the antimony (o) and quinhydrone (x) electrode. The cell e.m.f.  $E$  is measured using a  $\text{Ag(s)}|\text{AgCl(s)}|\text{Cl}^-(\text{aq.})$  reference electrode.

**Principle**

The course, reaction rate and equilibrium position of many chemical reactions are strongly influenced by the concentration or more accurately, the activity of hydrogen ions in solutions  $a_{\text{H}^+}$ . Rapid and accurate determinations of hydrogen ion activity are thus of great importance. Since  $a_{\text{H}^+}$  can vary over many orders of magnitude, it has proved convenient to introduce the pH scale (pH from the Latin "pondus hydrogenii" meaning "amount of hydrogen"). The most important and common method used to determine the pH value is to measure the potential of the electrode which is sensitive to hydrogen ion activity.

In certain practical situations, however, a simpler and more direct method of determining pH is required, and use is often made of pH indicators.

**Tasks**

- Calibrate the following pH-sensitive electrodes in buffer solutions of known pH:
  1. the glass electrode
  2. the antimony electrode
  3. the quinhydrone electrode
- Using these calibrated electrodes, measure the pH of an unknown solution. Compare and contrast the results obtained with the three pH-sensitive electrode.
- Use the glass electrode to determine the pH range in which the following indicators change colour:
  1. methyl orange
  2. bromothymol blue
  3. phenolphthalein

- Compare the suitability of the three indicators for different types of acid-base titrations.

**What you can learn about**

- Potentiometric determination of pH
- Glass electrode
- pH indicators
- Acid-base titrations

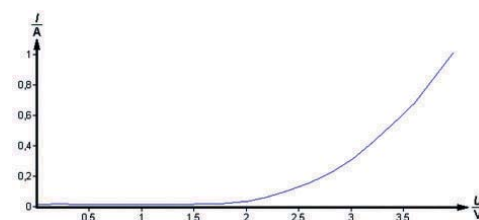
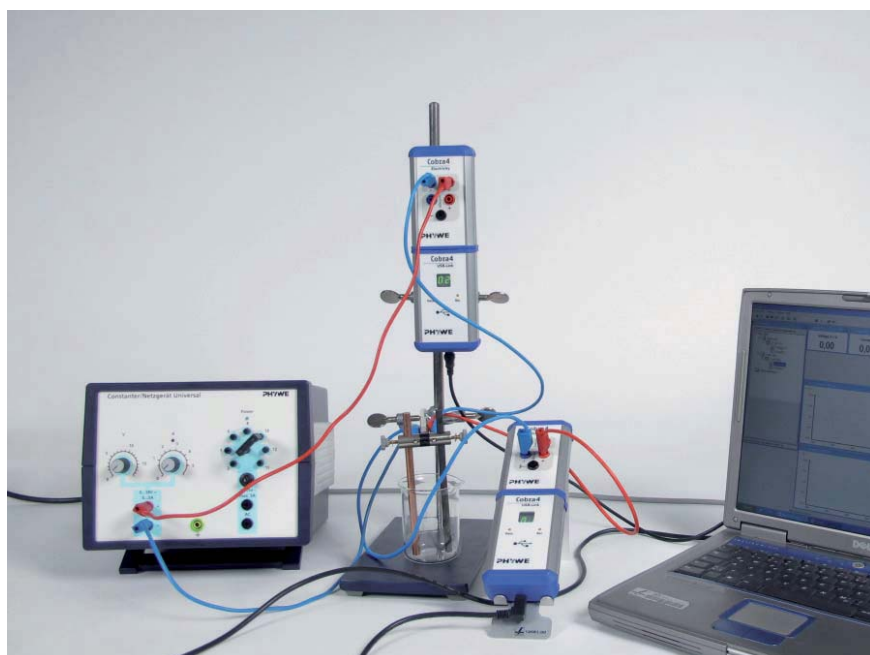
**Main articles**

Cobra4 Mobile-Link	12620-00	1
Cobra4 Sensor-Unit Chemistry	12630-00	1
Antimony electrode	18477-01	1
Immersion probe NiCr-Ni, teflon, 300 °C	13615-05	1
Magnetic stirrer Mini / MST	47334-93	1
Quinhydrone 100 g	31195-10	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1



Electrode kinetics: The hydrogen overpotential of metals with  
Cobra4

P3061861



Current-potential curve for the electrolysis of HCl solution using graphite electrodes.

**Principle**

If the oxidation and reduction steps of an electrode reaction are rapid (high exchange current densities) then the passage of charge across the electrode-solution interface will barely displace the reaction equilibrium. Such an electrode is said to be non-polarisable in the sense that its potential, for small currents, is stable and equal to the equilibrium electrode potential. If, on the other hand, reaction equilibrium is established only slowly due to the kinetic inhibition of a step involved in the electrode reaction, then the electrode is said to be polarisable. To induce the reaction to proceed in a given direction the kinetic inhibition of the reaction must be overcome by applying a high overpotential. Electrode polarisation and the presence of overpotentials are important concepts in understanding electrode processes. They underlie the fact that galvanic cells always deliver current at less than the equilibrium e.m.f. and that an applied potential greater than the equilibrium e.m.f. is required in order to drive a reaction in an electrolytic cell. Furthermore, a number of important electrochemical devices (e.g. the lead-acid accumulator) and electroanalytical techniques (e.g. polarography) make use of the inhibition (high overpotential) of certain electrode reactions.

**Tasks**

1. Record the current-potential curve for the electrolysis of a 1 M hydrochloric acid solution using graphite rod electrodes and determine the decomposition voltage.
2. Discuss the physical processes determining the form of this curve.
3. By replacing the graphite rod cathode with a series of different metal rod electrodes, compare the overpotentials for hydrogen evolution at these metals.

**What you can learn about**

- Electrode kinetics
- Polarisation
- Overpotential
- Irreversible processes
- The electrode-electrolyte interface
- Voltammetry and current-potential curves
- Relevance to electrolysis
- Fuel cells
- Corrosion
- Polarography

**Main articles**

Power supply, universal	13500-93	1
Software Cobra4 - multi-user licence	14550-61	1
Cobra4 USB-Link	12610-00	2
Cobra4 Sensor-Unit Electricity	12644-00	2
Retort stand, h = 750 mm	37694-00	1
Nickel electrode, d 8mm	45205-00	1
Holder for two electrodes	45284-01	1

## P3062101 Determination of Faraday's constant



### Principle

Faraday's laws of electrolysis describe the correlation between the amounts of substances transformed in the reactions at the electrodes and the charge applied (amount of electricity). Faraday's constant, which appears as a proportionality factor, can be determined experimentally from the dependence.

### Task

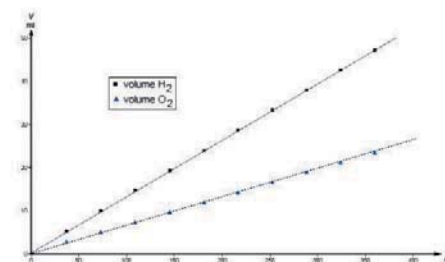
Determine Faraday's constant from the dependence of the volumes of hydrogen and oxygen evolved on the charge applied in the hydrolysis of dilute sulphuric acid.

### What you can learn about

- Electrolysis coulometry
- Charge
- Faraday's laws
- Avogadro's number
- General equation of state for ideal gases

### Main articles

Power supply, universal	13500-93	1
Electrolysis apparatus-Hofmann	44518-00	1
Weather monitor, 6 lines LCD	87997-10	1
Digital multimeter 2010	07128-00	1
On/off switch	06034-01	1
Retort stand, h = 750 mm	37694-00	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1



Correlation between the transferred charge and the evolved volumes of hydrogen and oxygen in the electrolysis of diluted sulphuric acid ( $T = 296.05 \text{ K}$  and  $p = 100.4 \text{ kPa}$ ).

### Electrolysis apparatus-Hofmann



### Function and Applications

Electrolysis apparatus-Hofmann.

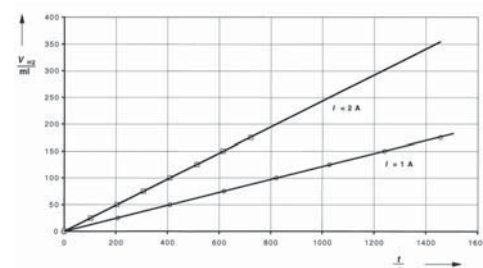
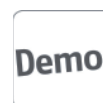
### Equipment and technical data

- Electrolysis apparatus-Hofmann
- 2 communicating glass tubes, l = 510 mm
- Measuring range: 50 ml
- Graduation: 0.2 ml

44518-00

## Characteristic curve and efficiency of a PEM fuel cell and a PEM electrolyser

P2411100



Volume of the hydrogen generated by the PEM electrolyser as a function of time at different current  $I$ .

**Principle**

In a PEM electrolyser, the electrolyte consists of a proton-conducting membrane and water (PEM = Proton-Exchange-Membrane). When an electric voltage is applied, hydrogen and oxygen are formed. The PEM fuel cell generates electrical energy from hydrogen and oxygen. The electrical properties of the electrolyser and the fuel cell are investigated by recording a current-voltage characteristic line. To determine the efficiency, the gases are stored in small gasometers in order to be able to measure the quantities of the gases generated or consumed.

**Tasks**

1. Recording the characteristic line of the PEM electrolyser.
2. Recording the characteristic line of the PEM fuel cell.
3. Determination of the efficiency of the PEM electrolysis unit.
4. Determination of the efficiency of the PEM fuel cell.

**What you can learn about**

- Electrolysis
- Electrode polarisation
- Decomposition voltage
- Galvanic elements
- Faraday's law

**Main articles**

Power supply, universal	13500-93	1
PEM electrolyser	06748-00	1
Cobra4 Mobile-Link set	12620-55	1
PEM fuel cell	06747-00	1
Cobra4 Sensor-Unit Weather	12670-00	1
Gas bar	40466-00	1
Digital multimeter 2010	07128-00	2

**PEM electrolyser****Function and Applications**

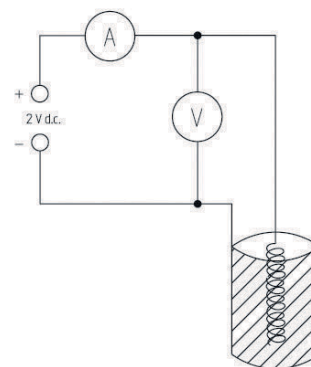
For the production of hydrogen and oxygen through electrolysis.

**Equipment and technical data**

- Electrolyser and storage container for distilled water mounted on a stable baseplate.
- Without use of caustic lyes or acids.
- Only distilled water is used for operating it.
- Voltage input protected against polarity reversal.
- Operating instructions with detailed description of experiment.
- Electrode surface: 16 cm<sup>2</sup>.
- Output: 4 W.
- Voltage required: 1.7...2 V.

06748-00

## P3062201 Electrogravimetric determination of copper



Electric circuit for electrolysis.

### Principle

Electrogravimetry is an important analytical method for the quantitative determination or separation of species in solution. The technique involves the quantitative electrolytic deposition of an element, usually a metal, on a suitable electrode in weighable form.

### Task

Perform an accurate electrogravimetric determination of the amount of copper in a given sample solution.

### What you can learn about

- Quantitative analysis
- Gravimetry
- Electrolysis
- Overpotential
- Electrode polarisation

### Main articles

Pt electrodes, electrogravimetry	45210-00	1
Power supply, universal	13500-93	1
Magnetic stirrer MR Hei-Standard	35750-93	1
Electronic temperature controller EKT Hei-Con	35750-01	1
Digital multimeter 2010	07128-00	2
Ethyl alcohol, absolute 500 ml	30008-50	1
Set of Analytical Balance Sartorius CPA 224S and measure software, 230 V	49221-88	1

### Digital multimeter 2010



### Function and Applications

3 ½ digit Steady performance digital-multimeter.

### Benefits

- Provides an overload protection and the functions of measuring like DCV, ACV, DCA, ACA, resistance, capacitance, frequency, diode, continuity test with buzzer and temperature.
- Ideal for the education- and service-fields.

### Equipment and technical data

- 3 ½-dgt. LCD display, 28 mm, with backlight
- Manual range selection
- Low battery indication
- FE-Test
- Peak-hold
- Auto power off
- Safety: IEC-1010-1; CAT II 1000 V

07128-00



### Voltage of a concentration cell with Cobra4

P1268360



NEW

4  
Cobra

#### Principle

The electric potential of a metal in a salt solution of it is dependent on the concentration of the solution. A potential difference can be measured between solutions of different concentrations when they are connected electrically conducting to one another. Two silver/silver nitrate half-cells to be are used to demonstrate this.

For more details refer to [www.phywe.com](http://www.phywe.com)

### Electrochemical series of metals with Cobra4

P1282360



NEW

4  
Cobra

#### Principle

The characteristics of a metal are determined to a great extent by how easily it can be oxidized. The listing of metals in the succession of their oxidizability, i.e. according to their striving to form cations, is called the electrochemical series of metals. When a metal is dipped into a solution which contains cations of that metal, a voltage is built up between the metal and the solution in this half-cell. Connection together of two such half-cells of different metals so that they are electrically conducting enables the voltage difference between them to be measured. The electrochemical series of metals can be derived from measurements of such voltage differences.

For more details refer to [www.phywe.com](http://www.phywe.com)

You need more information?

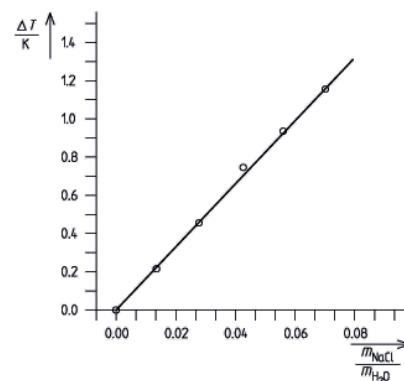
WEB@ PHYWE

Go to [www.phywe.com](http://www.phywe.com) or



send an email to [info@phywe.com](mailto:info@phywe.com)

## P3021060 Boiling point elevation - Raoult's law with Cobra4



Boiling point increase as a function of concentration of table salt in an aqueous solution.

### Principle

Raoult's law states: The vapour pressure of an ideal solution is directly dependent on the vapour pressure of each chemical component and the mole fraction of the component present in the solution.

That's why the boiling point of a solution is always higher than that of the pure solvent. The dependence of the temperature difference (elevated boiling point) on the concentration of the solute can be determined using a suitable apparatus.

### Tasks

1. Measure the increase in the boiling point of water as a function of the concentration of table salt, urea and hydroquinone.
2. Investigate the relationship between the increase in boiling point and the number of pellets.
3. Determine the molar mass of the solute from the relationship between the increase in boiling point and the concentration.

### What you can learn about

- Raoult's law; Henry's law; Ebullioscopic constants; Chemical potential; Gibbs-Helmholtz equation; Concentration ratio; Degree of dissociation

### Main articles

Cobra4 Wireless-Link	12601-00	1
Cobra4 Sensor-Unit Chemistry	12630-00	1
Software Cobra4 - multi-user licence	14550-61	1
Heating mantle f. roundbottom flask, 250ml	49542-93	1
Apparatus for elevation of boiling point	36820-00	1
Power regulator	32288-93	1

### Related Experiment

#### Boiling point elevation

P3021001

### Temperature meter digital, 4-2

#### Function and Application

Modern, user-friendly designed instrument for measuring temperature and temperature differences at four different measuring points.

#### Benefits

- Two demonstrative 4 digit LED display (+ sign), with 20 mm high digits for presentation of the values measured at the selected measuring points.
- RS 232 interface for simultaneous display and evaluation of the measured values from all four measuring points with a computer.

13617-93

## Freezing point depression

P3021101



## Principle

The freezing point of a solution is lower than that of the pure solvent. The depression of the freezing point can be determined experimentally using a suitable apparatus (cryoscopy). If the cryoscopy constants of the solvent are known, the molecular mass of the substance dissolved can be determined.

## Tasks

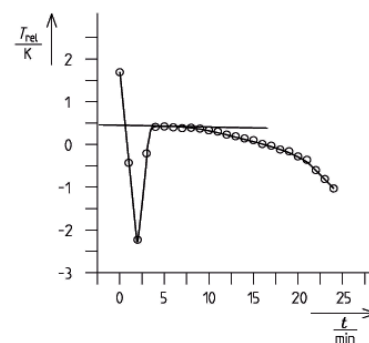
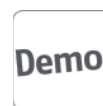
1. Determine the size of freezing point depression after dissolving a strong electrolyte (NaCl) in water. By comparing the experimental value with the theoretical one predicted for this concentration, determine the number of ions into which the electrolyte dissociates.
2. Determine the molar mass of a non-electrolyte (hydroquinone) from the value of freezing point depression.

## What you can learn about

- Raoult's law; Cryoscopic constant; Chemical potential
- Gibbs-Helmholtz equation; Concentration ratio
- Degree of dissociation; Van't Hoff factor

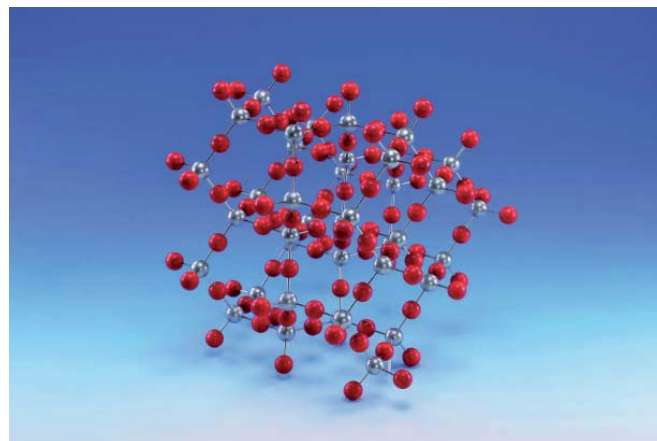
## Main articles

Temperature meter digital, 4-2	13617-93	1
Magnetic stirrer MR Hei-Standard	35750-93	1
Apparatus for freezing point depression	36821-00	1
Temperature probe, immersion type, Pt100	11759-01	2
Pellet press for calorimeter	04403-04	1
Gasket for GL25, 12mm hole, 10pcs	41243-03	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1



Cooling curve of water/table salt mixture.

## Crystal-lattice model ice



## Function and Applications

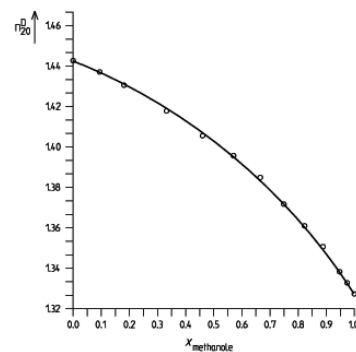
High quality crystal-lattice model consisting of coloured wooden balls and metallic links; the model will be delivered completely fixed.

## Equipment and technical data

- Scale to real crystals: 1 : 250 million
- Diameter of the balls: approx. 20 mm

40022-00

## P3030401 Boiling point diagram of a binary mixture



Index of refraction as a function of substance concentration in methanol/chloroform mixtures.

**Principle**

A boiling point diagram shows the boiling points of a binary mixture as a function of the vapour / liquid equilibrium of the mixture at constant pressure. The boiling points of various mixtures of methanol and chloroform are measured and the composition of the liquid phases are determined using refractometry and a calibration curve.

**Tasks**

1. Determine the refractive indices of the pure components and about 10 different mixtures of known composition.
2. Plot the boiling point diagram of the binary mixtures of methanol and chloroform.

**What you can learn about**

- Fundamentals of distillation
- Equilibrium diagram
- Chemical potential
- Activity coefficient
- Raoult's law

**Main articles**

Abbe refractometer	35912-00	1
Temperature meter digital, 4-2	13617-93	1
Immersion thermostat Alpha A, 230 V	08493-93	1
Heating mantle f. roundbottom flask, 100 ml	49541-93	1
Power regulator	32288-93	1
Condenser, Dimroth, IGJ19/26, 210mm	35816-05	1
Bath for thermostat, makrolon	08487-02	1

**Abbe refractometer****Function and Applications**

Abbe refractometer for measuring the refraction index of liquids and solids with light of 590 nm wavelength (sodium D line) and determining average dispersion  $n_D - n_F$ .

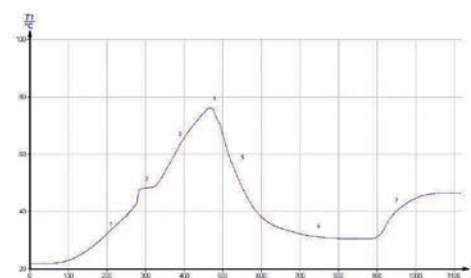
The refractive index scale also includes an additional scale indicating sugar content from 0 - 95%. The prism and scales can be illuminated by daylight or by a separate lighting unit.

35912-00



## Heat of fusion of sodium thiosulphate with Cobra4

P1273460



Measurement result, the temperature over time in the range from 20 °C to about 70 °C.

### Principle

The temperature course during the melting and crystallization of sodium thiosulphate is determined.

### Task

Investigate the temperature rise during crystallisation of sodium thiosulfate.

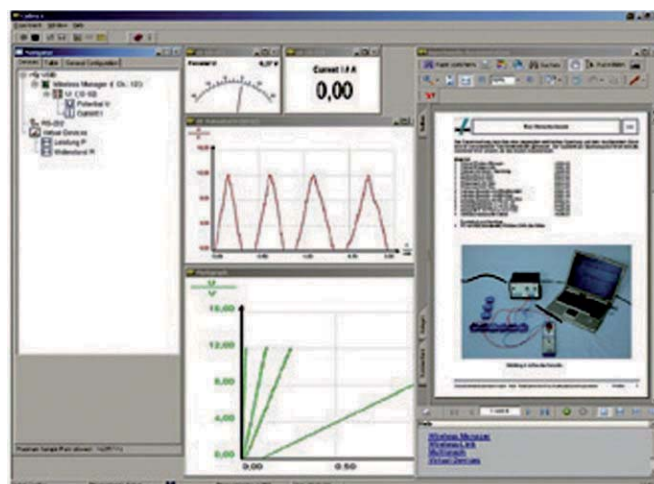
### What you can learn about

- Melting
- Crystallization
- Sodium thiosulphate
- Fusion enthalpy
- Supercooled melt

### Main articles

Cobra4 Wireless Manager	12600-00	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Sensor-Unit Chemistry	12630-00	1
Software Cobra4 - multi-user licence	14550-61	1
Immersion probe NiCr-Ni, steel, -50...400 °C	13615-03	1
Retort stand, 210mm × 130mm, 500mm	37692-00	1
Holder for Cobra4 with support rod	12680-00	1

### Software Cobra4 - multi-user licence



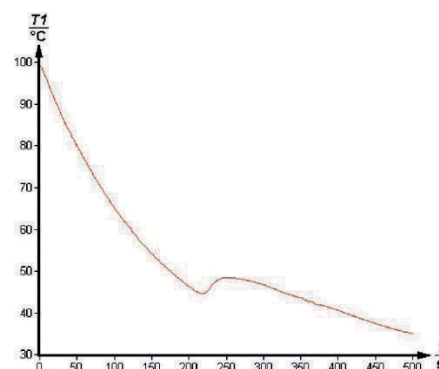
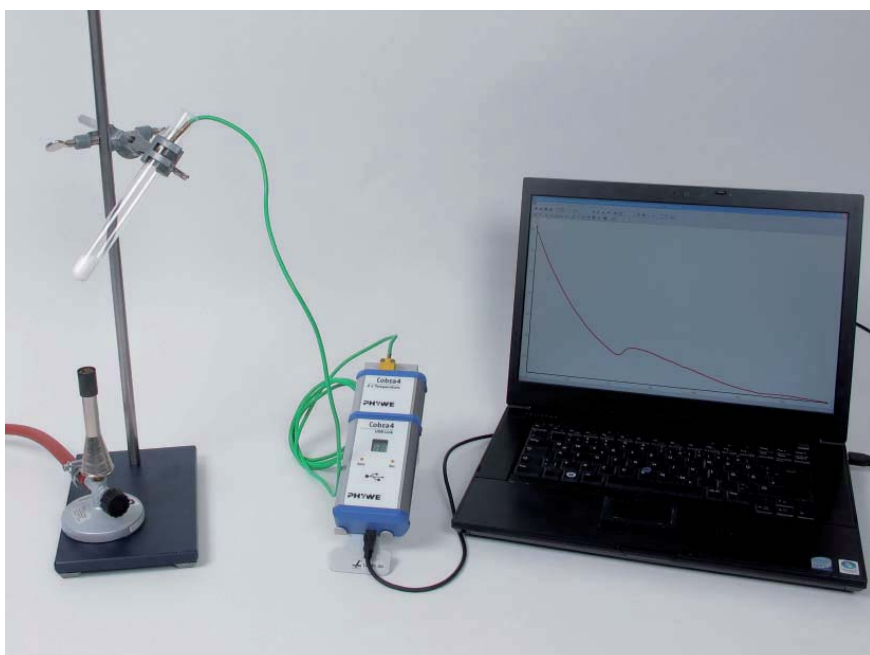
### Function and Applications

The "measure Cobra4" measuring software leaves nothing to be desired.

As soon as a Cobra4 sensor is connected to a PC, irrespective of whether by Cobra4 Wireless or Cobra4 USB Link, the "measure Cobra4" software opens completely automatically and shows the connected sensors, the required measuring windows and the current measuring data.

14550-61

## P3031361 Melting diagram of a binary mixture with Cobra4



Cooling curve of a mixture of naphthalene and biphenyl.

**Principle**

In plotting the cooling curves of binary mixtures one determines the temperatures of melting and solidification of specimens with differing fractions (molar fractions) of the two components. These results are entered in a temperature versus concentration diagram.

**Tasks**

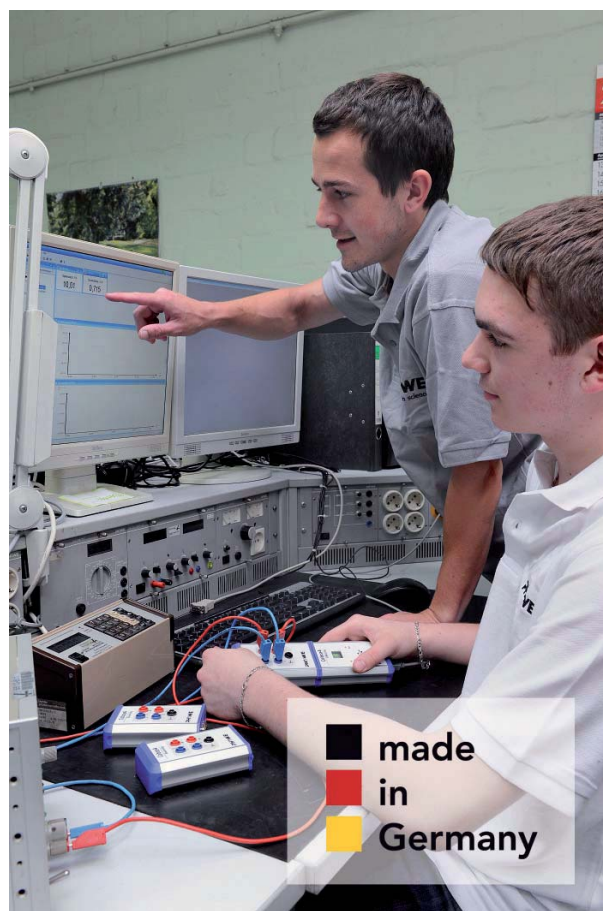
1. Record the melting point diagram of a mixture of biphenyl and naphthalene.
2. Determine the composition of the eutectic mixture and its melting point from the melting point diagram.

**What you can learn about**

- Melt
- Melting point
- Melting point diagram
- Binary system
- Miscibility gap
- Mixed crystal
- Eutectic mixture
- Gibbs' phase law

**Main articles**

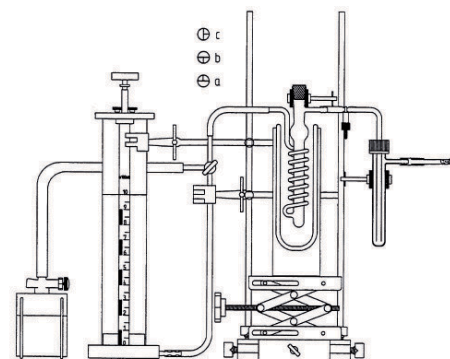
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1
Software Cobra4 - multi-user licence	14550-61	1
Cobra4 USB-Link	12610-00	1
Cobra4 Sensor-Unit 2 x Temperature, NiCr-Ni	12641-00	1
Thermocouple NiCr-Ni, -50..1100°C	13615-01	1
Retort stand, h = 750 mm	37694-00	1
Stand.petroil b.p.65-95 C 1000 ml	31311-70	1



made  
in  
Germany

## Condensation of gases through an increase of pressure and through cooling

P3011400



Schematical setup of the experiment.

**Principle**

Gases are condensing when they are cooled and at high pressure. In this experiment butane is condensed by cooling it to ca.  $-15\text{ }^{\circ}\text{C}$ . In the second part of the experiment butane is condensed by compressing it.

**Tasks**

1. Condense butane by cooling it under its boiling point of  $-0.4\text{ }^{\circ}\text{C}$ .
2. Condense butane at high pressure.

**What you can learn about**

- Condensation
- Gas laws

**Main articles**

Gasometer 1000 ml	40461-00	1
Gas liquefier	08173-00	1
Dewar vessel, 500 ml	33006-00	1
Lab jack, 160 x 130 mm	02074-00	1
Butane burner, Labogaz 206 type	32178-00	1
Quartz glass wool 10 g	31773-03	1

**Gas liquefier****Function and Applications**

Gas liquefier, for demonstrating isothermal condensation and evaporation due to changes in pressure and volume.

**Equipment and technical data**

- Plastic-coated glass tube, piston with handle.
- Length: 270 mm.
- Diameter: 27 mm.

08173-00

## P3031900 Sublimation and solubility of iodine

**Principle**

Iodine, whose melting point is at 113.5 °C, evaporates clearly below this temperature. It passes from the solid state directly to the gaseous state. This process is known as sublimation.

When iodine vapour cools down, solid crystals form, again without a liquid transitional phase. This process is known as resublimation.

**Tasks**

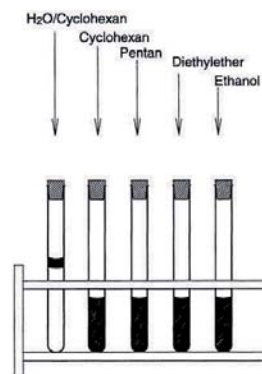
1. Show sublimation and resublimation of iodine.
2. Investigate the solubility of iodine in oxygen-containing and oxygen-free solvents.

**What you can learn about**

- Sublimation
- Resublimation
- Solubility
- Iodine

**Main articles**

Round bottom flask, 250 ml, 2-neck, GL25/12, GL18/8	35843-15	1
Retort stand, h = 750 mm	37694-00	1
Ethyl alcohol, absolute 500 ml	30008-50	1
Condenser, reflux,with 2GI conn.	35900-02	1
Cyclohexane 1000ml	31223-70	1
Closure caps,10, GL18	41220-03	1
Iodine resublimed 25 g	30093-04	1



Solubility of iodine in oxygenated and deoxygenated solvents.

**Condenser, reflux,with 2GI conn.****Function and Applications**

Condenser, reflux, with 2 GI connection.

**Equipment and technical data**

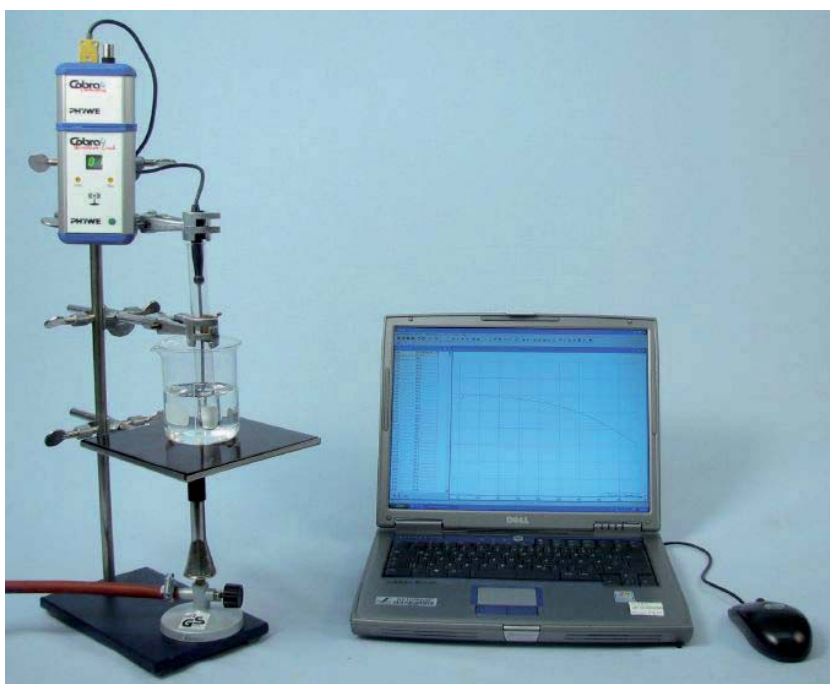
- Jacket length: 190 mm
- Diameter of the olives: 8 mm
- Made of DURAN®

**35900-02**



## Determination of freezing points of pure substances with Cobra4

P3022161



Crystallisation curve of naphthalene.

**Principle**

When a pure substance is heated or cooled, the temperature of it does not continually increase or decrease when it undergoes a change in the state of aggregation. Instead of this, and despite the continuing external supply or removal of heat respectively, the temperature of it remains constant until the change in phase has been completed. This can be used for the determination of the melting point of the substance.

**Tasks**

1. Measure the change in temperature during the change in the state of aggregation of naphthalene and palmitic acid.
2. Determine the melting points of the three substances from your measurements.

**What you can learn about**

- Crystallisation point
- Gibbs free energy
- Enthalpy
- Entropy
- Heat of fusion
- Freezing point depression

**Main articles**

Software Cobra4 - multi-user licence	14550-61	1
Hotplate Magnetic Stirrer, 5 ltr., 230 V	35730-93	1
Cobra4 Sensor-Unit Chemistry	12630-00	1
Cobra4 USB-Link	12610-00	1
Thermocouple NiCr-Ni, -50...500°C	13615-02	2
Safety gas tubing with couplings, l = 1 m	39281-00	1
Teclu burner, universal, air reg.	46920-35	1



## Steam distillation

P3031251



## Principle

An elegant and simple apparatus for carrying out water vapour distillations: the advantage of this arrangement is that it eliminates the need for a separate vapour generator, making it possible to operate with a single heat source (other set-ups require two). The vapour is generated in the outer chamber and then passes through the inner chamber. Due to the structural arrangement, the inner chamber is heated directly by the vapour generated in the outer chamber. This also eliminates the possibility of overheating the substances being extracted. Parts of plants suitable for the extraction of essential oils include orange peel and cloves, for example.

For more details refer to page 167.

## Rectification - the number of theoretical trays in a distillation column

P3031501



## Principle

The separation power of a rectification (fractionating) column can be determined using an appropriate binary mixture whose equilibrium composition is measured in the distillation flask and in the domed glass head of the distillation apparatus. The number of theoretical trays can be numerically or graphically obtained from the measured values.

For more details refer to pages 166, 181.

## Fractional distillation with the bubble tray column with Cobra4

P3031660



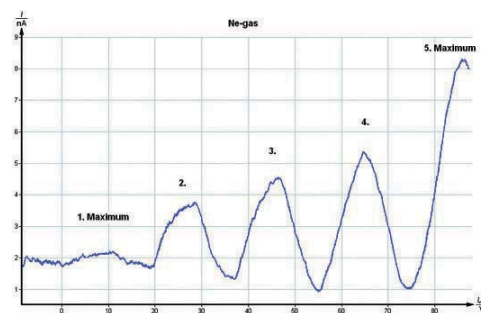
## Principle

In countercurrent distillation (rectification) using a column, the rising vapour can enter into interactions with the condensate. In this manner, a fractional distillation, i.e. a distillation in several steps for the separation of substances with similar boiling points, can be performed in a single apparatus. If bubble tray columns are used condensate can be removed from the individual bubble trays.

For more details refer to page 180.

## Franck-Hertz experiment with a Ne-tube

P2510315



Example of a Franck-Hertz curve for Ne-gas.

### Principle

Electrons are accelerated in a tube filled with neon vapour. The excitation energy of neon is determined from the distance between the equidistant minima of the electron current in a variable opposing electric field.

### Tasks

1. To record the counter current strength  $I$  in a Franck-Hertz tube as a function of the anode voltage  $U$ .
2. To determine the excitation energy  $\mathcal{E}$  from the positions of the current strength minima or maxima by difference formation.

### What you can learn about

- Energy quantum
- Quantum leap
- Electron collision
- Excitation energy

### Main articles

Franck-Hertz control unit	09105-99	1
Franck-Hertz Ne-tube w. housing	09105-40	1
Connect.cord for Franck-H. Ne-tube	09105-50	1
Software Measure Franck-Hertz experiment	14522-61	1
Screened cable, BNC, l = 750 mm	07542-11	1
Data cable, plug/ socket, 9 pole	14602-00	1

### Related Experiment

Franck-Hertz experiment with a Hg-tube

P2510311



James Franck (left) and Gustav Hertz (right)  
1925, Nobel Prize in Physics

### P2510600 Fine structure: one and two electron spectra



Spectrum of sodium.

#### Principle

The well-known spectral lines of He are used for calibrating the diffraction spectrometer. The wave-lengths of the spectral lines of Na, Hg, Cd and Zn are determined using the spectrometer.

#### Tasks

1. Calibration of the spectrometer using the He spectrum and the determination of the constant of the grating.
2. Determination of the spectrum of Na.
3. Determination of the fine structure splitting.
4. Determination of the most intense spectral lines of Hg, Cd and Zn.

#### What you can learn about

- Diffraction spectrometer; Spin
- Angular momentum
- Spin-orbital angular momentum interaction
- Multiplicity; Energy level; Excitation energy
- Selection rules; Doublets; Parahelium
- Orthohelium, Exchange energy
- Angular momentum; Singlet and triplet series
- Selection rules; Forbidden transitions

#### Main articles

Spectrometer/goniom. w. vernier	35635-02	1
Spectral lamp He, pico 9 base	08120-03	1
Power supply for spectral lamps	13662-97	1
Spectral lamp Na, pico 9 base	08120-07	1
Spectral lamp Hg 100, pico 9 base	08120-14	1
Spectral lamp Zn, pico 9 base	08120-11	1
Spectral lamp Cd, pico 9 base	08120-01	1

#### Spectrometer/goniom. w. vernier



#### Function and Applications

Spectrometer/ goniometer with double vernier.

#### Equipment and technical data

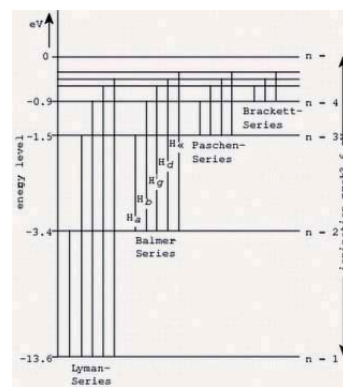
- With magnifying glasses
- 60° glass prism
- Illumination device and telescope

35635-02



## Balmer series/ determination of Rydberg's constant

P2510700



Energy level diagram of the H atom.

### Principle

The spectral lines of hydrogen and mercury are examined by means of a diffraction grating. The known spectral lines of Hg are used to determine the grating constant. The wave lengths of the visible lines of the Balmer series of H are measured.

### Tasks

1. Determination of the diffraction grating constant by means of the Hg spectrum.
2. Determination of the visible lines of the Balmer series in the H spectrum, of Rydberg's constant and of the energy levels.

### What you can learn about

- Diffraction image of a diffraction grating
- Visible spectral range
- Single electron atom
- Atomic model according to Bohr
- Lyman-, Paschen-, Brackett and Pfund Series
- Energy level
- Planck's constant
- Binding energy

### Main articles

High voltage supply unit, 0-10 kV	13673-93	1
Object holder, 5x5 cm	08041-00	1
Spectrum tube, hydrogen	06665-00	1
Spectrum tube, mercury	06664-00	1
Diffraction grating, 600 lines/mm	08546-00	1
Tripod base PHYWE	02002-55	1
Insulating support	06020-00	2

### High voltage supply unit, 0-10 kV



### Function and Applications

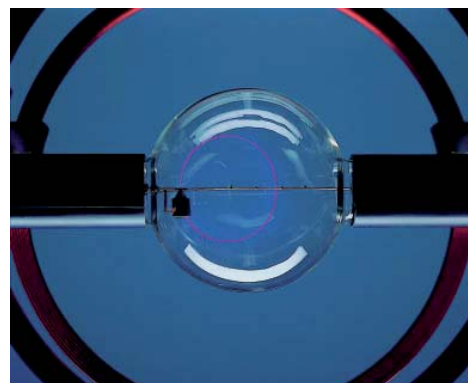
For electrostatic experiments and for operation of spectral and gas discharge tubes.

### Equipment and technical data

- It supplies 3 continuously variable DC voltages isolated from earth and ground.
- Two of the voltages are connected in series 0-5 kV DC = total of 0 -10 kV DC.
- Selectable positive and negative polarity.
- 3-figure LED display. Outputs short-circuit proof.
- Special safety sockets.
- Modern plastic housing, impact resistant, easy to service, light stackable with retractable carrying handle and stand.
- Internal resistance: approx. 5 MΩhm.
- Ripple: < 0.5%; Supply voltage: 230 V.
- Short circuit current: max. 3 mA.
- Housing dimensions (mm): 230 x 236 x 168.

13670-93

### P2510200 Specific charge of the electron $e/m$



Detail of experimental setup.

#### Principle

Electrons are accelerated in an electric field and enter a magnetic field at right angles to the direction of motion. The specific charge of the electron is determined from the accelerating voltage, the magnetic field strength and the radius of the electron orbit.

#### Task

Determination of the specific charge of the electron ( $e/m$ ) from the path of an electron beam in crossed electric and magnetic fields of variable strength.

#### What you can learn about

- Cathode rays
- Lorentz force
- Electron charge
- Electron in crossed fields
- Electron mass

#### Main articles

Narrow beam tube	06959-00	1
Helmholtz coils, one pair	06960-00	1
Power supply, 0...600 VDC	13672-93	1
Power supply, universal	13500-93	1
e/m - Observation Chamber	06959-01	1
Digital multimeter 2010	07128-00	2

#### In Cooperation with:



National University of Science and Technology  
"MISIS" in Moscow, Russia

#### e/m - Observation chamber



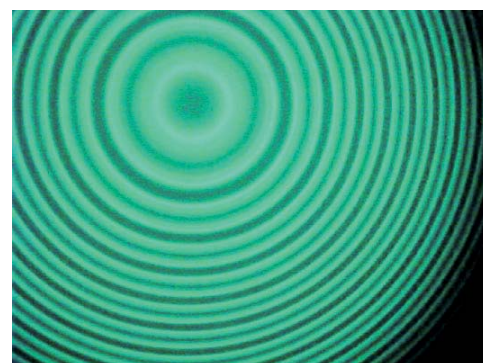
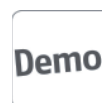
#### Function and Application

Observation Chamber for Covering the e/m experiment (helmholtz coils and narrow beam tube).

06959-01

## Zeeman effect with a variable magnetic system

P2511006



Interference rings with the anomalous Zeeman effect.

### Principle

The "Zeeman effect" is the splitting up of the spectral lines of atoms within a magnetic field. The simplest is the splitting up of one spectral line into three components called the "normal Zeeman effect". In this experiment the normal Zeeman effect as well as the anomalous Zeeman effect are studied using a cadmium spectral lamp as a specimen. The cadmium lamp is submitted to different magnetic flux densities and the splitting up of the cadmium lines (normal Zeeman effect 643.8 nm, red light; anomalous Zeeman effect 508.6 nm, green light) is investigated using a Fabry-Perot interferometer. The evaluation of the results leads to a fairly precise value for Bohr's magneton.

### Tasks

1. Using the Fabry-Perot interferometer and a selfmade telescope the splitting up of the central line into different lines is measured in wave numbers as a function of the magnetic flux density.
2. From the results of point 1. a value for Bohr's magneton is evaluated.
3. The light emitted within the direction of the magnetic field is qualitatively investigated.

### What you can learn about

- Bohr's atomic model
- Quantisation of energy levels
- Electron spin
- Bohr's magneton
- Interference of electromagnetic waves
- Fabry-Perot interferometer

### Main articles

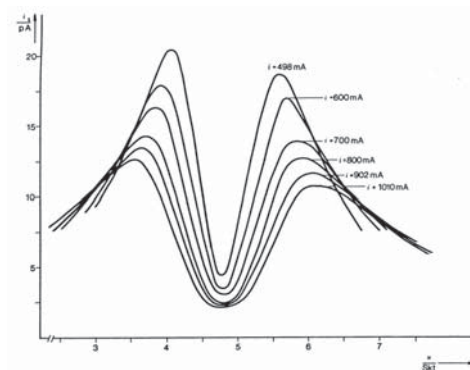
Fabry-Perot interferometer	09050-03	1
Magnetic System, variable	06327-00	1
Cadmium lamp for Zeeman effect	09050-20	1
Power supply for spectral lamps	13662-97	1
Sliding device, horizontal	08713-00	1
Optical profile-bench, l 1000mm	08282-00	1
Polarising filter, on stem	08610-00	1



Pieter Zeeman

1902, Nobel Prize in Physics

## P2511111 Stern-Gerlach experiment with a step motor and interface



Ionization current as a function of position ( $u$ ) of detector with large excitation currents in the magnetic analyser.

### Principle

A beam of potassium atoms generated in a hot furnace travels along a specific path in a magnetic two-wire field. Because of the magnetic moment of the potassium atoms, the nonhomogeneity of the field applies a force at right angles to the direction of their motion. The potassium atoms are thereby deflected from their path. By measuring the density of the beam of particles in a plane of detection lying behind the magnetic field, it is possible to draw conclusions as to the magnitude and direction of the magnetic moment of the potassium atoms.

### Tasks

1. Recording the distribution of the particle beam density in the detection plane in the absence of the effective magnetic field.
2. Fitting a curve consisting of a straight line, a parabola, and another straight line, to the experimentally determined special distribution of the particle beam density.
3. Determining the dependence of the particle beam density in the detection plane with different values of the non-homogeneity of the effective magnetic field.
4. Investigating the positions of the maxima of the particle beam density as a function of the non-homogeneity of the magnetic field.

### What you can learn about

- Magnetic moment; Bohr magneton; Directional quantisation
- g-factor; Electron spin; Atomic beam
- Maxwellian velocity distribution; Two-wire field

### Main articles

Stern-Gerlach apparatus	09054-88	1
High vacuum pump assembly, compact	09059-99	1
Step motor Stern-Gerlach apparatus	09054-06	1
Electromagnet w/o pole shoes	06480-01	1
DC measuring amplifier	13620-93	1
Step motor unit	08087-99	1
Matching transformer	09054-04	1



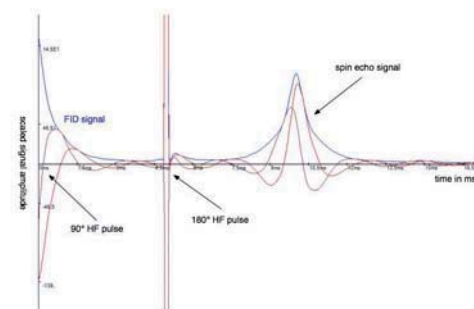
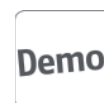
**Otto Stern**

1943, Nobel Prize in Physics



## Fundamental principles of Nuclear Magnetic Resonance (NMR)

P5942100



Spin echo signal of an oil sample occurring 10 ms (echo time) after a 90° HF pulse (FID signal is shown). To generate the echo signal a 180° HF pulse has to be switched after half the echo time.

### Principle

The basic principles concerning the phenomenon of nuclear magnetic resonance (NMR) are demonstrated. Experiments are executed with a MRT training device giving the opportunity to investigate some small probes in the sample chamber. Device control is done with the provided software. Investigations comprise the tuning of the system frequency to the Larmor frequency, the determination of the flip angle of the magnetisation vector, the effects of the substance quantity, the influence of particular magnetic field inhomogeneities, the measurement of a spin echo signal and an averaging procedure to maximise the signal-to-noise ratio. The adjustment of all parameters in these experiments are inevitable to obtain an adequate MR image.

### Tasks

1. Tuning of the system frequency to the Larmor frequency.
2. Setting of the HF (High Frequency) pulse duration to determine the flip angle of the magnetisation vector.
3. Effects of the substance quantity on the FID signal (Free Induction Decay) amplitude.
4. Minimising magnetic field inhomogeneities via a superimposed magnetic field (shim).
5. Retrieving a relaxed FID signal via a spin echo flipping nuclear spins by 180°.
6. Improving the signal-to-noise ratio (SNR) of the FID signal.

### What you can learn about

- Nuclear spins; Atomic nuclei with a magnetic moment
- Precession of nuclear spins; Magnetisation
- Resonance condition, MR frequency
- MR flip angle
- FID signal (Free Induction Decay); Spin echo
- Relaxation times (T1: longitudinal magnetisation, T2: transverse magnetisation); Signal-to-noise ratio

### Main articles

Compact magnetic resonance tomograph (MRT)	09500-99	1
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### Training recommended Service PHYWE

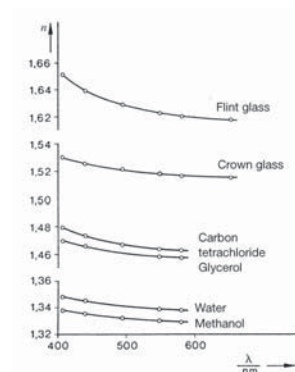
For this experiment we recommend a seminar on equipment technology, handling and information of equipment-specific characteristics on site.

03333-02



Felix Bloch (left) and Edward Mills Purcell (right)  
1952, Nobel Prize in Physics

## P2210300 Dispersion and resolving power of a prism and a grating spectroscope



Dispersion curves of various substances.

### Principle

The refractive indices of liquids, crown glass and flint glass are determined as a function of the wave length by refraction of light through the prism at minimum deviation. The resolving power of the glass prisms is determined from the dispersion curve.

### Tasks

1. To adjust the spectrometer-goniometer.
2. To determine the refractive index of various liquids in a hollow prism.
3. To determine the refractive index of various glass prisms.
4. To determine the wavelengths of the mercury spectral lines.
5. To demonstrate the relationship between refractive index and wavelength (dispersion curve).
6. To calculate the resolving power of the glass prisms from the slope of the dispersion curves.
7. Determination of the grating constant of a Rowland grating based on the diffraction angle (up to the third order) of the high intensity spectral lines of mercury.
8. Determination of the angular dispersion of a grating.
9. Determination of the resolving power required to separate the different Hg-Lines. Comparison with theory.

### What you can learn about

- Maxwell relationship
- Dispersion
- Polarisability
- Refractive index
- Prism
- Rowland grating
- Spectrometer
- Goniometer

### Main articles

Spectrometer/goniom. w. vernier	35635-02	1
Power supply for spectral lamps	13662-97	1
Spectral lamp Hg 100, pico 9 base	08120-14	1
Hollow prism	08240-00	1
Lamp holder, pico 9, f. spectr. lamps	08119-00	1
Diffraction grating, 600 lines/mm	08546-00	1
Prism, 60 degrees, h.30 mm, crown	08231-00	1

### Spectrometer/goniom. w. vernier



### Function and Applications

Spectrometer/ goniometer with double vernier.

### Equipment and technical data

- With magnifying glasses
- 60° glass prism
- Illumination device and telescope

35635-02



## Inorganic Chemistry

8.1	Chemistry of Metals	140
8.2	Coordination Chemistry	143
8.3	Organometallic Chemistry	144
8.4	Solid-state Chemistry and Cristallography	146
8.5	Literature	158



## P3110600 Redox reactions between metals and metal oxides (thermite process)



Experimental setup.

### Principle

The experiments described here are highly suitable for demonstrating the different affinity of various metals in view of oxygen. The less noble a metal is the higher its affinity to oxygen and the more thermal energy is released during its oxidation. The technical importance of the thermite process for the welding of iron parts is that it is relatively easy to produce large amounts of liquid iron and, thereby, to fill wider weld grooves. This is why this process is mainly used for welding thick steel beams, rail tracks, and machine parts.

### Tasks

1. Reduction of copper oxide with iron.
2. Reduction of iron oxide with aluminium (thermite process, aluminothermics).

### What you can learn about

- Redox reaction; Thermite process
- Metals; Welding of iron
- Aluminothermics
- Iron; Aluminium

### Main articles

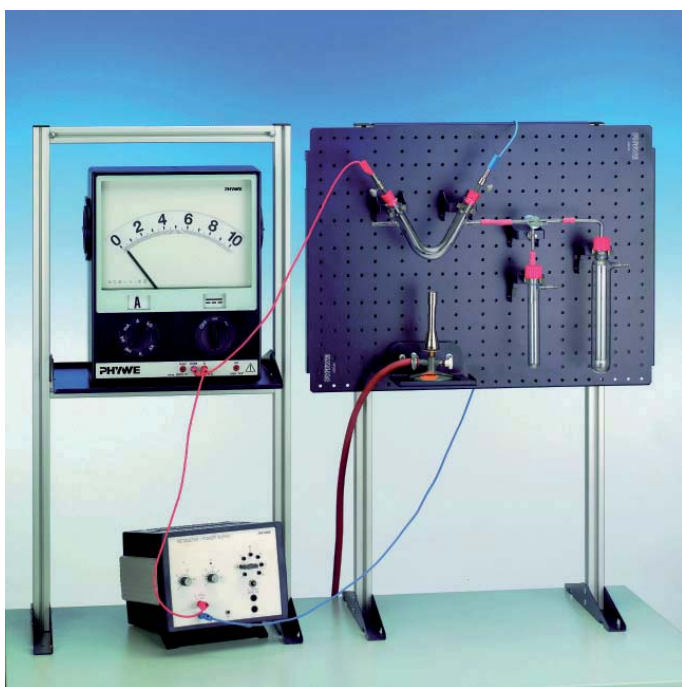
Retort stand, h = 750 mm	37694-00	1
Iron powder xtra pure 1000 g	30068-70	1
Magnet, d 10mm, l = 200mm	06311-00	1
Teclu burner, DIN, natural gas	32171-05	1
Ignition sticks f. thermite, 50 pcs.	31921-05	1
Set of Precision Balance Sartorius CPA 6235 and measure software, 230 V	49224-88	1





## Molten-salt electrolysis

P1310500



### Principle

The electrolysis of molten sodium chloride to obtain chlorine and sodium, which can be further processed to produce sodium hydroxide, is an important industrial-scale process. The experiment depicted here can be used for a simple demonstration of the important steps in this process. Due to the high melting point of sodium chloride, however, lower-melting lead chloride is used as the raw material in the model experiment.

### Task

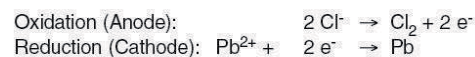
Demonstration the electrolysis of molten sodium chloride to obtain chlorine and sodium.

### What you can learn about

- Electrolysis
- Melt
- Chlorine
- Starch-iodine solution

### Main articles

Multimeter ADM2, demo., analogue	13820-01	1
Power supply, universal	13500-93	1
Frame for complete experiments	45500-00	2
Shelf with hanging device	45505-00	1
Wash tube with fritted disc	36699-00	1
Lead-II chloride 500 g	31117-50	1
Panel for complete experimental setups	45510-00	1



Oxidation/reduction process during the experiment.

### Related Experiments

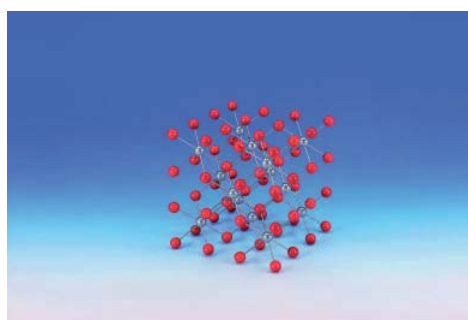
#### Oxidation of metals

P1025200

#### Effects of acids on metals

P3100100

### Crystal-lattice model fluorite

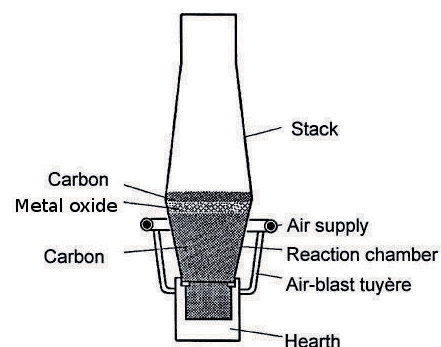


### Function and Applications

High quality crystal-lattice model consisting of coloured wooden balls and metallic links; the model will be delivered completely fixed.

40018-00

## P3100400 Reduction of lead oxide



The blast furnace with which iron can be obtained from iron oxide.

**Principle**

Lead oxide is reduced to lead; in the process the carbon is oxidised to carbon dioxide. In this experimental set-up and also in the blast furnace process, the reducing agent proper is not carbon, but rather the carbon monoxide generated due to the oxygen deficit.

**Task**

Demonstrate the reduction of lead oxide.

**What you can learn about**

- Lead
- Carbon monoxide
- Reduction
- Oxidation
- Redox reaction

**Main articles**

Support base variable	02001-00	1
Lead-II oxide -litharge- 500 g	31121-50	1
Bunsen burner DIN, natural gas	32165-05	1
Ring with boss head, i. d. = 10 cm	37701-01	1
Activated carbon, granular 250 g	30011-25	1
Support rod, stainless steel, l = 600 mm, d = 10 mm	02037-00	1
Safety gas tubing, DVGW, sold by metre	39281-10	1

**Related Experiments****Reduction of silver oxide**

P1026800

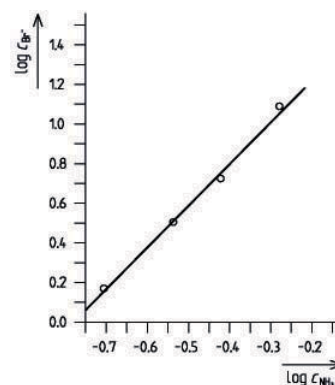
**Reduction of copper oxide**

P1026900

You need more information? **WEB@**   
Go to [www.phywe.com](http://www.phywe.com) or  
 send an email to [info@phywe.com](mailto:info@phywe.com)

## Complex formation equilibrium / complex formation constant

P3031001



Determination of the number of ligands bound in the complex.

**Principle**

Many metals, in particular transition elements, can form complexes with charged or neutral ligands. Complex formation reactions are equilibrium reactions. The stability of these complexes is described by the complex formation constant.

**Tasks**

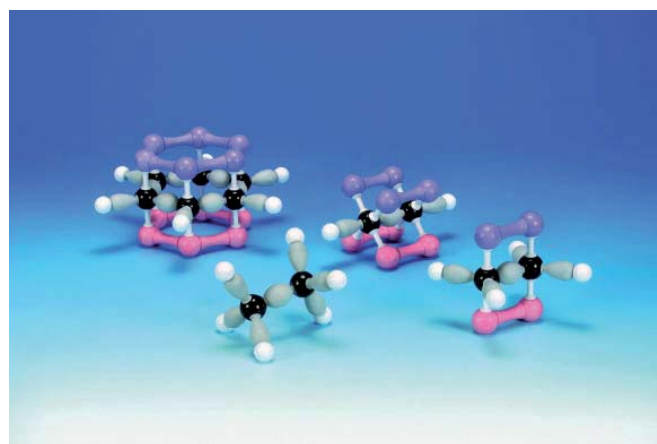
Determine the number of ligands of the silver amine complex with a precipitation titration from a silver salt solution.

**What you can learn about**

- Complex formation
- Chemical equilibrium
- Equilibrium constant

**Main articles**

Magnetic stirrer Mini / MST	47334-93	1
Silver nitrate, cryst. 15 g	30222-00	1
Retort stand, h = 750 mm	37694-00	1
Burette, lateral stopcock, Schellbach, 25 ml	36506-01	1
Burette clamp, roller mount., 2 pl.	37720-00	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

**Molecular orbital models, organics****Function and Applications**

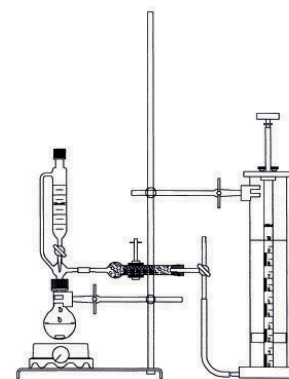
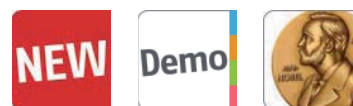
The kit includes all the parts to build up 4 molecular orbital models of the following organic compounds: benzene, ethane, ethylene and acetylene.

**Benefits**

The models show bonding s- and p- orbitals. The concept of hybridisation and delocalisation can be demonstrated so well.

39837-00

P3101000 Haloalkanes: Grignard reagent



Set-up to determine the molar mass of the gas that is produced during the reaction.

**Principle**

Haloalkanes react with magnesium to the so-called Grignard reagents in accordance with the general formula  $\text{RMgX}$ . With  $\text{X} =$  bromide or iodide, the reaction works best. Chlorides are usually more inert and require higher temperatures and longer reaction times for the conversion. The compounds that were discovered by Victor Grignard probably exist as dimeric structures.

**Task**

Investigate the reaction of n-propyl bromide with magnesium turnings in tetrahydrofuran.

**What you can learn about**

- n-propyl bromide
- Magnesium
- Haloalkanes
- Grignard reagent
- Organometallic compounds

**Main articles**

Gasometer 1000 ml	40461-00	1
Weather monitor, 6 lines LCD	87997-10	1
Condenser, Dimroth type GL25/12	35815-15	1
Magnetic stirrer Mini / MST	47334-93	1
Separating funnel, 50 ml, GL18	35853-15	1
Funnel f. gas generator, 50 ml, GL18	35854-15	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

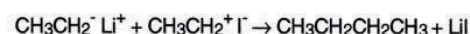


François Auguste Victor Grignard  
1912, Nobel Prize in Chemistry



## Haloalkanes: Wurtz reaction - lithium organyls

P3101100



Reaction of lithium with ethyl iodide and the following Wurtz reaction of ethyl lithium with ethyl iodide.

### Principle

Unlike the other alkali-organyls, lithium organyls - with the exception of methyllithium - show a stronger covalent behaviour. They dissolve rather well in organic solvents, such as diethyl ether, tetrahydrofuran, and alkanes, and they are relatively stable in these solvents.

Wurtz synthesis was developed in 1854 for the preparation of higher alkanes based on haloalkanes. Alkyl iodides react the easiest. The reaction can be controlled best with lithium, since the other alkali metals react much more violently. Wurtz synthesis is often a side reaction that occurs during organometallic conversions.

### Task

Investigate the reaction of ethyl iodide with lithium and the following reaction of ethyllithium with ethyl iodide.

### What you can learn about

- Alkali-organyls; Lithium organyls
- Wurtz synthesis; Organometallic compounds

### Main articles

Gasometer 1000 ml	40461-00	1
Weather monitor, 6 lines LCD	87997-10	1
Condenser, Dimroth type GL25/12	35815-15	1
Gasket for GL25, 8 mm hole, 10 pcs.	41242-03	1
Retort stand, h = 750 mm	37694-00	1
Round bottom flask, 100ml, GL25/12, GL18/8	35842-15	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

### Gasometer 1000 ml



### Function and Applications

Gasometer.

### Equipment and technical data

- Content 1000 ml
- Adjustable outer scale
- Readability 10 ml

40461-00

### XRE 4.0 expert set – Details at a glance

Experience the perfect synthesis of innovative technology, highest level of safety, well-proven PHYWE quality and modern design. Extensive performance characteristics and ideas make working with the PHYWE XR 4.0 a special experience.

We have presented some device highlights for you here.

#### XXL Chamber

- Large space for large experiments
- Temperature-controlled, internally-ventilated experimentation space

#### Tube XChange Technology

- Self-adjusting X-ray tubes with quick-change technology
- Contact protection against hot parts
- 4 anode materials for specific experiments (W, Mo, Cu, Fe)



#### Touch Panel

- Simultaneous control, manually and by computer
- Interactive, intuitive handling
- Self-explanatory icons for fast operation

#### 3View – Insight provides a transparent view

- Exceptional observability of the experimentation space
- Extra-large window front on 3 sides (Diagonals: 18"/18"/14", 46cm/46cm/36cm)



### Optical bench with riders

- Radiography experiments
- Simple, precise positioning of optical components



### S-Lock – new PHYWE Safety interlock

- Electrical and mechanical safety lock
- Prevents door opening with switched on X-radiation
- Thus offers the highest possible safety
- Patent pending

### Goniometer (not pictured)

- Self-calibrating
- Collision protected
- Easy, safe handling



### MultiLINK

- Connection field internal and external
- USB 2.0, N<sub>2</sub>, BNC, XRED, Aux, etc.
- No annoying „cable-laying“
- In addition, extra-large cable conduit

### High-resolution TFT backlit display

- Diagonal 4.3"
- 480 x 272 Pixel
- 16 Bit, 65.536 colors
- With LED lighting
- Optimal, dynamic representation of all important device parameters and measured values



### Safekeeping drawer








- All accessories are kept safely and always ready at hand
- Lockable



## XR 4.0 expert unit – Sets for all applications

Basic set	Core components (incl. further Accessories)	Areas of application	Application examples
<b>XRE 4.0 expert set</b> Art. No. 09110-88  (Basic set)	<ul style="list-style-type: none"> <li>■ XR 4.0 expert unit (X-ray device);</li> <li>■ Tungsten tube (W),</li> <li>■ XR measure 4.0 X-ray software,</li> <li>■ optical bank</li> <li>■ TESS expert manual</li> <li>■ fluorescent screen</li> <li>■ USB cable, mains cable + adaptor</li> </ul>		<ul style="list-style-type: none"> <li>■ Basics &amp; applications of X-radiation</li> <li>■ Radiographic experiments</li> <li>■ Radiology</li> </ul>

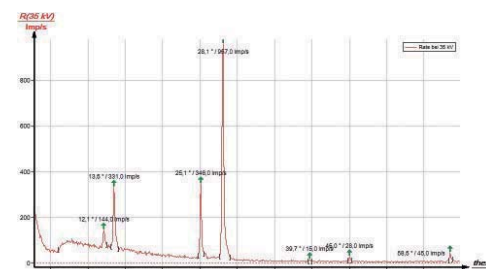
Extend the basic set with the respective extension set according to area of application

Extension sets (optional)	Core components (incl. further accessories)	Areas of application	Application examples
<b>XRP 4.0 solid-state physics</b> Art. No. 09120-88	<ul style="list-style-type: none"> <li>■ Goniometer, GM counter tube,</li> <li>■ LiF / KBr single crystal</li> <li>■ absorption set</li> </ul>		<ul style="list-style-type: none"> <li>■ Diffractometry</li> <li>■ X-ray spectroscopy</li> <li>■ Bragg-reflection / Bremsspectrum</li> <li>■ Characteristic lines</li> </ul>
<b>XRC 4.0 characterization</b> Art. No. 09130-88	<ul style="list-style-type: none"> <li>■ 3 X-ray tubes (Cu, Fe, Mo)</li> <li>■ Goniometer, GM counter tube,</li> <li>■ LiF / KBr single crystal</li> </ul>		<ul style="list-style-type: none"> <li>■ Radiation spectrums of the anode</li> <li>■ Moseley law</li> <li>■ Rydberg constant</li> <li>■ Duane-Hunt law</li> </ul>
<b>XRS 4.0 structure analysis</b> Art. No. 09140-88	<ul style="list-style-type: none"> <li>■ Goniometer, GM counter tube,</li> <li>■ LiF / KBr / NaCl single crystal</li> <li>■ Crystal holder</li> <li>■ powder samples</li> </ul>		<ul style="list-style-type: none"> <li>■ Structure investigations</li> <li>■ Laue patterns</li> <li>■ Debye-Scherrer recordings</li> <li>■ X-ray analysis</li> </ul>
<b>NEW 2014!</b> <ul style="list-style-type: none"> <li>■ Improved and extended experiments</li> <li>■ &gt; 10 times higher signal to noise ratio</li> <li>■ 1/10 of current measure time</li> </ul>			
<b>XRM 4.0 material analysis</b> Art. No. 09160-88	<ul style="list-style-type: none"> <li>■ Goniometer</li> <li>■ X-ray energy detector</li> <li>■ Multi-channel analyzer</li> <li>■ Sample sets</li> </ul>		<ul style="list-style-type: none"> <li>■ X-ray fluorescence spectroscopy</li> <li>■ Non-destructive testing (NDT)</li> <li>■ Compton Effect</li> <li>■ Energy-dispersive experiments</li> </ul>
<b>NEW 2014!</b> <ul style="list-style-type: none"> <li>■ Improved and extended experiments</li> <li>■ Unbeatable energy solutions &lt; 200 eV</li> </ul>			
<b>XRI 4.0 radio photography</b> Art.-Nr. 09150-88	<ul style="list-style-type: none"> <li>■ Camera</li> <li>■ Radiographic object</li> <li>■ Model loader</li> <li>■ Implant model</li> </ul>		<ul style="list-style-type: none"> <li>■ Basics for the X-ray image provision</li> <li>■ Radiography</li> <li>■ Radiology</li> <li>■ Non-destructive testing (NDT)</li> </ul>
<b>XRD 4.0 dosimetry and radiation damage</b> Art. No. 09170-88	<ul style="list-style-type: none"> <li>■ Parallel-plate capacitor</li> <li>■ Power supply unit 600 V</li> <li>■ DC current amplifier</li> <li>■ Camera</li> </ul>		<ul style="list-style-type: none"> <li>■ Dosimetry</li> <li>■ Degradation</li> <li>■ Damage</li> <li>■ Ionization of air</li> </ul>
<b>XRCT 4.0 computer tomography</b> Art. No. 09180-88	<ul style="list-style-type: none"> <li>■ Direct, digital X-ray image sensor</li> <li>■ Rotation unit, vertical rotation</li> <li>■ measure Tomography software package</li> </ul>		<ul style="list-style-type: none"> <li>■ 3-dimensional reconstruction</li> <li>■ Sectional drawings in respective position</li> <li>■ Direct, digital image provision</li> </ul>



## Examination of the structure of NaCl monocrystals with different orientations

P2541301



Intensity of the X-ray spectrum of copper as a function of the glancing angle theta: NaCl monocrystals with [111] crystal orientation as Bragg analyser.

### Principle

The spectra of the X-rays that are reflected with various different orientations by NaCl monocrystals are analysed. The associated interplanar spacings are determined based on the Bragg angles of the characteristic lines.

### Tasks

1. Determine the intensity of the X-rays that are reflected by the NaCl monocrystals with the orientations [100], [110], and [111] as a function of the Bragg angle.
2. Assign the reflections to the corresponding lattice planes that are given by way of their respective Miller indices.
3. Determine the lattice constant and calculate the interplanar spacing.
4. Determine the mass of a cell and the number of atoms in the cell.

### What you can learn about

- Characteristic X-radiation
- Energy levels
- Crystal structures
- Reciprocal lattices
- Miller indices
- Atomic form factor
- Structure factor
- Bragg scattering

### Main articles

XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 X-ray Plug-in Cu tube	09057-50	1
XR 4.0 X-ray NaCl-monocrystals, set of 3	09058-01	1
XR 4.0 Software measure X-ray	14414-61	1
Geiger-Mueller Counter tube, type B	09005-00	1

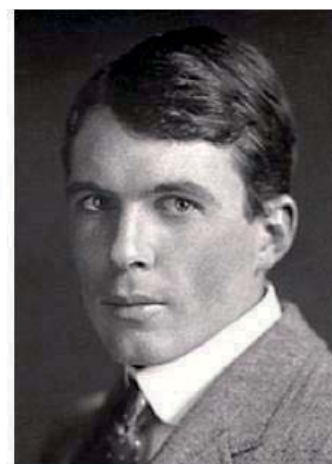
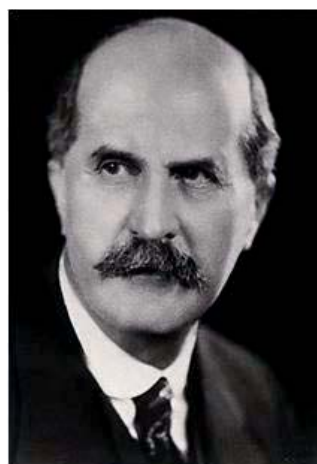
### Best fitting X-ray sets:

#### XR 4.0 X-ray expert set

09110-88

#### XRS 4.0 X-ray structural analysis upgrade set

09140-88



Sir William Henry Bragg (left) and Sir William Lawrence Bragg (right)  
1915, Nobel Prize in Physics

## P2541401 X-ray investigation of cubic crystal structures / Debye- Scherrer powder method



Debye-Scherrer pattern of a powdered sample of NaCl. Thickness of the sample: 0.4 mm. Exposure time: 2.5 h. Mo X-ray tube:  $U_a = 35$  kV;  $I_a = 1$  mA

### Principle

When polycrystalline samples are irradiated with X-rays a characteristic diffraction pattern results. These Debye-Scherrer reflections are photographed and then evaluated.

### Tasks

1. Debye-Scherrer photographs are to be taken of powdered samples of sodium chloride and caesium chloride.
2. The Debye-Scherrer rings are to be evaluated and assigned to the corresponding lattice planes.
3. The lattice constants of the sample materials are to be determined.
4. The number of atoms in the unit cells of each sample are to be determined.

### What you can learn about

- Crystal lattices; Crystal systems
- Reciprocal lattice; Miller indices
- Structure amplitude
- Atomic form factor
- Bragg scattering

### Main articles

XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray Plug-in Mo tube	09057-60	1
XR 4.0 X-ray film holder	09057-08	1
XR 4.0 X-ray optical bench	09057-18	1
XR 4.0 X-ray films, 100 pieces	09058-23	1
XR 4.0 X-ray Diaphragm tube $d = 1$ mm	09057-01	1
Slide mount for optical bench, $h = 30$ mm	08286-01	1

### Related Experiment

**X-ray investigation of hexagonal crystal structures / Debye-Scherrer powder method**

P2541501

### Best fitting X-ray sets:

**XRE 4.0 X-ray expert set**

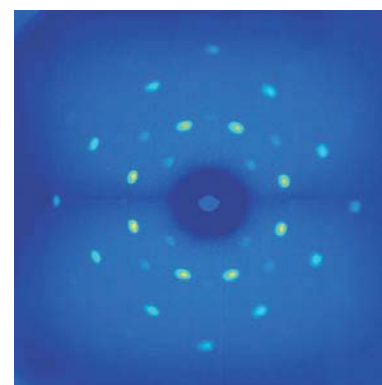
09110-88

**XRS 4.0 X-ray structural analysis upgrade set**

09140-88

## X-ray investigation of crystal structures / Laue method with digital X-ray image sensor (XRIS)

P2541602



Laue pattern of the LiF (100) crystal.

### Principle

Laue diagrams are produced when monocrystals are irradiated with polychromatic X-rays. This method is primarily used for the determination of crystal symmetries and the orientation of crystals. When a LiF monocrystal is irradiated with polychromatic X-rays, a characteristic diffraction pattern results. This pattern is photographed with the digital X-ray sensor XRIS.

### Tasks

1. The Laue diffraction of an LiF mono-crystal is to be recorded on a film.
2. The Miller indices of the corresponding crystal surfaces are to be assigned to the Laue reflections

### What you can learn about

- Crystal lattices; Crystal systems; Crystal classes
- Bravais lattice; Reciprocal lattice; Miller indices
- Structure amplitude; Atomic form factor; The Bragg equation

### Main articles

XRCT 4.0 X-ray Computed Tomography upgrade set	09180-88	1
XR 4.0 expert unit X-ray unit, 35 kV	09057-99	1
XR 4.0 X-ray plug-in unit W tube	09057-80	1
XR 4.0 X-ray LiF crystal, mounted	09056-05	1
XR 4.0 X-ray optical bench	09057-18	1
XR 4.0 X-ray Crystal holder for Laue-pattern	09058-11	1
XR 4.0 X-ray Diaphragm tube d = 1 mm	09057-01	1

### Related X-ray Experiment

**X-ray investigation of crystal structures / Laue method**

P2541601

### Best fitting X-ray sets:

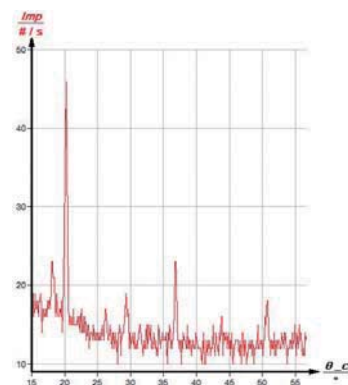
**XR 4.0 X-ray expert set**

09110-88

**XRCT 4.0 X-ray Computed Tomography upgrade set**

09180-88

## P2542101 Debye-Scherrer diffraction patterns of powder samples with three cubic Bravais lattices (Bragg-Brentano-geometry)



Bragg-Cu-K $\alpha$  and Cu-K $\beta$ -lines of Mo.

### Principle

Polycrystalline powder samples, which crystallize in the three cubic Bravais types, simple, face-centered and body-centered, are irradiated with the radiation from a Roentgen tube with a copper anode. A swivelling Geiger-Mueller counter tube detects the radiation that is constructively reflected from the various lattice planes of the crystallites. The Bragg diagrams are automatically recorded. Their evaluation gives the assignment of the Bragg lines to the individual lattice planes, their spacings as well as the lattice constants of the samples, and so also the corresponding Bravais lattice type.

### Tasks

1. Record the intensity of the Cu X-rays back scattered by the four cubic crystal powder samples with various Bravais lattice types as a function of the scattering angle.
2. Calculate the lattice plane spacings appropriate to the angular positions of the individual Bragg lines.
3. Assign the Bragg reflections to the respective lattice planes. Determine the lattice constants of the samples and their Bravais lattice types.
4. Determine the number of atoms in the unit cell.

### What you can learn about

- Crystal lattices
- Crystal systems
- Bravais-lattice
- Reciprocal lattice
- Miller indices
- Structure factor
- Atomic scattering factor
- Bragg scattering
- Characteristic X-rays
- Monochromatisation of X-rays
- Bragg-Brentano Geometry

### Main articles

XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 X-ray Plug-in Cu tube	09057-50	1
XR 4.0 Software measure X-ray	14414-61	1
Geiger-Mueller Counter tube, type B	09005-00	1
XR 4.0 X-ray LiF crystal, mounted	09056-05	1
Molybdenum, Powder, 99,7%, 100 g	31767-10	1

### Related Experiments

#### Debye-Scherrer diffractions pattern of powder samples with a diamond structure (according to Bragg-Brentano)

P2542201

#### Debye-Scherrer diffraction patterns of powder samples with a hexagonal lattice structure

P2542301

#### Debye-Scherrer diffraction patterns of powder samples with a tetragonal lattice structure

P2542401

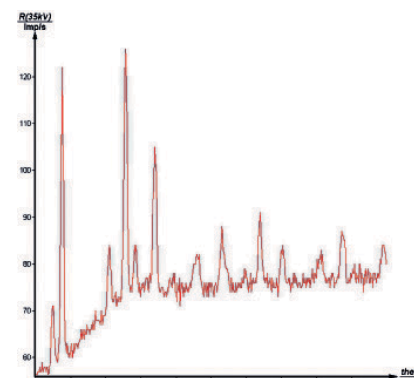
#### Debye-Scherrer diffraction patterns with a cubic powder sample

P2542501



## Debye-Scherrer diffractions pattern of powder samples with a diamond structure (according to Bragg-Brentano)

P2542201



Bragg-Cu-K $\alpha$  and Cu-K $\beta$  lines of germanium powder

### Principle

Polycrystalline powder samples, which crystallize in the three cubic Bravais types, simple, face-centered and body-centered, are irradiated with the radiation from a Roentgen tube with a copper anode. A swivelling Geiger-Mueller counter tube detects the radiation that is constructively reflected from the various lattice planes of the crystallites. The Bragg diagrams are automatically recorded. Their evaluation gives the assignment of the Bragg lines to the individual lattice planes, their spacings as well as the lattice constants of the samples, and so also the corresponding Bravais lattice type.

### Tasks

1. Record the intensity of the Cu X-rays back scattered by the four cubic crystal powder samples with various Bravais lattice types as a function of the scattering angle.
2. Calculate the lattice plane spacings appropriate to the angular positions of the individual Bragg lines.
3. Assign the Bragg reflections to the respective lattice planes. Determine the lattice constants of the samples and their Bravais lattice types.
4. Determine the number of atoms in the unit cell.

### What you can learn about

- Crystal lattices; Crystal systems; Bravais-lattice; Reciprocal lattice; Miller indices; Structure factor; Atomic scattering factor; Bragg scattering; Characteristic X-rays; Monochromatization of X-rays; Bragg Brentano geometry

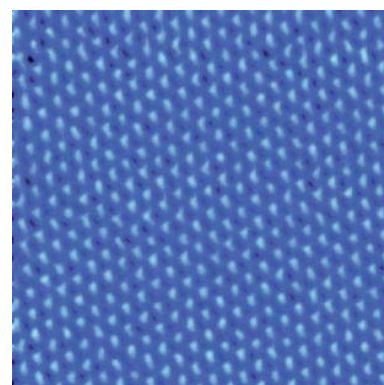
### Main articles

XR 4.0 expert unit	09057-99	1
XR 4.0 X-ray goniometer	09057-10	1
XR 4.0 X-ray Plug-in Cu tube	09057-50	1
XR 4.0 Software measure X-ray	14414-61	1
Geiger-Mueller counter tube, type B	09005-00	1

XR 4.0 X-ray LiF crystal, mounted	09056-05	1
Germanium, Powder, 99%, 10 g	31768-03	1



## P2532000 Atomic Resolution of the graphite surface by STM (Scanning Tunneling Microscope)



Atomic resolved image of the graphite surface (5nm x 5nm).

### Principle

Approaching a very sharp metal tip to an electrically conductive sample by applying a electrical field leads to a current between tip and sample without any mechanical contact. This so-called tunneling current is used to investigate the electronic topography on the sub nanometer scale of a fresh prepared graphite (HOPG) surface. By scanning the tip line-by-line across the surface graphite atoms and the hexagonal structure are imaged.

### Tasks

1. Prepare a Pt-Ir tip and the graphite (HOPG) sample and approach the tip to the sample.
2. Investigate the topography of clean terraces and the step height between neighboring terraces in constant-current mode.
3. Image the arrangement of graphite atoms on a clean terrace by optimize tunneling and scanning parameters. Interpret the structure by analyzing angles and distances between atoms and atomic rows and by using the 2D and 3D graphite model.
4. Measure and compare images in the constant-height and constant-current mode.

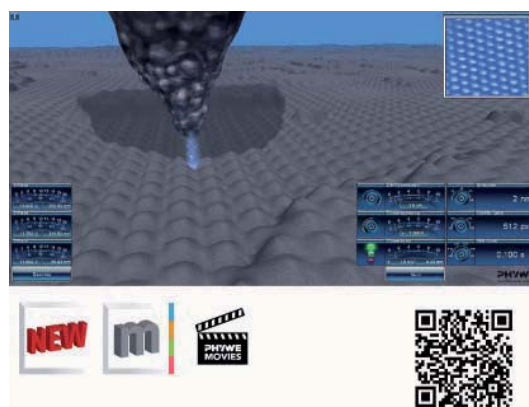
### What you can learn about

- Tunneling effect; Hexagonal Structures
- Scanning Tunneling Microscopy (STM)
- Imaging on the sub nanometer scale
- Piezo-electric devices; Local Density Of States (LDOS)
- Constant-Height-Mode; Constant-Current-Mode

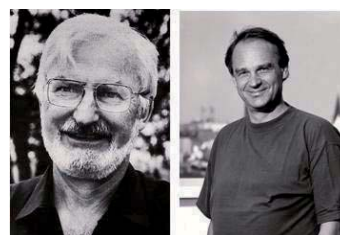
### Main articles

Compact-Scanning Tunneling Microscope (STM)	09600-99	1
Crystal lattice kit: graphite	39840-00	1
Graphite model, 2D	09620-00	1

### Interactive nano simulation



Prior to the student's hands on experimentation, the interactive nano simulation enables the student to visualize and control all relevant nano properties of the STM within an attractive multimedia environment. While 'playing' with the properties and fictive parameters the students gain a much deeper understanding of the main physical principles the STM imaging provides. The simulation is part of the packages **compact AFM** (09700-99) and **compact STM** (09600-99).



Heinrich Rohrer (left) and Gerd Binnig (right)  
1986, Nobel Prize in Physics

## Compact-Scanning Tunneling Microscope (STM)



### Function and Applications

Easy to use scanning tunneling microscope to image conducting surfaces and to investigate effects and characteristics on atomic and molecular scale. A variety of experiments in the fields of Material Sciences, Solid State Physics/Chemistry, Nanotechnology and Quantum Mechanics can be performed. For example: micro- and nano morphology of surfaces, nano structures, imaging of atoms and molecules, conductivity, tunneling effect, charge density waves, single molecule contacts, and nanostructuring by self organisation (self assembled monolayers).

### Benefits

- Out-of-the-box-device incl. all necessary accessories for a prompt entry into the world of atoms and molecules.
- Portable and compact: transportable, easy to install with a small footprint.
- Single device for more stable measurements.
- Quick atomic resolution on a normal table. No need for expensive vibration isolation.
- Easy to use: Ideal for nanotechnology education, preparing students for their work on high-level research devices, and outreach.
- Accessible sample stage and scanning tip: Quick exchange of tip and sample.
- Low operating voltage: Safe for all users.

### Equipment and technical data

- Scan head with integrated control-unit on vibration-isolated experimentation board:
  - Maximum scan range (XY) 500 nm x 500 nm
  - Maximum Z-range 200 nm
  - Resolution in XY better than 8 pm
  - Resolution in Z better than 4 pm
  - Current 0.1-100 nA in 25 pA steps
  - Tip voltage +/-10 V in 5 mV steps
  - Dimensions 21 cm x 21 cm x 10 cm
  - Constant-Current Mode
  - Constant-Height Mode
  - Current-Voltage Spectroscopy
  - Current-Distant Spectroscopy
  - Control-Unit with USB socket, 16-Bit

- DA converter for all three dimensions, up to 7 measurement channels, and maximum scanning speed of 60 ms/line
- Scan head cover with magnif. lense: 10x
- Toolset for preparing and mounting tunneling tips: side-cutter, tong and tweezers
- Pt-Ir wire for tunneling tips: length 30 cm, diameter 0.25 mm
- Sample kit: Graphite (HOPG), Gold(111) films, and 4 spare sample supports
- Power supply (100-240 V, 50/60 Hz)
- USB cable: length 3 m; Aluminium case (44 cm x 32 cm x 14 cm)
- Software for measuring, analysing and visualisation (one, two, and three dimensions)
- Handbook incl. short description of starting experiments with HOPG and gold films; Quick Installation Guide; Weight (incl. case) 6.7 kg

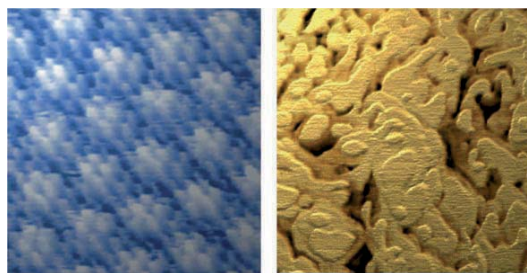
### Accessories

- Computer with Windows 2000/XP/Vista/7, USB interface, 256MB RAM, 1024x758 graphics card, 16-bit colour resolution or better
- other samples
- electrical conductive adhesive for mounting own samples
- ethanol and cloth for cleaning

09600-99

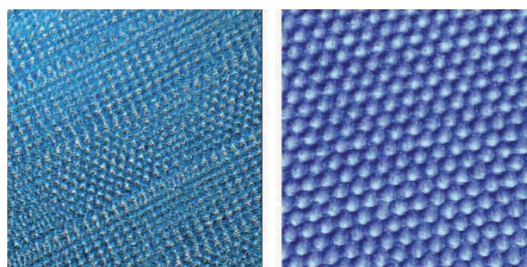
## Set samples nanomorphology, for Compact Scanning Tunneling Microscope (STM)

09613-00



Left: Charge density waves on TaS<sub>2</sub>, 6 nm

Right: Gold film, 560 nm

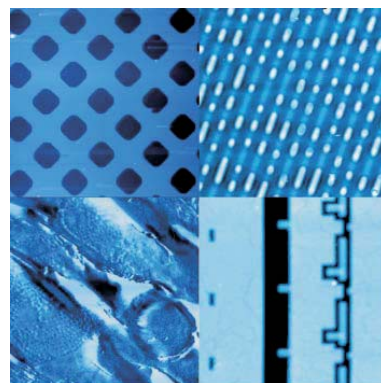


Left: 2D- molecular crystal (octadecanol) on graphite (HOPG), 13 nm

Right: Graphite (HOPG), atomic resolution, 2 nm



## P2538000 Basic methods in imaging of micro and nanostructures with atomic force microscopy (AFM)



Topography of microstructure (50  $\mu\text{m}$ ), CD stamper (20  $\mu\text{m}$ ), skin cross-section (60  $\mu\text{m}$ ), and SCA chip structure (40  $\mu\text{m}$ ) FLTR.

### Principle

Approaching a sharp silicon tip mounted on a cantilever to a sample surface leads to an atomic scale interaction. The result is a bend of the cantilever which is detected by a laser. In static mode the resulting deflection is used to investigate the topography of the sample surface line-by-line using a feedback loop. In dynamic mode the cantilever is oscillated at fixed frequency resulting in a damped amplitude near the surface. The measurement parameters (setpoint, feedback gain,...) play a crucial role for image quality. The dependence on the imaging quality is investigated for different nano structured samples.

### Tasks

1. Set-up the microscope and start up the software. Mount a cantilever (with tip) and approach the tip towards a sample.
2. Investigate the influence of the scanning parameters on the imaging quality and performance, e.g. PID gain, setpoint (force), vibrational amplitude, and scanning speed. Use both static and dynamic force mode.
3. Image 7 different samples (microstructures, carbon nano tubes, skin cross-section, bacteria, CD stamper, chip structure, glass beads) by optimizing the parameters respectively.

### What you can learn about

- Atomic Force Microscopy (AFM)
- Lennard-Jones potential
- Imaging of nano structures
- Static Force Mode; Dynamic Force Mode
- Feedback loop; Force
- Vibrational amplitude

### Main articles

Compact AFM, Atomic Force Microscope 09700-99 1

### Related Experiment

**Imaging of biological and medical micro and nanostructure with atomic force microscopy (AFM)**

P2538400

Training recommended **Service** PHYWE

For this experiment we recommend a seminar on equipment technology, handling and information of equipment-specific characteristics on site.

03333-02



## Compact-Atomic Force Microscope (AFM)



### Function and Applications

Compact and easy to use atomic force microscope to visualize and image structures on the micro and nano meter scale. Developed for educational purposes in practical lab course and pre-research labs in physics, chemistry, life sciences and material sciences. Also suitable to determine material characteristics (e.g. stiffness, magnetization, charging, material and phase contrast) and for manipulation (e.g. lithography).

### Benefits

- Out-of-the-box device with integrated damping plate and control unit underneath
- Complete set, incl. sample set, cantilever, tools and consumables
- Tip scanner AFM for standard cantilever
- Easy and safe cantilever exchange and use: Flip mechanism with automatic laser switch off
- No laser alignment, mechanical stopper for longer lifetime of cantilevers
- Digital top view camera for easy positioning and side view lens for easy and fast approach
- Portable and compact: Transportable, easy to install with a small footprint
- Easy to use: Ideal for nanotechnology education, preparing students for their work on high-level research devices, and outreach

### Equipment and technical Data

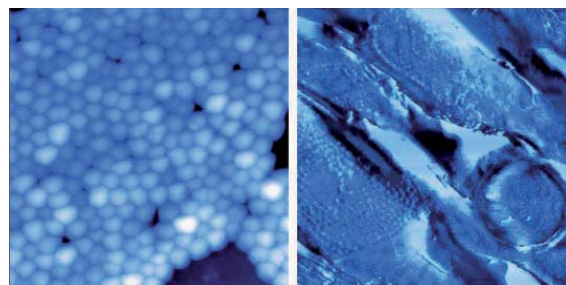
- Scan head with integrated control-unit on vibration-isolated experimentation board: 21 cm x 21 cm x 18 cm, USB 2.0 interface, 16 bit DA converter (XYZ), 16 bit AD converter (7 channels)
- Max scanning speed 60 ms/line, up to 2048x2048 data points
- Scan type (tip scanner): Linear low voltage electro magnetic
- Scan Range: 70  $\mu\text{m}$  (1.1 nm resolution)
- Z-range: 14  $\mu\text{m}$  (1.1 nm resolution); Z noise level (RMS): 0.6 / 0.5 nm (static / dynamic); Automatic approach: vertical, range 4.5 mm
- Sample: max. 13 mm in diameter, horizontal mount, LED illumination; Micrometer translation stage xy: min. +/- 5 mm
- Cantilever Alignment: automatic adjustment, alignment grooves from various suppliers; Camera system for top view: USB digital color, 3.1 M pixels
- Modes of operation: Static Force, Dynamic Force, Force Distance Spectroscopy, Amplitude Distance Spectroscopy
- Other modes (MFM, AFM, Phase contrast, lithography and advanced spectroscopy modes)
- Available with upgrade options material and spectroscopy and manipulation

- User expandability (scripting) available (upgrade option); Set of 10 cantilever, 6 samples, toolset
- Software for measuring, manipulation, analysing and visualisation, Hhandbook and Quick Installation Guide

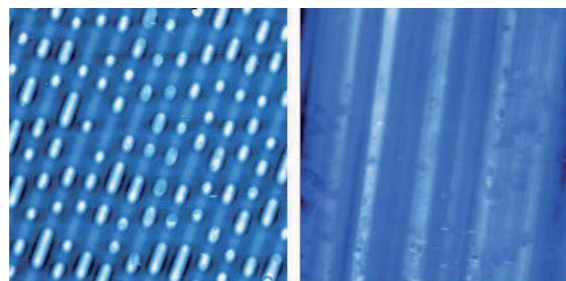
### Accessories

- Material upgrade (Art. 09701-00): Additional Operating Modes (Phase Contrast, EFM, MFM, Force Modulation, Spreading Resistance), set of samples and cantilevers
- Spectroscopy and Manipulation upgrade (Art. 09702-00): Additional Operating Modes (Advanced Spectroscopy, Lithography (scratching, oxidation), Manipulation (oxidation, cutting and moving/pushing of nanoparticles)), User expandability (Visual basic, LabView, etc.), set of cantilevers and samples
- Side View Camera System (available 2013), other samples

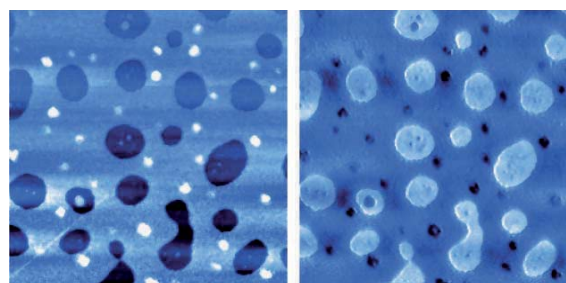
### 09700-99



Staphylococcus Spec., 10  $\mu\text{m}$  and skin cross-section, 60  $\mu\text{m}$ .



CD stamper, 20  $\mu\text{m}$  and aluminum foil, 60  $\mu\text{m}$ .



PS/PMMA films: Topography and phase contrast, 3  $\mu\text{m}$ .

## Handbook Physics X-Ray Experiments

**Article no. 01200-02**

Experiments with X-rays and their use in physics, chemistry, biology, medicine, material science, and geology.

**Description**

Comprehensive collection of reference experiments concerning the fundamental principles and use of X-rays in physics, chemistry, biology, medicine, material science, and geology with the XR 4.0 X-ray unit platform as a pool of ideas concerning the potential areas of application in demonstration and laboratory experiments. A clear matrix simplifies the orientation in terms of scientific fields and topics.

**Topics**

- Characteristic X-radiation / atomic structure / quantum physics and chemistry
- X-ray absorption
- Compton scattering
- Dosimetry
- Crystal structures/structural analysis with X-rays/Debye-Scherrer experiments (counting tube goniometer)
- Transirradiation experiments/non-destructive testing

**Features**

- Experiment descriptions with clearly structured learning objectives, fundamental principles, photo of the setup, equipment list, tasks, illustrated instructions concerning the setup and procedure, theory and evaluation with example results plus important notes concerning the operation and safety of the equipment. This simplifies the orientation and execution as well as the selection of the experiment parts for personalised laboratory experiments. The information provided is so comprehensive that no other background information is required.
- For every experiment, the software package "XRM 4.0 measure X-ray" includes presettings for the easy and direct execution of

the experiment at the push of a button as well as numerous example measurements.

- Experiment matrix for quick orientation.
- Operating instructions concerning the components of the XR 4.0 platform including detailed information.
- DIN A4 format, spiral-bound, colour print.

**This documentation contains the following experiments:**

Counter tube characteristics

**P2540010**

Radiographic examination of objects

**P2540020**

Qualitative examination of the absorption of X-rays

**P2540030**

Ionising effect of X-radiation

**P2540040**

Characteristic X-rays of copper

**P2540101**

Characteristic X-rays of iron

**P2540301**

The intensity of characteristic X-rays as a function of the anode current and anode voltage

**P2540401**

Monochromatisation of molybdenum X-rays

**P2540501**

Monochromatisation of copper X-rays

**P2540601**

K alpha double splitting of molybdenum X-rays/ fine structure

**P2540701**

K alpha doublet splitting of iron X-rays / fine structure

**P2540801**

Duane-Hunt displacement law and Planck's "quantum of action"

**P2540901**

Absorption of X-rays

**P2541101**

K and L absorption edges of X-rays / Moseley's law and the Rydberg constant

**P2541201**

Examination of the structure of NaCl monocrystals with different orientations

**P2541301**

X-ray investigation of cubic crystal structures / Debye-Scherrer powder method

**P2541401**

X-ray investigation of hexagonal crystal structures / Debye-Scherrer powder method

**P2541501**

Compton scattering of X-rays

**P2541701**

**Complete experiment list see: [www.phywe.com](http://www.phywe.com)**

**01200-02**

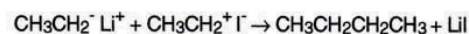
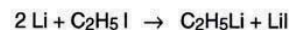


## Organic Chemistry

9.1	Organic Synthesis	160
9.2	Distillation, Purification	166



## P3101100 Haloalkanes: Wurtz reaction - lithium organyls



Reaction of lithium with ethyl iodide and the following Wurtz reaction of ethyl lithium with ethyl iodide.

**Principle**

Unlike the other alkali-organyls, lithium organyls - with the exception of methyllithium - show a stronger covalent behaviour. They dissolve rather well in organic solvents, such as diethyl ether, tetrahydrofuran, and alkanes, and they are relatively stable in these solvents.

Wurtz synthesis was developed in 1854 for the preparation of higher alkanes based on haloalkanes. Alkyl iodides react the easiest. The reaction can be controlled best with lithium, since the other alkali metals react much more violently. Wurtz synthesis is often a side reaction that occurs during organometallic conversions.

**Task**

Investigate the reaction of ethyl iodide with lithium and the following reaction of ethyllithium with ethyl iodide.

**What you can learn about**

- Alkali-organyls; Lithium organyls
- Wurtz synthesis; Organometallic compounds

**Main articles**

Gasometer 1000 ml	40461-00	1
Weather monitor, 6 lines LCD	87997-10	1
Condenser, Dimroth type GL25/12	35815-15	1
Gasket for GL25, 8mm hole, 10 pcs.	41242-03	1
Retort stand, h = 750 mm	37694-00	1
Round bottom flask, 100ml, GL25/12, GL18/8	35842-15	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

**Molecular model construction kit, polymer chemistry****Function and Application**

With these big elements (Atoms) for molecular models structures of chemical compounds can be presented especially vividly also to a greater number of observers.

**Benefits**

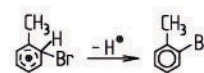
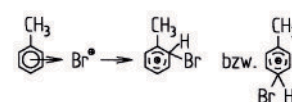
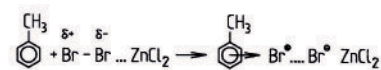
- Structural elements of shockproof plastic (robust).
- Diameter of the elements: 38 mm (ostentatious).
- Chemical elements characterised by internationally usual colours.
- Angularity of the connections by precisely rivetted push-buttons according to the valences of the elements.
- Transparent connectors: straight for single bonds and curved for double and triple bonds.

39818-88



## Toluene: Bromination in the nucleus

P3101300



Reaction mechanism of the bromination of toluene.

## Principle

Bromine is polarised and, thereby, activated by zinc chloride as a Lewis acid. It can attach itself in an ionic manner to the toluene nucleus via several complex intermediate stages. Following a dehydrobromination, bromotoluene is formed, i.e. the product of bromination in the nucleus.

In the absence of a catalyst and under the influence of light, however, side-chain bromination takes place via radical intermediate stages. The reaction can be controlled in a targeted manner by varying the reaction conditions.

## Tasks

1. Brominate toluene using bromine.
2. Change the reaction conditions to optimise your results.
3. Distillate the resulting mixture.

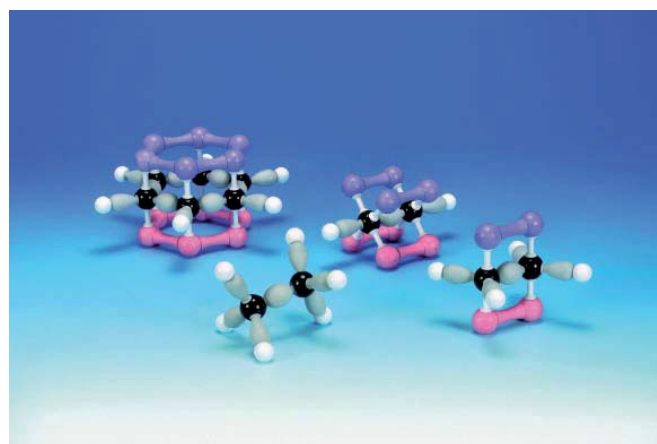
## What you can learn about

- Bromine
- Toluene
- Lewis acid
- Bromination
- Distillation

## Main articles

Magnetic stirrer MR Hei-Standard	35750-93	1
Sec.bottle500ml,2xGL18/8,1x25/12	34170-01	1
Separating funnel,50ml,GL18	35853-15	1
Liebig Condenser, with head, GL18/8	35795-15	1
Lab jack, 200 x 230 mm	02074-01	1
Silicone oil 500 ml	31849-50	1

## Molecular orbital models,organics



## Function and Applications

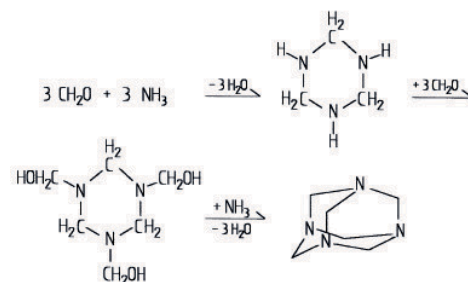
The kit includes all the parts to build up 4 molecular orbital models of the following organic compounds: benzene, ethane, ethylene and acetylene.

## Benefits

- The models show bonding s- and p- orbitals.
- The concept of hybridisation and delocalisation can be demonstrated so well.

39837-00

## P3101400 Aldehydes - reactions with ammonia



Reaction of aldehyde with ammonia.

**Principle**

When a formaldehyde and ammonia solution mixture is concentrated a solid white substance results. Ammonia reacts with formaldehyde (methanal) to hexamethylenetetramine.

**Tasks**

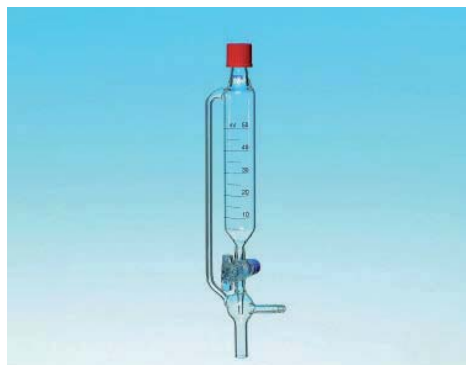
1. Addition of ammonia to acetaldehyde and benzaldehyde.
2. Preparation of hexamethylenetetramine (urotropine).

**What you can learn about**

- Ammonia
- Formaldehyde urotropine
- Hexamethylenetetramine
- Hydrolysis

**Main articles**

Funnel for gas generator, 50 ml, GL18	35854-15	1
Lab jack, 160 x 130 mm	02074-00	1
U tube, 2 side tubes, GL25/8	36959-15	1
Quartz glass wool 10 g	31773-03	1
Teclu burner, DIN, natural gas	32171-05	1
Test tube GL25/8, with hose connection	36330-15	2

**Funnel for gas generator, 50 ml, GL18****Function and Applications**

Funnel for gas generator

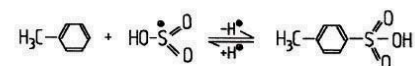
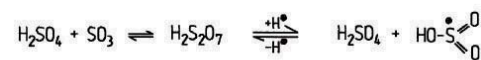
**Equipment and technical data:**

- Lower connecting pipe diameter: 12 mm
- Outer Diameter Gasolive: 8 mm
- Overall height: approx 270 mm
- Contents: 50 ml

35854-15

## Preparation of p-toluenesulfonic acid

P3101500



Reaction of toluene with sulfonic acid.

### Principle

This is a model experiment to show the industrial blast furnace process to produce iron from iron(III) oxide. During the experiment a furnace gas flame that is approximately 10 to 20 cm high can be ignited at the stack outlet. Cavities form in the burning carbon layer. These cavities collapse over time. Apart from ash and carbon residues, metallic lumps can also be found in the frame after the end of the experiment. Samples of these lumps lead to the formation of hydrogen when they are treated with hydrochloric acid.

### Tasks

1. Investigate the reduction of iron(III) oxide to iron(II) oxide.
2. Show the blast furnace process in a model experiment.

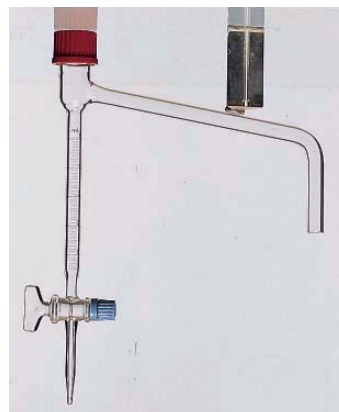
### What you can learn about

- Iron; Blast furnace process
- Slug; Production of iron
- Reduction; Oxidation

### Main articles

Heating mantle f. roundbottom flask, 100 ml	49541-93	1
Desiccator, Wertex, diam. 150 mm	34126-00	1
Support base DEMO	02007-55	1
Power regulator	32288-93	1
Condenser, Dimroth type GL25/12	35815-15	1
Water separator GL25/12	35790-15	1
Retort stand, h = 750 mm	37694-00	1

### Water separator GL25/12



### Function and Applications

Water separator to separate two non-miscible liquids with different densities.

### Equipment and technical data

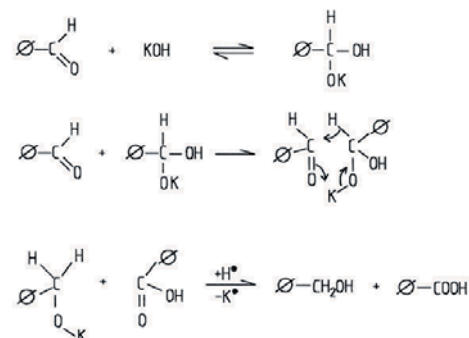
- Made of DURAN®
- With glass cock and GL 25/12 connection and connecting pipe
- Diameter connecting pipe: 12 mm
- Graduated; Content: 5 ml

35790-15

## P3101600 Cannizzaro reaction and reaction of benzaldehyde with ethylene glycol



**NEW** **Demo**



Reaction mechanism of the disproportionation of benzaldehyde to benzyl alcohol and benzoic acid.

### Principle

In the first part of the experiment, benzaldehyde disproportionates under the effect of alkalis to alcohol-soluble benzyl alcohol and water-soluble benzoic acid that precipitates when the aqueous solution is acidified. In the second part, benzaldehyde reacts with ethylene glycol to form a cyclic acetal. This ethylene acetal is resistant against basic and oxidising reagents. In an acid medium, it once again splits up into its original products. It is because of these characteristics that cyclic acetals are used for blocking the carbonyl function in preparative, organic chemistry.

### Tasks

1. Show the Cannizzaro reaction of benzaldehyde under basic conditions.
2. Prepare benzaldehyde ethylene acetal from benzaldehyde with ethylene glycol.

### What you can learn about

- Cannizzaro reaction; Benzaldehyde
- Acetals; Distillation; Micro distillation

### Main articles

Abbe refractometer	35912-00	1
Immersion thermostat Alpha A, 230 V	08493-93	1
Heating mantle for roundbottom flask, 250 ml, 230 V, with safety switch	49542-93	1
Heating mantle for roundbottom flask, 100 ml, 230 V, with safety switch	49541-93	1
Condenser, Dimroth type GL25/12	35815-15	1
Sec.bottle 500ml, 2x G18/8, 1x 25/12	34170-01	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

### Abbe refractometer



### Function and Applications

Abbe refractometer for measuring the refraction index of liquids and solids with light of 590 nm wavelength (sodium D line) and determining average dispersion  $n_D - n_F$ .

The refractive index scale also includes an additional scale indicating sugar content from 0 - 95 %. The prism and scales can be illuminated by daylight or by a separate lighting unit.

**35912-00**



## Haloalkanes: Grignard reagent

P3101000



NEW

Demo



### Principle

Haloalkanes react with magnesium to the so-called Grignard reagents in accordance with the general formula  $\text{RMgX}$ . With  $\text{X} =$  bromide or iodide, the reaction works best. Chlorides are usually more inert and require higher temperatures and longer reaction times for the conversion. The compounds that were discovered by Victor Grignard probably exist as dimeric structures.

For more details refer to page 144.

## Electrophilic addition of bromine to acetylene (ethyne)

P3120500



NEW

Demo

### Principle

Like an olefin, ethyne adds bromine to the trans-1,2-dibromoethene by way of a bromonium ion. Under the given circumstance, further bromine can be added to the trans-1,2-dibromoethene to form 1,1,2,2-tetrabromoethane. The tetrabromoethane is the stable final product of this reaction.

The cis-1,2-dibromoethene can result from ethyne as a by-product as well as from the tetrabromoethane as a result of dehalogenation. Three peaks can be distinguished in the gas chromatogram.

For more details refer to [www.phywe.com](http://www.phywe.com)

You need more information?

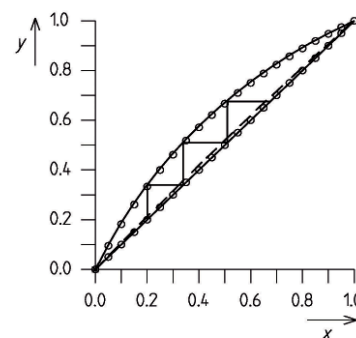
WEB @ PHYWE

Go to [www.phywe.com](http://www.phywe.com) or



send an email to [info@phywe.com](mailto:info@phywe.com)

## P3031501 Rectification - the number of theoretical trays in a distillation column



Equilibrium diagram.

### Principle

The separation power of a rectification (fractionating) column can be determined using an appropriate binary mixture whose equilibrium composition is measured in the distillation flask and in the domed glass head of the distillation apparatus. The number of theoretical trays can be numerically or graphically obtained from the measured values.

### Tasks

1. Prepare 10 mixtures of methyl cyclohexane and *n*-heptane with substance ratios (mole fractions) from 0 to 1 and with step width of approximately 0.1. To record a calibration curve, determine the refractive indices of the mixtures and plot them against the mole fractions.
2. Distill a mixture of methyl cyclohexane and *n*-heptane in a rectification column with total reflux until an equilibrium has been established. Determine the composition of the condensate and the number of theoretical trays in the column for a throughput of 500 and 1000 ml/h.

### What you can learn about

- Bubble tray column; Rectification
- Raoult's law; Henry's / Dalton's law
- Boiling-point diagram; Reflux ratio

### Main articles

Set rectification plant, 230 V	35918-88	1
Abbe refractometer	35912-00	1
Data acquisition set for set rectification plant, 230 V	35918-50	1
Set of Precision Balance Sartorius CPA 6235 and measure software, 230 V	49224-88	1

### Related Experiment

Fractional distillation with the bubble tray column with Cobra4

P3031661

### Set rectification plant, 230 V

#### Function and Applications

Distillation plant with a height of 235 cm to the demonstration and processing the principles of countercurrent-distillation (phase equilibrium of multicomponent systems) or to the preparative separation of mixtures difficult to separate

#### Benefits

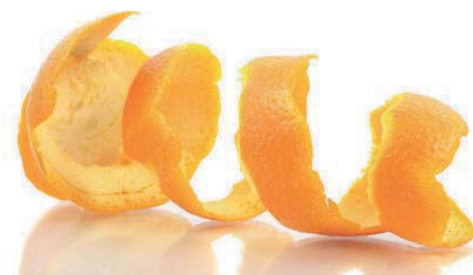
This set allows to execute the measurements in a didactical clear and easy way:

- Complete insight into all running processes, because all components have an evacuated, but not silvered isolating-coat
- High separation efficiency through 2 large packed columns (h = 400 mm); Simple withdrawal of samples through 2 column intermediate pieces
- Secure, because the high-efficiency condenser of the column head also condense high-volatile liquids
- Simple adjustment of thereflux ratio's through onehand-controlled column head

35918-88

## Steam distillation

P3031251



Orange peel and cloves are both very suitable for winning ethereal oils.

### Principle

An elegant and simple apparatus for carrying out water vapour distillations: the advantage of this arrangement is that it eliminates the need for a separate vapour generator, making it possible to operate with a single heat source (other set-ups require two). The vapour is generated in the outer chamber and then passes through the inner chamber. Due to the structural arrangement, the inner chamber is heated directly by the vapour generated in the outer chamber. This also eliminates the possibility of overheating the substances being extracted.

Parts of plants suitable for the extraction of essential oils include orange peel and cloves, for example.

### Task

Extract ethereal oils from parts of plants e.g. orange peel and cloves using steam distillation.

### What you can learn about

- Distillation
- Steam distillation
- Etheral oils
- Flavour

### Main articles

Glass jacket	02615-00	1
Heating apparatus for glass jacket system	32246-93	1
Power regulator	32288-93	1
Lab jack, 160 x 130 mm	02074-00	1
Insert w.ext.tube f.glass jack.	02615-06	1
Cooling jacket, GL 25/8	34880-01	1

### Heating apparatus for glass jacket system



### Function and Applications

Hot plate. For a uniform and hence material protecting heating of cylindrical bodies or devices made of metal, ceramic or glass.

### Equipment and technical data

- Power requirement 500 W max.
- Surface temperature 500 °C
- Mains supply: 230 V, 50...60 Hz
- Dimensions (mm): 160 x 95 x 90 mm
- Items suitable for heating: minimum length: 130 mm, diameter: 36...100 mm

32246-93

## P1308962 Distillation - determination of the alcohol content of wine with Cobra4



### Principle

If the alcohol content of a wine is determined directly with an alcohol meter (hydrometer), the resulting alcohol content reading is approximately 0% by volume. This is due to the composition of the wine. The effect of the alcohol on the density is cancelled out by other components such as sugars, acids, essential oils, etc.. For this reason, in order to determine alcohol content by density, the alcohol must be separated out by means of distillation prior to the determination. This corresponds to the official method which currently applies for measuring alcohol in wines. First the wine is titrated to neutrality against bromothymol blue. After transfer to the distillation apparatus, two thirds of this wine sample is distilled off into the receiver flask. Subsequently the distillate is filled back up to the original volume again. Now the density is measured with a pycnometer or hydrometer.

### Task

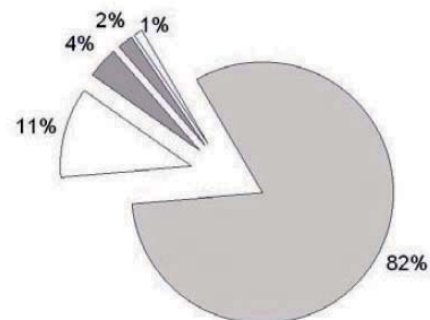
Distillate a sample of wine to determine the content of ethanol.

### What you can learn about

- Ethanol; Distillation

### Main articles

Cobra4 Mobile-Link	12620-00	1
Cobra4 Display-Connect	12623-88	1
Cobra4 Sensor-Unit Chemistry	12630-00	1
Large-scale display, digital, RS-232 port	07157-93	1
Heating mantle f. roundbottom flask, 250ml	49542-93	1
Frame for complete experiments	45500-00	1
Power regulator, 230 V, with phase controlled modulator	32286-93	1



Content of wine: 82 % water, 11 % ethanol, 4 % sugar and glycerol, 2 % acids and salts, 1 % rest.

### Large-scale display, digital, RS-232 port



### Function and Applications

Special four-digit large-format display for presenting the measurement data supplied by the new Cobra4 Mobile-Link with Cobra4 Display-Connect, the Cobra3 Com-Unit, the PHYWE hand-held measuring instruments and Sartorius or Scaltec balances equipped with data interfaces.

### Benefits

Fit for the future: The large-format display can be updated and adapted to other measuring instruments which are not available on the market yet.

07157-93

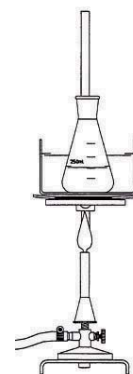


## Separation of mixtures of liquids and of solutions by extraction, stirring, centrifugation

P3120100



NEW



Separation by liquid-liquid extraction.

### Principle

Different methods to separate liquid mixtures are shown. In the first part a mixtures of immiscible or only poorly miscible liquids is separated. In the next example a substance that is dissolved in a certain solvent is better soluble in another solvent and the separation is achieved via shaking. Relatively stable emulsions can't be separated by liquid-liquid extraction alone, since the emulsified liquids will not unmix with a sufficiently sharp delineation. However, separation can be achieved by centrifugating the emulsion in a first step. In this case, the emulsion is unmixed under the influence of the centrifugal force and it can then be separated by liquid-liquid extraction.

### Tasks

1. Separation by liquid-liquid extraction.
2. Separation shaking and liquid-liquid extraction.
3. Separation of an emulsion by centrifugation and liquid-liquid extraction.

### What you can learn about

- Separation procedure; Liquid-liquid extraction
- Shaking; Centrifugation; Emulsion

### Main articles

Manual centrifuge f. 4 specimens	45052-00	1
Retort stand, h = 750 mm	37694-00	1
Ethyl alcohol, absolute 500 ml	30008-50	1
Cyclohexane 1000 ml	31223-70	1
Teclu burner, DIN, natural gas	32171-05	1
Separatory funnel 250 ml pear-sh.	36884-00	1

### Manual centrifuge f. 4 specimens



### Function and Applications

Manual centrifuge with for 4 specimens.

### Benefits

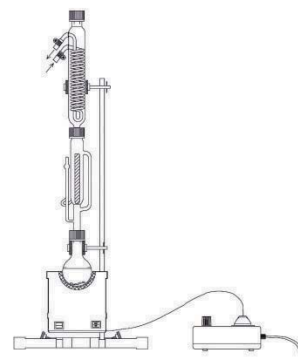
- To attach to the work bench
- Combined plastic / metal housing
- The gearbox is self lubricating and very smooth with sleeves made of plastic
- Comes with four centrifuge tubes

### Equipment and technical data

- Speed: 3,000 rpm
- Centrifuge tube: contents 15 ml, conical, ungraduated

45052-00

## P3120200 Quantitative determination of fat / Soxhlet extraction



Schematic setup of the experiment.

### Principle

The discussion of healthy nutrition focuses on the fat content of foodstuffs. For this reason, it is important to know the exact fat content of individual foodstuffs. The experiment shown here presents a method for the quantitative determination of the fat content of foodstuffs by extraction using a Soxhlet apparatus. This small size of this Soxhlet extractor makes it possible to extract small quantities using extremely small amounts of solvent.

### Task

Calculate the fat content of a sausage using soxhlet extraction.

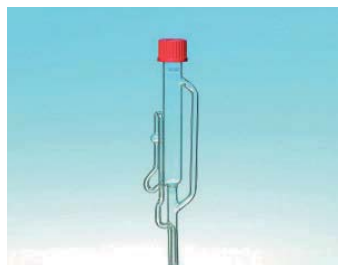
### What you can learn about

- Soxhlet apparatus
- Fat extraction
- Food chemistry
- Food analysis

### Main articles

Universal oven, 32 liters, 220 °C, 230 V	49559-93	1
Heating mantle f. roundbottom flask, 100 ml	49541-93	1
Power regulator	32288-93	1
Condenser, Dimroth type GL25/12	35815-15	1
Micro distil.app., GL18/8,w.head	35818-15	1
Soxhlet attachment, GL25/12	35809-15	1
Set of Precision Balance Sartorius CPA 423S and measure software, 230 V	49223-88	0

### Soxhlet attachment, GL25/12



### Function and Applications

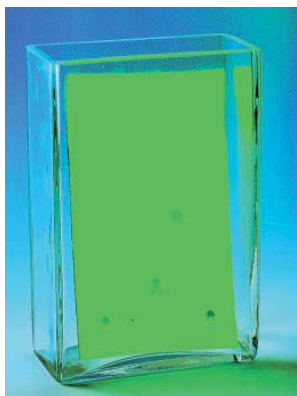
The sample for extraction is placed in an extraction thimble made of compressed filterpaper, the thimble is slipped into the Soxhlet attachment and the attachment is fitted onto a flask containing an appropriate solvent. A reflux condenser is fitted to the top of the attachment and the solvent is heated so that it evaporates. Solvent vapour ascends up the vapour by-pass tube into the reflux condenser, where it condenses and drops back down into the extraction thimble.

Here it dissolves out soluble matter from the sample and collects in and around the thimble until the solvent level here reaches the highest point of the siphon tube. The whole of this solvent is then automatically siphoned back into the flask and the procedure repeats itself. In this way, countless extraction steps can be carried out simply and successively, whereby the components extracted from the sample are concentrated in the flask.

35809-15

## Chromatographic separation processes: thin layer chromatography

P3120400



NEW

### Principle

Chromatographic separation processes are very important for analytical chemistry. Their relatively simple technique and the possibility to separate even the smallest portions of mixtures explain the rapid development of these processes. There are numerous variations of this method.

As a result, the optimum chromatographic separation method can be found for nearly every separation task. The method that is described here can be used to demonstrate the fundamental principles and possibilities of this method with relatively simple means.

For more details refer to page 54.

## Chromatographic separation processes: Gas chromatography with Cobra4

P3031760



NEW

4  
Cobra

### Principle

Chromatographic procedures allow a separation of substance mixtures with the aid of a stationary separation phase and a mobile phase. In gas chromatography the mobile phase is a gas. The mobile phase, to which the mixture to be separated is added, transports the substance mixture through the separation column at a constant flow rate. Interactions occur between the mobile phase and the stationary phase. The establishment of equilibria between the stationary phase and the different substances (distribution equilibria, adsorption-desorption equilibria) results in different migration rates of the individual components.

For more details refer to page 55.

## Column chromatography - separation of leaf pigments

P3120300



NEW

Demo

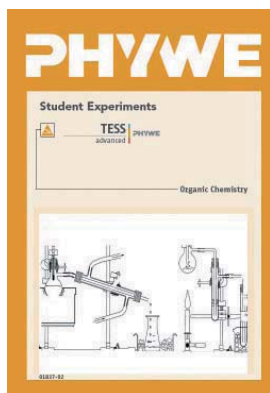
### Principle

In this investigation, a uniformly green raw extract of fresh leaves is first separated into different fractions by means of column chromatography. To do so, the extract is added to a column filled with starch and drawn through the column under slightly reduced pressure (to increase the flow rate of the mobile phase) with ligroin as the eluent. A separation occurs in a clearly recognisable, broad, yellow area and in a narrow, green band. This means that the xanthophylls (yellow) are separated from the chlorophylls (green). If the vacuum is reduced during the separation, the separation is much better, but then separation also takes considerably longer.

For more details refer to page 56.

Find further experiments in the following manual:

### TESS Chemistry manual Organic Chemistry



Article no. 01837-02

This documentation contains the following experiments:

The decomposition of organic substances  
**P1035700**

The detection of carbon with lime water  
**P1035800**

The detection of carbon by oxidation  
**P1035900**

The detection of oxygen  
**P1036000**

The detection of nitrogen  
**P1036100**

The detection of sulphur  
**P1036200**

The Beilstein test  
**P1036301**

Marsh gas  
**P1036400**

Preparation of methane  
**P1036500**

Homologous series of alkanes  
**P1036600**

Reactivity of alkanes  
**P1036700**

Preparation of ethene  
**P1036800**

Preparation of ethyne  
**P1036900**

Naphthalene  
**P1037000**

Petroleum deposits  
**P1037100**

Fractional distillation  
**P1037200**

Properties of petroleum fractions  
**P1037300**

Petroleum combustion  
**P1037400**

Cracking of petroleum  
**P1037500**

Removal of paraffin by extraction  
**P1037600**

Removal of paraffin with urea  
**P1037700**

Alcoholic fermentation  
**P1037800**

Production of methanol "wood spirit"  
**P1037900**

The ascending tube test  
**P1038000**

Alcotest tubes  
**P1038100**

Distillation  
**P1038200**

The borax test  
**P1038300**

The iodoform test  
**P1038400**

The properties of the homologous series  
**P1038500**

Polyhydric alcohols  
**P1038600**

The oxidation of alkanols  
**P1038700**

Complete experiment list see: [www.phywe.com](http://www.phywe.com)

01837-02



Cracking of petroleum - P1037500

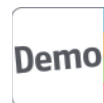
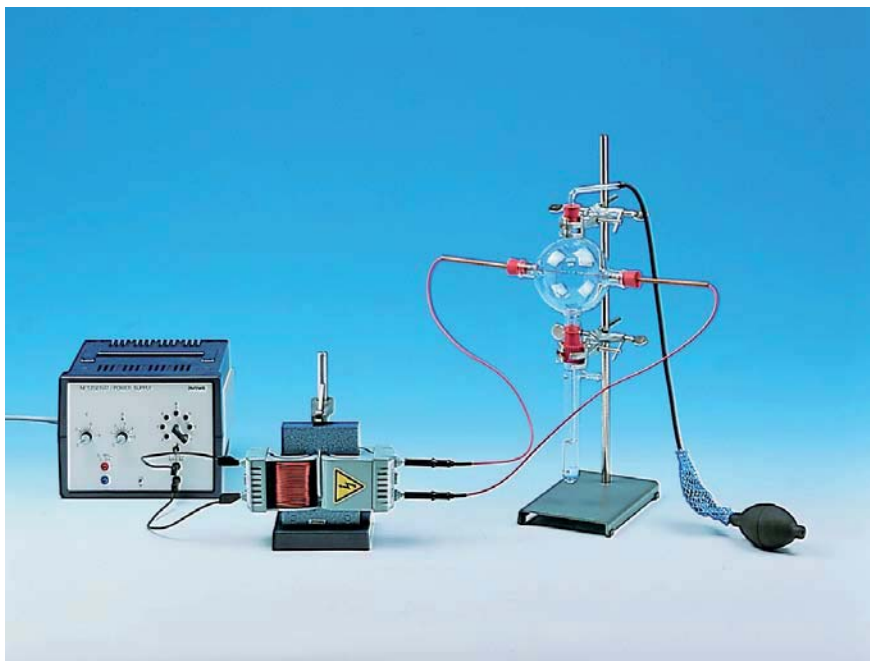




## Industrial Chemistry

<b>10.1</b>	<b>Gases</b>	<b>174</b>
<b>10.2</b>	<b>Salts</b>	<b>178</b>
<b>10.3</b>	<b>Disposal, Environment Protection</b>	<b>179</b>
<b>10.4</b>	<b>Petrochemistry</b>	<b>180</b>
<b>10.5</b>	<b>Metallurgy</b>	<b>184</b>

## P3110100 Obtaining nitrogen oxides by burning air



Chemical process for the production of nitric acid.

### Principle

In an electric arc nitrogen and oxygen are caused to react with each other. In a first step, this leads to the generation of colourless nitrogen monoxide that continues to react with oxygen, thus forming the red-brown nitrogen dioxide. When the gas reacts with water in the presence of even more oxygen, the result is nitric acid that causes the litmus solution to turn red.

### Tasks

1. Demonstrate the reaction of nitrogen and oxygen using high voltage.
2. Investigate the reaction of nitrogen dioxide with water.

### What you can learn about

- Nitrogen oxides
- Air
- Nitrogen monoxide
- Nitrogen dioxide
- Nitric acid

### Main articles

Power supply, universal	13500-93	1
Coil, 10000 turns	06519-01	1
Bar electrodes, HV, insul., 1 pair	45253-00	1
Clamping device	06506-00	1
Coil, 150 turns, short	06520-01	1
Iron core, U-shaped, laminated	06501-00	1
Retort stand, h = 750 mm	37694-00	1

### Power supply, universal



### Function and Applications

Versatile heavy duty power supply which can also be used as a constant current supply in schools, laboratories or workshops.

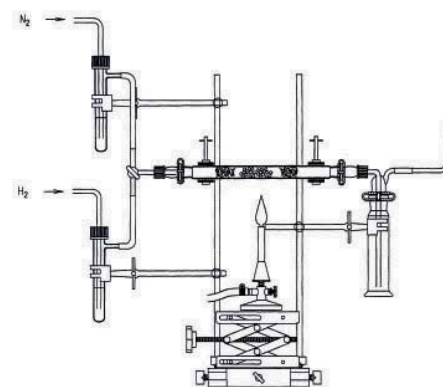
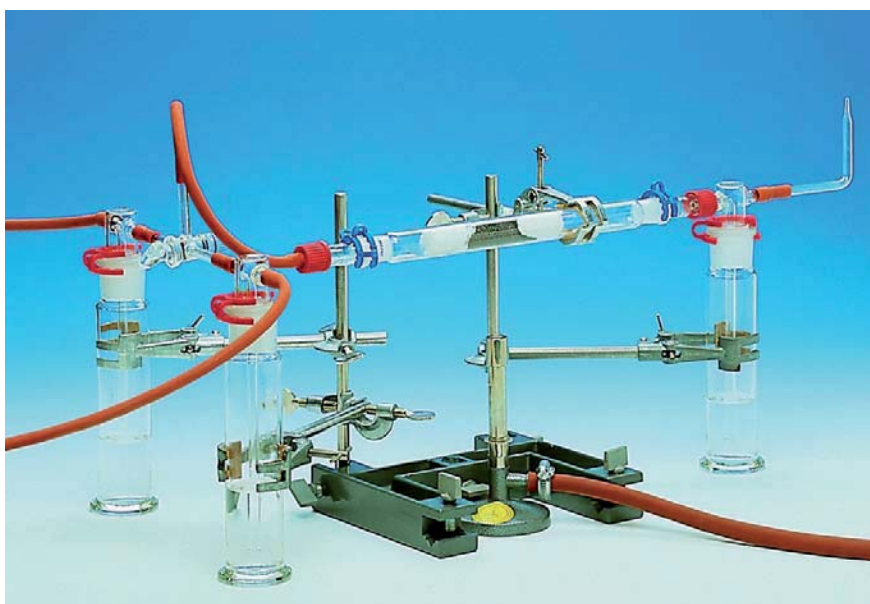
### Equipment and technical data

- Direct current source: Stabilised, regulated output direct voltage, continuously adjustable from 0...18 V
- Adjustable current limit between 0...5 A
- LED display for constant current operation
- Permanently short-circuit proof & protected against exterior voltages
- Alternative voltage output:
  - Multitap transformer 2...15 V, outputs galvanically separated from mains grid
  - Full load capacity (5 A), even if direct current is supplied simultaneously

13500-93

## Ammonia preparation from the elements (Haber-Bosch process)

P3110200



Schematical setup of the experiment.

**Principle**

The Haber-Bosch process was the first large-scale technical method for producing nitrogen compounds based on the nitrogen in the air. The formation of ammonia benefits from a falling temperature and rising pressure since it is an exothermic reaction that is accompanied by a decrease in volume. At room temperature, however, the reaction rate would be so small that it could not be measured. In addition, current catalysts are only effective at higher temperatures (approximately 400-500 °C). If these temperatures are used at normal pressure, the ammonia yield is approximately 0.1% by volume. Technical processes, in which the pressure is increased in a continuous process, yield approximately 11% (establishment of equilibrium at 200 bar: 17.6% of ammonia).

The setup that is used here can be used to demonstrate the Haber-Bosch process in a simplified manner. The optimum conditions that are necessary for the process cannot be realised with the means that are available at schools or it would be extremely difficult to realise them.

**Task**

Demonstrate the principle of the Haber-Bosch process.

**What you can learn about**

Ammonia preparation from the elements (Haber-Bosch process)

**Main articles**

Steel cylinder hydrogen, 2 l, filled	41775-00	1
Steel cylinder nitrogen, 2 l, filled	41777-00	1
Bead catalyst, Pt-Pd-Al-oxide 10 g	31763-03	1
Reducing valve for nitrogen	33483-00	1
Reducing valve for hydrogen	33484-00	1



Carl Bosch (left) and Friedrich Bergius (right)  
1931, Nobel Prize in Chemistry



## P3110300 Combustion of ammonia to produce nitrogen dioxide - Ostwald process



Combustion process of gas/air mixtures.

### Principle

In the presence of a suitable catalyst and while giving off heat, ammonia-air mixtures burn and form nitrogen monoxide and water. Nitrogen monoxide reacts immediately with the excess oxygen, thereby forming nitrogen dioxide.

At higher temperatures, nitrogen monoxide is decomposed into nitrogen and oxygen. This is why the contact with the catalyst must be very brief. In the presence of water and oxygen, nitrogen dioxide forms nitric acid. On a large industrial scale, the combustion of ammonia with atmospheric oxygen is performed under contact with platinum (Ostwald process). The resulting nitric acid is used for the production of fertilisers and numerous other chemical products.

### Task

Burn an ammonia-air mixture in the presence of a catalyst (platinum-palladium-aluminium-oxide beads) and prove the resulting nitrogen oxide.

### What you can learn about

- Ostwald process; Ammonia; Nitrogen dioxide
- Nitrogen monoxide; Nitric acid

### Main articles

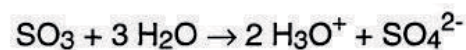
Bead catalyst, Pt-Pd-Al-oxide 10 g	31763-03	1
Quartz glass wool 10 g	31773-03	1
Teclu burner, DIN, natural gas	32171-05	1
Glycerol 250 ml	30084-25	1
Test tube GL25/8, with hose connec.	36330-15	2
Water jet pump, plastic	02728-00	1





## Sulphur trioxide - the sulphuric acid contact process

P3110400



Formation of sulfuric acid during the experiment.

### Principle

The contact process is currently used in the chemical industry to produce sulphuric acid in the high concentrations needed for industrial processes. In this model experiment, platinum-palladium-aluminium-oxide beads are employed as a catalyst for the reaction.

### Tasks

1. Oxidise sulphur dioxide to sulphur trioxide.
2. Use the sulphur trioxide to produce sulphuric acid.

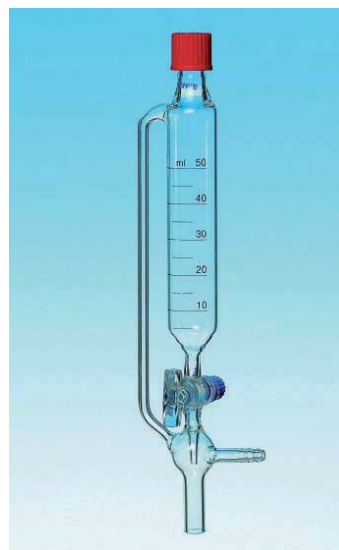
### What you can learn about

- Sulphur trioxide
- Sulphuric acid
- Contact process
- Oxidation
- Redox reaction

### Main articles

Steel cylinder oxygen, 2 l, filled	41778-00	1
Bead catalyst, Pt-Pd-Al-oxide 10 g	31763-03	1
Reducing valve for oxygen	33482-00	1
Funnel for gas generator, 50 ml, GL18	35854-15	1
Table stand for 2 l steel cylinders	41774-00	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

### Funnel for gas generator, 50 ml, GL18



### Function and Applications

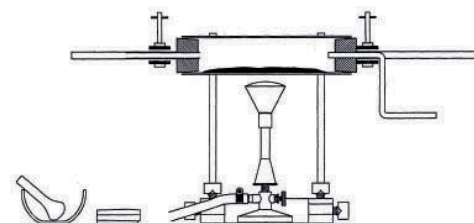
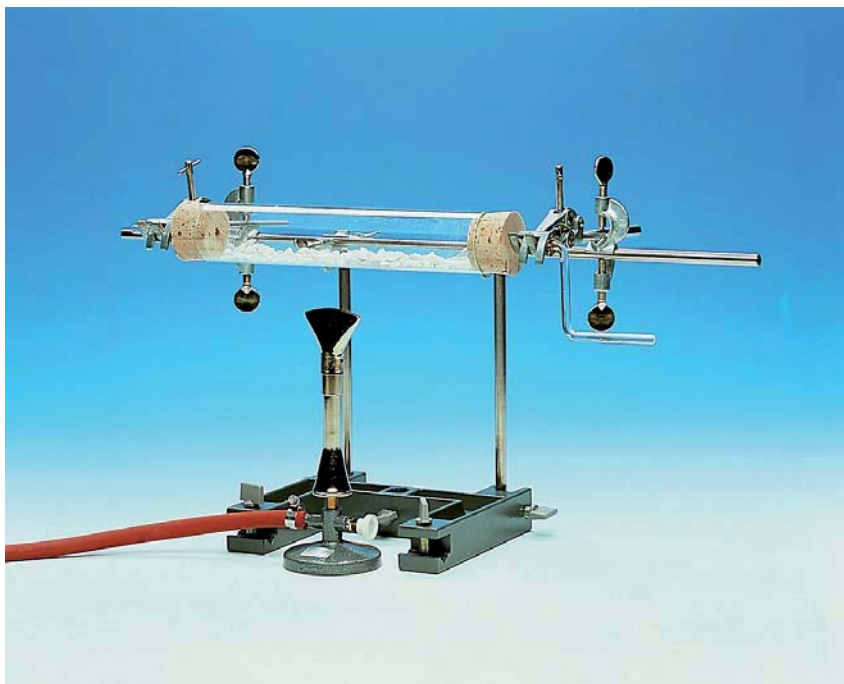
Funnel for gas generator

### Equipment and technical data:

- Lower connecting pipe diameter: 12 mm
- Outer Diameter Gasolive: 8 mm
- Overall height: approx 270 mm
- Contents: 50 ml

35854-15

## P3110700 Salts of sulphuric acid - sulphates



Schematic construction of the experiment.

**Principle**

Natural gypsum has the formula  $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$ . When it is heated above  $130\text{ }^\circ\text{C}$ , part of the crystal water is released. The result is a so-called hemihydrate  $\text{CaSO}_4 \cdot 1/2\text{H}_2\text{O}$ . Following the absorption of water, the hemihydrate is once again converted into a dihydrate. During this process, needle-shaped crystals are formed. This is why barium sulphate precipitates when barium ions are added to sulphate ions, even if the concentrate of sulphate ions is as low as it is in the present case. This reaction is generally used for the detection of sulphate ions.

**Tasks**

1. Investigate the properties of gypsum.
2. Detect sulphate ions in solution using barium-solution.

**What you can learn about**

- Sulphate
- Gypsum
- Sulphuric acid
- Gypsum calcination

**Main articles**

Glass tube f. calcin. of gypsum	45145-00	1
Teclu burner, DIN, natural gas	32171-05	1
Gypsum, crude pieces, 250 g	48273-25	1
Hydrochloric acid 37 %, 1000 ml	30214-70	1
Barium chloride 250 g	30033-25	1
Calcium sulphate precipit. 100 g	31182-10	1



## Electrostatic flue gas cleaning

P1309200



Smoking chimneys.

### Principle

Smoke consists of particles of solid substances suspended in gas. Fog is made up of suspended droplets. In cigarette smoke, as in many industrial processes, smoke and fog are frequently present together. The removal of particles contained in gases - predominately waste gases - is increasingly gaining in importance, both in everyday life and industrially, because frequently the particles and the substances absorbed on them are toxic. Well known examples are adsorbed polycyclic aromatics on soot particles in diesel exhaust, and dioxins, heavy metals and radioactive elements in waste gases from power stations and waste incinerators. The deposited filter dusts are highly toxic, and must be treated as hazardous waste. The experimental set-up used here also enables constituents of cigarette smoke to be semi-quantitatively deposited even in quite large amounts, so that they can be extracted with light petrol and be examined.

### Task

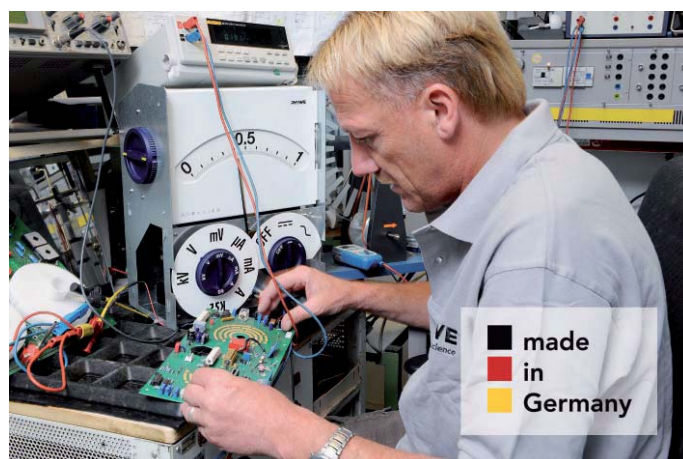
Clean cigarette smoke using high voltage.

### What you can learn about

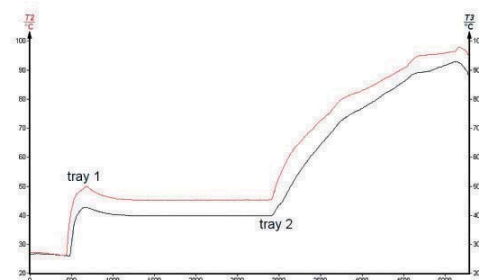
- Smoke
- Electric filter
- Electrostatic filter
- Exhaust gas filter

### Main articles

High voltage supply unit, 0-10 kV	13670-93	1
Frame for complete experiments	45500-00	1
Holder for syringes	45523-00	1
Insert with joining tube	02615-04	1
Gas syringe, 100 ml, with 3-way cock	02617-00	1
Panel for complete experimental setups	45510-00	1
Apparatus carrier w. fix. magnet	45525-00	1



## P3031660 Fractional distillation with the bubble tray column with Cobra4



### Principle

In countercurrent distillation (rectification) using a column, the rising vapour can enter into interactions with the condensate. In this manner, a fractional distillation, i.e. a distillation in several steps for the separation of substances with similar boiling points, can be performed in a single apparatus. If bubble tray columns are used condensate can be removed from the individual bubble trays.

### Tasks

1. Investigate the mode of operation of a fractionating tower on a two-stage bubble tray column. Distil a mixture of three n-alkanes first with total reflux and then without any reflux.
2. Subsequently, examine and compare the initial mixture, the sump product, the head products and the condensates of both trays gas chromatographically.

### What you can learn about

- Bubble tray column; Rectification; Continuous and discontinuous distillation; Vapour pressure; Vaporisation; Condensation; Raoult's law; Gas chromatography

### Main articles

Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1
Immersion thermostat Alpha A, 230 V	08493-93	1
Control unit gas chromatograph	36670-99	1
Bubble tray column, model, with 2 trays	35914-15	1
Software Cobra4 - multi-user licence	14550-61	1
Cobra4 Wireless-Link	12601-00	2
Glass jacket	02615-00	1

### Bubble tray column, model, with 2 trays



### Function and Application

For the demonstration of fractionating counter current distillation.

### Benefits:

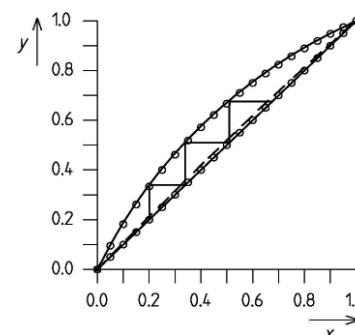
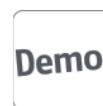
- Made of DURAN® glass.
- The tube of the column has two bubbletrays (length 240 mm)
- The overflow from them flows backdown inside for a better separation effect.
- Two upward pointing side arms with GL 18/8 threaded connectors for thermometers
- Two downward pointing side arms with Teflon spindle taps for fraction sampling

**35914-15**



## Rectification - the number of theoretical trays in a distillation column

P3031501



Equilibrium diagram.

### Principle

The separation power of a rectification (fractionating) column can be determined using an appropriate binary mixture whose equilibrium composition is measured in the distillation flask and in the domed glass head of the distillation apparatus. The number of theoretical trays can be numerically or graphically obtained from the measured values.

### Tasks

1. Prepare 10 mixtures of methyl cyclohexane and *n*-heptane with substance ratios (mole fractions) from 0 to 1 and with step width of approximately 0.1. To record a calibration curve, determine the refractive indices of the mixtures and plot them against the mole fractions.
2. Distill a mixture of methyl cyclohexane and *n*-heptane in a rectification column with total reflux until an equilibrium has been established. Determine the composition of the condensate and the number of theoretical trays in the column for a throughput of 500 and 1000 ml/h.

### What you can learn about

- Bubble tray column; Rectification
- Raoult's law; Henry's / Dalton's law
- Boiling-point diagram; Reflux ratio

### Main articles

Set rectification plant, 230 V	35918-88	1
Abbe refractometer	35912-00	1
Data acquisition set for set rectification plant, 230 V	35918-50	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

### Set rectification plant, 230 V

#### Function and Applications

Distillation plant with a height of 235 cm to the demonstration and processing the principles of countercurrent-distillation (phase equilibrium of multicomponent systems) or to the preparative separation of mixtures difficult to separate

#### Benefits

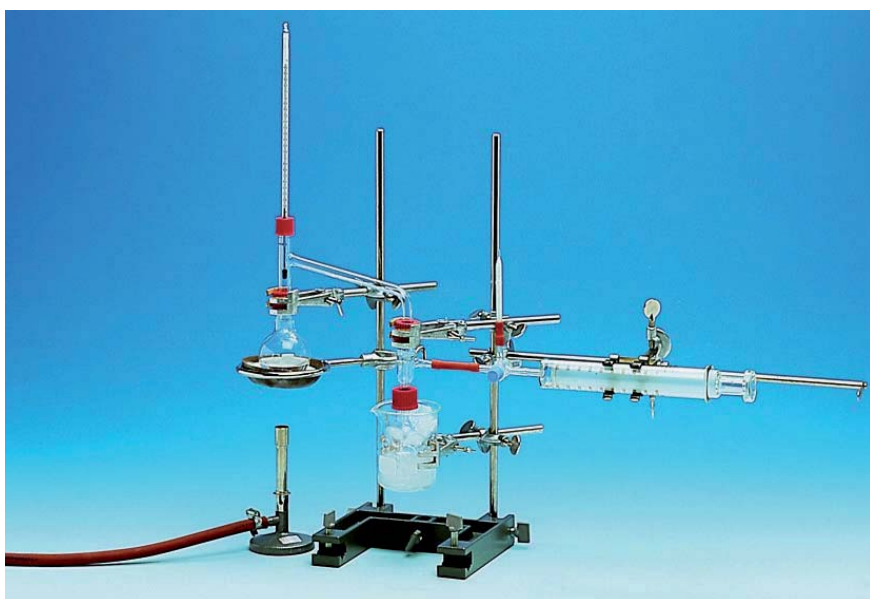
- Complete insight into all running processes, because all components have an evacuated, but not silvered isolating-coat
- High separation efficiency through 2 large packed columns (h = 400 mm)
- Simple withdrawal of samples through 2 column intermediate pieces
- Secure, because the high-efficiency condenser of the column head also condense high-volatile liquids
- Simple adjustment of thereflux ratio's through onehand-controlled column head

#### Equipment and technical Data

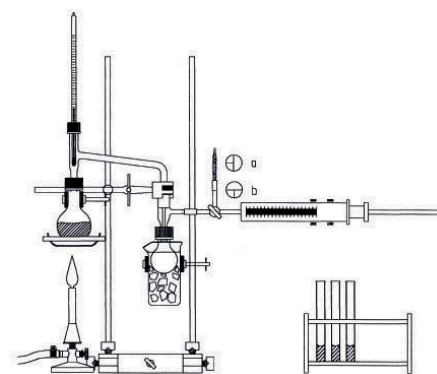
- It will be delivered complete with tripod material and all necessary small hardware items.
- 6 l four-neck flask; Electrical heating hood
- Power regulator; 2 packed columns
- Packing bodys (wire mesh rings); 2 column intermediate pieces; Column head; Separate product condensor
- Rack system for the set-up of the plant
- Small hardware items; CD with literature

35918-88

## P3110800 Cracking of hydrocarbons



**NEW** Demo



Schematic setup of the experiment.

### Principle

Under the influence of energy, e.g. heat, light, and electric discharge, all chemical compounds can be broken down into smaller fractions. The reaction can continue up to the elements themselves. In general, low-volatile crude oil components are disintegrated at approximately 400 °C. The presence of a catalyst lowers the activation energy of this cracking reaction so that the decomposition products are formed already at lower temperatures. Saturated carbohydrates are then transformed into smaller saturated and unsaturated molecules. Cycloalkanes are dehydrated to aromatic compounds, straight-chain molecules to branched-chain molecules, and branched-chain molecules to cyclic molecules.

### Task

Investigate the cracking of hydrocarbons using a model experiment.

### What you can learn about

- Cracking
- Hydrocarbons
- Catalyst

### Main articles

Gas syringe, 100 ml, with 3-way cock	02617-00	1
Bead catalyst, 500 g	31761-50	1
Vacuum adaptor, straight, GL25/12	35806-15	1
Gas-syringe holder with stop	02058-00	1
Sea sand, purified 1000 g	30220-67	1
Bromine 100 ml	30046-10	1

## Molecular model construction kit, organic chemistry



Demo

### Function and Applications

With these big elements (atoms) for molecular models structures of chemical compounds can be presented especially vividly also to a greater number of observers

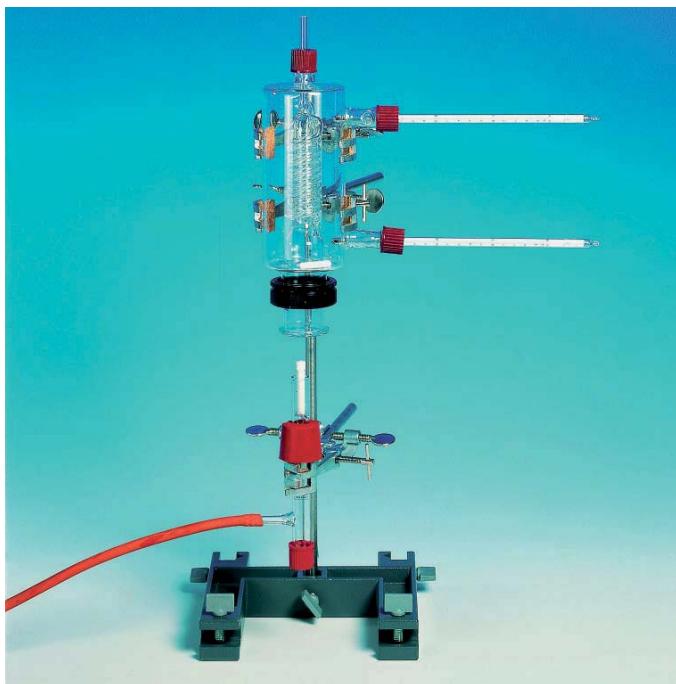
### Benefits

- Structural elements of shockproof plastic
- Diameter of the elements: 38 mm (ostentatious)
- Chemical elements characterised by internationally usual colours
- Angularity of the connections by precisely rivetted push-buttons according to the valences of the elements
- Transparent connectors: straight for single bonds and curved for double and triple bonds

39821-88

## Determination of the heating value of fuel oil and of the calorific value of olive oil

P3021701



$$H = \frac{(m_w \cdot c_w + C_{\text{cal}}) \cdot \Delta T}{m}$$

Equation to calculate the calorific value (of fuels) and the gross calorific value (of food-stuffs).

### Principle

The heat of reaction generated during the complete combustion of 1000 g of solid or liquid fuel is known as the calorific value  $H$ . In the case of complete combustion of nutritional fats, the gross calorific value can also be determined. In order to ensure complete combustion, the reaction takes place under oxygen. The heat generated during the combustion of a specific amount of fuel is absorbed by a glass jacket calorimeter of known heat capacity. The calorific value of the test substance can be calculated from the temperature increase in the calorimeter.

### Task

Determine the calorific value of heating oil and the gross calorific value of olive oil.

### What you can learn about

- Heat of reaction
- Heat of combustion
- Enthalpy of combustion
- First law of thermodynamics

### Main articles

Glass jacket	02615-00	1
Steel cylinder oxygen, 2 l, filled	41778-00	1
Calorimeter insert for glass jacket	02615-01	1
Reducing valve for oxygen	33482-00	1
Table stand for 2 l steel cylinders	41774-00	1
Combustion lance for gases	02613-00	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

### Glass jacket



### Function and Applications

Glass jacket, used as cooling or heating mantle.

### Benefits

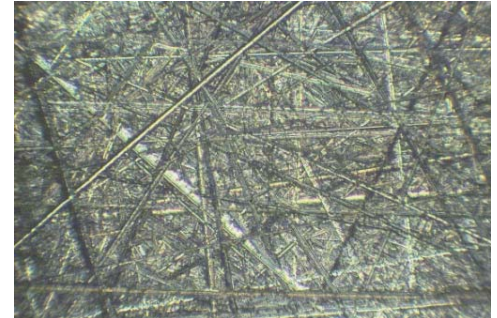
The cylinder is made of DURAN 50®, which gave him an extreme heat resistance, high thermal shock resistance, mechanical strength and excellent chemical resistance.

### Equipment and technical data

- Cylindrical glasstube with screw closures for different inserts
- Length: 205 mm
- Outer diameter: 75 mm
- Connecting nut and gasket for flanging cylindrical inserts with an outer diameter of 36 mm watertight and airtight
- 1 Flange with ring nut

02615-00

### P5510100 Metallographic sample preparation - grinding and polishing



Surface condition of brass sample after step 1 (MD-Primo 220; Lubricant: water; Time: 2 min; Speed: 300 rpm): Magnification: 100x.

#### Principle

Metallography is the art of preparing metallic samples by grinding, polishing and eventual etching for subsequent microscopic examination. Grinding and polishing is to prepare the specimen surface so as to enable the microstructure to be revealed by a suitable etching procedure.

#### Tasks

1. Check the six metal specimens by means of the magnifier for any coarse defects.
2. Grind and polish the samples according to the general rules and the detailed instructions given, considering the hardness and ductility data and the basic processing guidelines specified.
3. Evaluate the influence of the individual process parameters on the surface quality obtained in the intermediate steps and after the final polishing.
4. Try to optimise the grinding and polishing procedures.

#### What you can learn about

- Grinding; Polishing
- Metallographic preparation; Ductility

#### Main articles

Grinding and polishing machine, 230 V 200/250 mm, 50-600 rpm, variable	70000-93	1
Ultrasonic cleaning bath, RK100H	46423-93	1
Diamantstick 6 µm, 25 g	70050-04	1
Grinding and polishing wheel Al, 200 mm	70000-11	1
Polishing cloth Ø 200 mm, METAPO-P, 10 pcs. for 10-6 micron diamonds	70002-03	1
Polishing cloth Ø 200 mm, METAPO-B, 10 pcs. for 3-1 micron diamonds	70003-03	1
Polishing cloth Ø 200 mm, METAPO-V, 10 pcs. for 1-0,1 micron diamonds	70004-03	1

#### Grinding and polishing machine, 230V200/250 mm, 50-600 rpm, variable



#### Function and application

Grinding and polishing machine to prepare metallographic samples.

#### Benefits

Variable grinding speed to prepare hard and soft samples.

#### Equipment and technical data

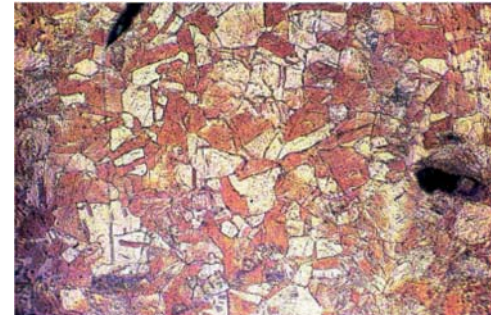
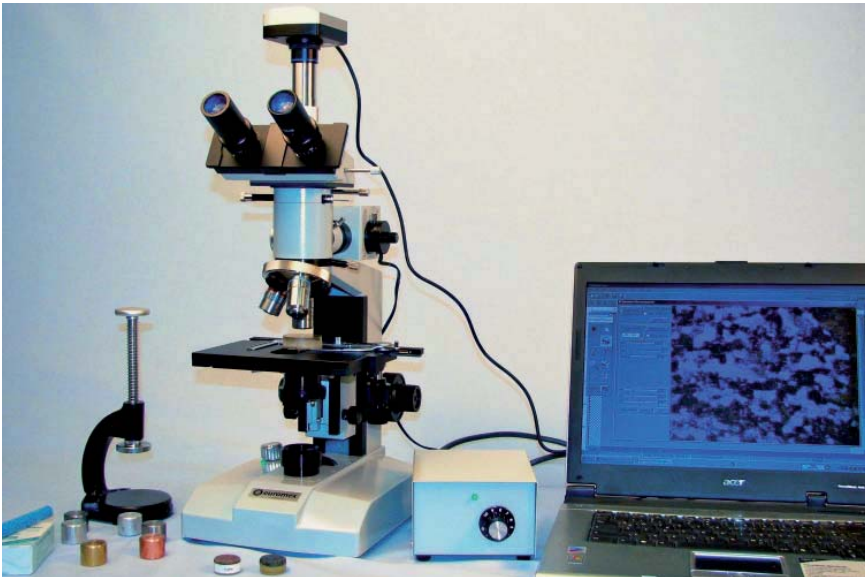
- Diameter grinding platen: 200 and 250 mm, respectively
- Speed: 50-600 rpm
- Connected power: 60 W
- Power supply : 230 VAC
- Dimensions (L x B x H): 380 x 690 x 340 mm
- Weight: 30 kg

**70000-93**



## Metallographic sample preparation - chemical etching

P5510200



Copper, etched in sol. 5, grain contrast/precip. etching, magnification approx. 100x.

### Principle

Chemical etching is the most common method for contrasting polished metal surfaces to reveal structural details of pure metals and alloys. The precondition for a good result in etching is a carefully polished and clean surface. The experiment describes the basic procedure, gives some recipes and presents a few pictures of several metal structures and phases.

### Tasks

1. Check the six metal specimens polished by means of the microscope to see if any macroscopic or microscopic structural features can be noticed.
2. Prepare the etching solutions and etch the specimens according to the instructions.
3. Examine the specimen surfaces as to whether the structural details have been satisfactorily revealed.

### What you can learn about

- Etching; Reveal crystallographic structure
- Micrography; Metallographic phases; Metal microscopy

### Main articles

Microscope with incident and transmitted illumination set with USB CAM, 230 V For metallographic appl.	62244-88	1
Press for polished section	62244-15	1
Sample set metallurgy containing 8 metall samples	70001-01	3
Compact Balance, 500 g / 0.1 g	49243-93	1
Labels GHS, blank, chemistry, 20 pcs	38687-01	1
Pasteur pipettes, 3ml, PE, 500pcs	36616-00	1
Hot air blower, 1200 W	47540-95	1



## P3110500 Preparation of iron from oxidic ores (blast furnace process)



Iron oxide is reduced to iron by hydrogen, which reacts with hydrochloric acid with evolution of hydrogen.

### Principle

This is a model experiment to show the industrial blast furnace process to produce iron from iron(III) oxide. During the experiment a furnace gas flame that is approximately 10 to 20 cm high can be ignited at the stack outlet. Cavities form in the burning carbon layer. These cavities collapse over time. Apart from ash and carbon residues, metallic lumps can also be found in the frame after the end of the experiment. Samples of these lumps lead to the formation of hydrogen when they are treated with hydrochloric acid.

### Tasks

1. Investigate the reduction of iron(III) oxide to iron(II) oxide.
2. Show the blast furnace process in a model experiment.

### What you can learn about

- Iron
- Blast furnace process
- Slug
- Production of iron
- Reduction
- Oxidation

### Main articles

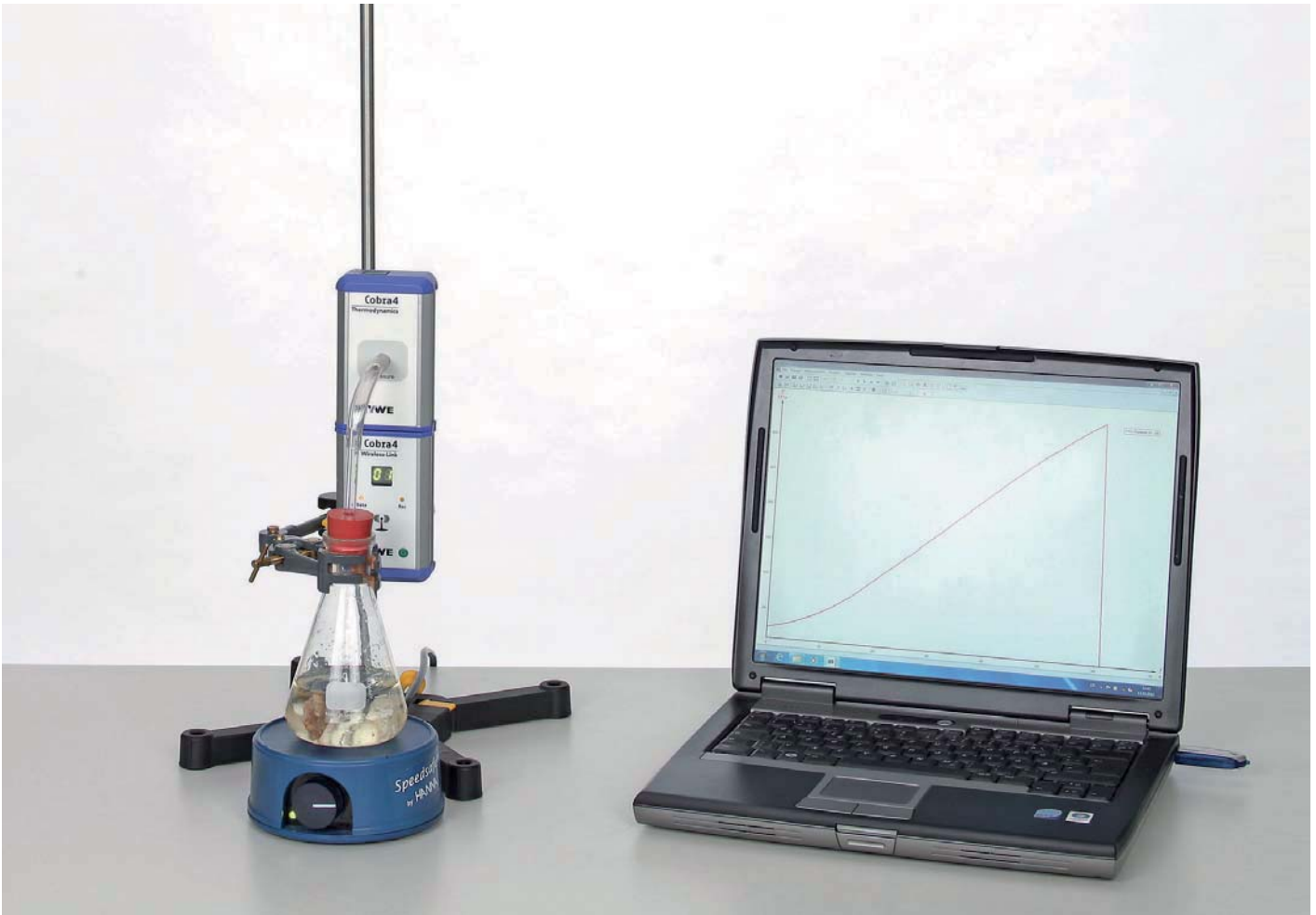
Steel cylinder Hydrogen, 2 l, full	41775-00	1
Support, with closed-circuit pipeline	36688-01	1
Hot air blower with adaptor	36688-93	1
Reducing valve for hydrogen	33484-00	1
Table stand for 2 l steel cylinders	41774-00	1
Set of Precision Balance Sartorius CPA 623S and measure software, 230 V	49224-88	1

### Related Experiment

Redox reactions between metals and metal oxides (thermite process)

P3110600

You need more information? **WEB@**   
Go to [www.phywe.com](http://www.phywe.com) or  
 send an email to [info@phywe.com](mailto:info@phywe.com)

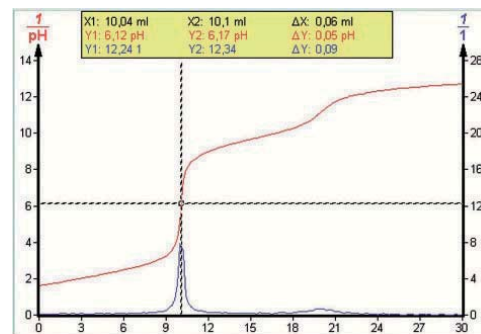


## Biochemistry and Biotechnology

11.1	Biochemistry	188
11.2	Biotechnology	192
11.3	Literature	193



### P4120160 Determination of the isoelectric point of an amino acid glycine with Cobra4



Titration curve for hydrochloric acid glycine solution against 1 mol/l NaOH.

#### Principle

Amino acid molecules carry both acid and amino groups. They can therefore form both acidic anions and basic cations. The pH at which these two types of ions are both present in the same concentration is called the isoelectric point.

#### Task

This isoelectric point is to be determined by recording the titration curve for the amino acid glycine.

#### What you can learn about

- Isoelectric point
- Acidic anions
- Basic cations
- Zwitterions
- Equivalence (inflection) points
- pKs value
- Titration
- Motor piston burette

#### Main articles

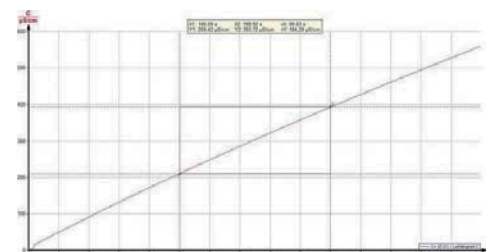
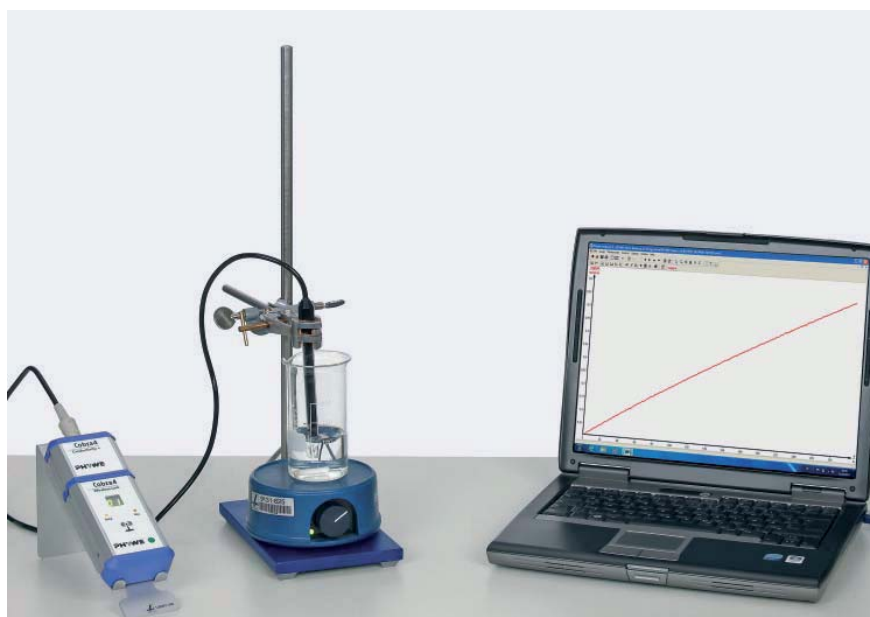
Cobra4 Wireless Manager	12600-00	1
Cobra4 Wireless-Link	12601-00	2
Cobra4 Sensor-Unit Chemistry	12630-00	1
Cobra4 Sensor-Unit Drop Counter	12636-00	1
Software Cobra4 - multi-user licence	14550-61	1
Immersion probe NiCr-Ni, teflon, 300 °C	13615-05	1
Precision Balance, Sartorius TE 212, 210 g / 0,01 g, 230V	48833-93	1





## Determination of the Michaelis constant with Cobra4

P4120360



Conductivity-time-diagram of the urea hydrolysis by urease.

**Principle**

The enzymatic hydrolysis of urea in aqueous solution liberates carbon dioxide and ammonia. The ions of these compounds increase the conductivity of the solution. Conductivity measurements can so be made to determine the rate of hydrolysis of urea by the enzyme urease at various substrate concentrations.

**Task**

The Michaelis constant can then be calculated from these values.

**What you can learn about**

- Michaelis constant
- Enzymatic hydrolysis of urea
- Conductivity measurement
- Bodenstein principle
- Enzyme-substrate complex
- Lineweaver-Burk plot

**Main articles**

Cobra4 Wireless Manager	12600-00	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Sensor-Unit Conductivity+	12632-00	1
Software Cobra4 - multi-user licence	14550-61	1
Conductivity temperature probe Pt1000	13701-01	1
Urease soln.in 50% glycerol, 10ml	31924-03	1
Precision Balance, Sartorius TE 212, 210 g / 0,01 g, 230 V	48833-93	1

**Cobra4 Sensor-Unit Conductivity+****Function and Applications**

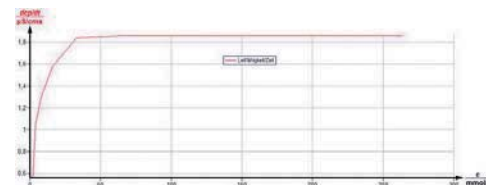
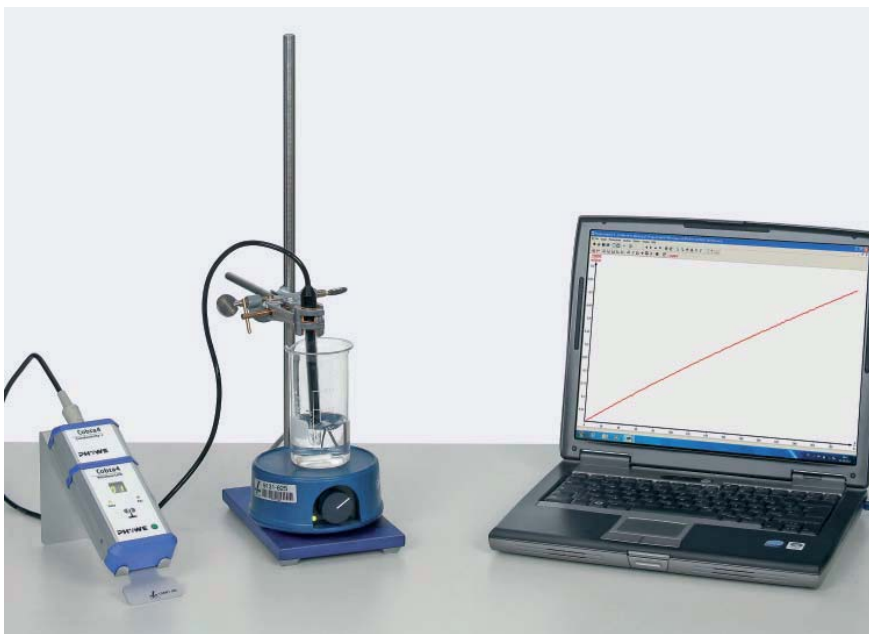
The Cobra4 Sensor Unit, Conductivity/Temperature (Pt1000), is a microcontroller-based measuring recorder with a 5-pin diode socket for connecting conductance measuring sensors with a cell constant of  $K = 1.00/\text{cm}$  or Pt1000 thermocouples.

**Benefits**

- Measure conductivity or temperature - multipurpose-sensor
- The Cobra4 sensor may be connected directly to the Cobra4 Wireless-Link, the Cobra4 Mobile-Link, the Cobra4 USB-Link or the Cobra4 Junior-Link using a secure and reliable snap-in connection.

12632-00

### P4120460 Substrate inhibition of enzymes with Cobra4



The dependence of the rate of enzymolysis on the concentration.

#### Principle

The enzymatic hydrolysis of urea in aqueous solution liberates carbon dioxide and ammonia. The ions of these compounds increase the conductivity of the solution.

#### Tasks

Conductivity measurements enable the rate of hydrolysis of urea by the enzyme urease to be determined at various substrate concentrations. Inhibition of the enzyme by the substrate occurs at excessive substrate concentrations.

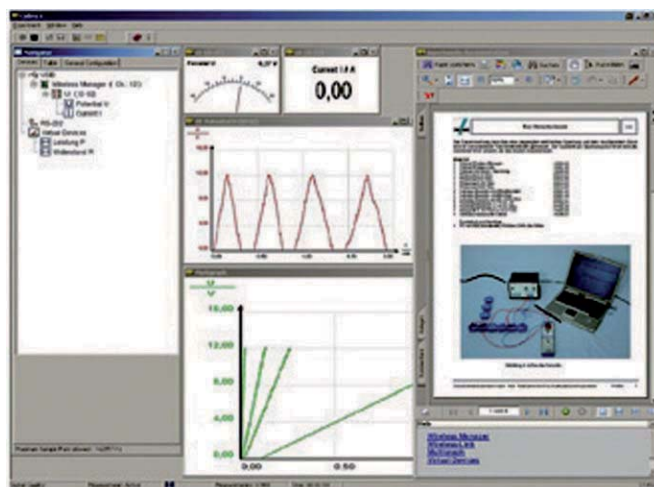
#### What you can learn about

- Substrate inhibition
- Enzymolysis of urea
- Conductivity-time plot
- Reaction velocity of enzymatic hydrolysis

#### Main articles

Cobra4 Wireless Manager	12600-00	1
Cobra4 Wireless-Link	12601-00	1
Cobra4 Sensor-Unit Conductivity+	12632-00	1
Conductivity temperature probe Pt1000	13701-01	1
Software Cobra4 - multi-user licence	14550-61	1
Magnetic stirrer Mini / MST	47334-93	1
Urease soln.in 50% glycerol,10ml	31924-03	1

#### Software Cobra4 - multi-user licence



#### Function and Applications

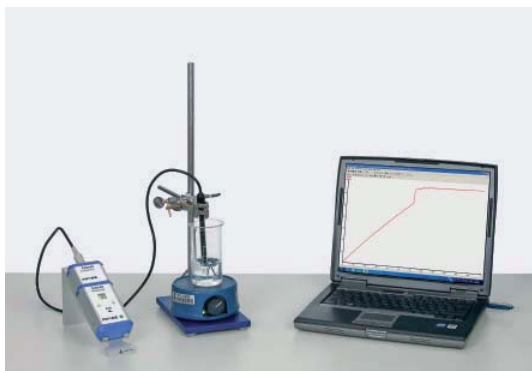
The "measure Cobra4" measuring software leaves nothing to be desired.

As soon as a Cobra4 sensor is connected to a PC, irrespective of whether by Cobra4 Wireless or Cobra4 USB Link, the "measureCobra4" software opens completely automatically and shows the connected sensors, the required measuring windows and the current measuring data.

Measurement recording is then started with a single CLICK.

This all takes under 40 seconds!

14550-61

**Enzyme inhibition (poisoning of enzymes) with Cobra4****P4120560****NEW****4**  
Cobra**Principle**

The enzymatic hydrolysis of urea in aqueous solutions liberates carbon dioxide and ammonia. The ions of these compounds increase the conductivity of the solution.

For more details refer to [www.phywe.com](http://www.phywe.com)

**The enzymatic activity of catalase with Cobra4****P4120660****NEW****4**  
Cobra**Principle**

Catalase is an enzyme that - in humans - is found predominantly in the liver and erythrocytes. It decomposes hydrogen peroxide, which is a toxic byproduct of cellular respiration, into water and oxygen.

For more details refer to [www.phywe.com](http://www.phywe.com)

You need more information?

**WEB@** | PHYWE

Go to [www.phywe.com](http://www.phywe.com) or



send an email to [info@phywe.com](mailto:info@phywe.com)

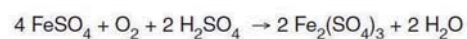
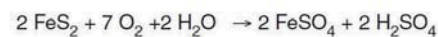
### P1313962 Bacteria and mining - microbial extraction of ore by *Thiobacillus ferrooxidans* and thiooxidans with Cobra4



NEW

Cobra4

Demo



Chemical process during extraction.

#### Principle

Scientists first recognised importance of certain bacteria for the extraction of metals from ore in the 1950s. Nowadays the microbial ore leaching with so-called 'lean ores' represents more than 10% of the total production of copper in the USA alone. The bioreactor shown here can be used to clearly demonstrate to the students this method of extraction (e.g. copper from copper ore) using such bacteria (*Thiobacillus ferrooxidans*).

#### Tasks

1. Reactivate and multiply the two bacteria strains *Thiobacillus ferrooxidans* and *Thiobacillus thiooxidans*
2. Extract copper from copper ore using the "percolator leaching" method

#### What you can learn about

- Ore; Bubble bioreactor; Oxidation; Bacterial leaching; Microbial extraction

#### Main articles

Autoclave with insert	04431-93	1
Drying oven UNB200, timer, 32 l	46959-93	1
Cobra4 Mobile-Link set, incl. rechargeable batteries, SD memory card, USB cable and software "measure"	12620-55	1
Cobra4 Sensor-Unit Chemistry, pH and 2 x Temperature NiCr-Ni	12630-00	1
Bubble bioreactor	65999-00	1
Frame for complete experiments	45500-00	1
Set of Precision Balance Sartorius CPA 423S and measure software, 230 V	49223-88	1

#### Cobra4 Mobile-Link set



#### Function and Applications

The Cobra4 Mobile-Link is a modern, high performance hand measuring device for mobile data recording, to which all Cobra4 Sensor-Units can be connected via secure plug-in/ lockable connection.

12620-55



## Complete Experiments Chemistry/ Biotechnology



Demo

### Article no. 01855-02

Complete Experiments Chemistry and Biotechnology

**This documentation contains the following experiments:**

Model experiment on the fractional distillation of petroleum

**P1308600**

Reaction of aldehydes with ammonia

**P1308700**

Determination of molar masses with the vapour density method

**P1308800**

Distillation - determination of the alcohol content of wine

**P1308900**

Determination of enthalpies of combustion

**P1309000**

Synthesis of ethyl acetate and butyl acetate

**P1309100**

Electrostatic flue gas cleaning

**P1309200**

Column chromatography - separation of leaf pigments

**P1309300**

Determination of the molar masses of metals

**P1309400**

Faraday's laws

**P1309500**

Avogadro's law

**P1309600**

Air analysis (nitrogen in air)

**P1309700**

E.M.F. measurements with a standard hydrogen electrode

**P1309800**

Obtaining vegetable oils by extraction

**P1309900**

Model experiment on the desulphurisation of flue gas

**P1310000**

Chemical fountain

**P1310100**

Boiling point elevation

**P1310200**

Gas laws

**P1310300**

The contact process

**P1310400**

Molten-salt electrolysis

**P1310500**

Steam distillation

**P1311500**

PEM fuel cell

**P1312000**

Synthesis of water

**P1312100**

Fermentation of molasse to ethanol with yeast

**P1313600**

Microbial synthesis of ethanol by *Zymomonas mobilis* subsp. *mobilis*

**P1313700**

Production of amino acids by fermentation of *Corynebacterium glutamicum*

**P1313800**

Bacteria and mining - microbial extraction of ore by *Thiobacillus ferrooxidans* and thiooxidans

**P1313900**

Immobilised cells in the service of biotechnology - microbial synthesis of acetic acid with *Acetobacter acetii*

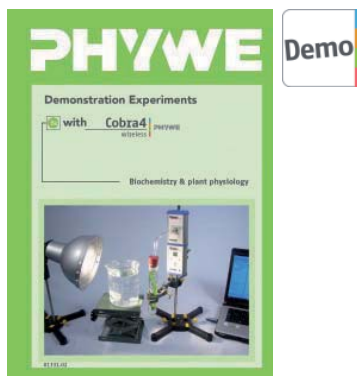
**P1314000**

### 01855-02



**Microbial synthesis of ethanol by *Zymomonas mobilis* subsp. *mobilis* - P1313700**

### Demo advanced Biology Manual Cobra4 Biochemistry & plant physiology



Article no. 01331-02

#### Description

Experimental descriptions from the fields of biochemistry and plant physiology that pay particular attention to the advantages of data acquisition with the Cobra4 system. In total more than 10 demonstration experiments are described in detail.

#### Topics

- Photosynthesis (2 different methods)
- Transpiration of leaves
- Glycolysis (2 different methods)
- The ionic permeability of the cell membrane
- Determination of the Michaelis constant
- Enzyme inhibition
- Substrate inhibition of enzymes
- The enzymatic activity of catalase

#### Equipment and technical data

Din A4 stapled, in colour

56 pages

#### This documentation contains the following experiments:

Transpiration of leaves (with Cobra4)

**P1351260**

Photosynthesis (O<sub>2</sub> pressure measurement) (with Cobra4)

**P1351360**

Glycolysis (temperature measurement) (with Cobra4)

**P1351460**

The enzymatic activity of catalase (with Cobra4)

**P1360760**

Photosynthesis (bubble-counting-method) (with Cobra4)

**P1360860**

Glycolysis (pressure measurement) (with Cobra4)

**P1360960**

Ionic permeability of the cell membrane (with Cobra4)

**P1369760**

Determination of the Michaelis constant (with Cobra4)

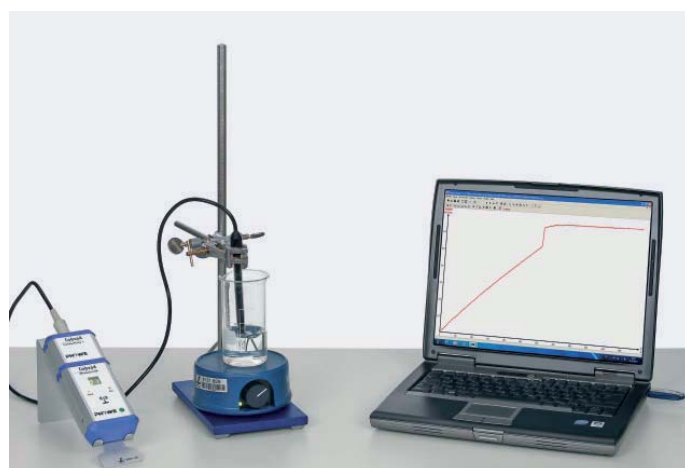
**P1369860**

Complete experiment list see: [www.phywe.com](http://www.phywe.com)

01331-02



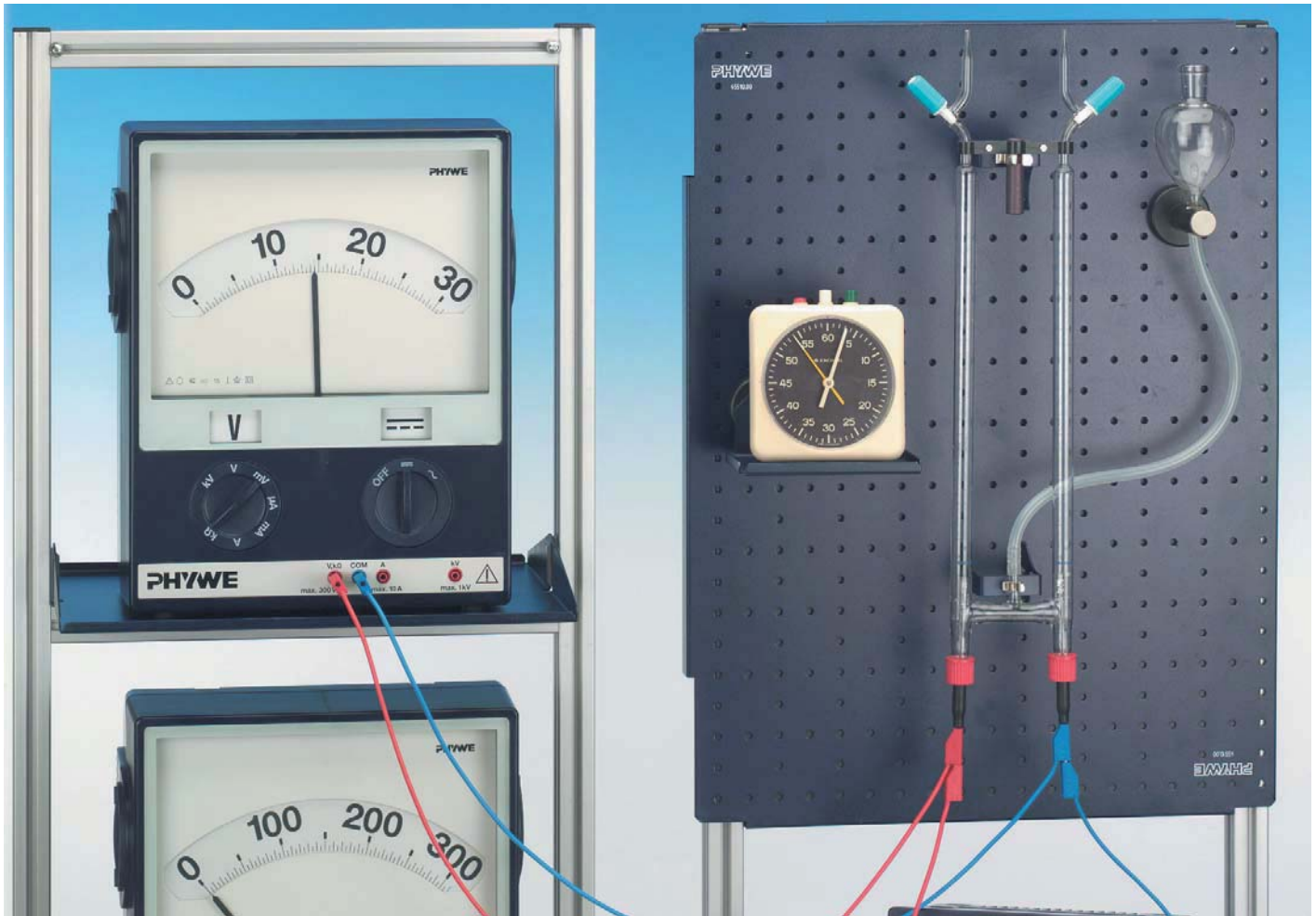
Glycolysis - P1351460



Enzyme inhibition - P4120560



Photosynthesis (bubble-counting-method) - P1360860



## Demonstration Equipment

12.1	Demonstration sets and corresponding experiments	196
12.2	Models and measuring devices	205
12.3	Furniture	211



## 12 Demonstration Equipment

### 12.1 Demonstration sets and corresponding experiments

#### Complete experiments ,basic set

##### Function and Applications

If you want to work with the system "Chemistry on the board" you need different clamping holders and panels to set up experiments. With this comfort set we have put together a number of clamping holders and panels, which allows to show experimental set-ups, where 2 "Frames for complete experiments" are used simultaneously, or to set up 2 different experiment at the same time on 2 frames.

##### Equipment and technical data

- 2 Frames for complete experiments (45500-00)
- 2 Rear-covers for complete-experiments panel (45501-00)
- 2 Panels for complete experimental setups (45510-00)
- 3 Clamping holders,18-25mm (45520-00)
- 2 Clamping holders, turnable, 18-25 mm (45521-00)
- 2 Clamping holders, turnable, 8-10mm (45522-00)
- 1 Apparatus carrier with fixing magnets (45525-00)
- 1 Apparatus holder, variable (45526-00)
- 1 Spring plugs, 50 pcs. (45530-00)
- 1 Fixing bands,universal,100 pcs. (45535-00)
- 2 G-clamps (02014-00)

45560-00

#### Complete experiments, comfort set

##### Function and Applications

If you want to work with the system "Chemistry on the board" you need different clamping holders and panels to set up experiments. With this comfort set we have put together a number of clamping holders and panels, which allows to show experimental set-ups, where 2 "Frames for complete experiments" are used simultaneously, or to set up 2 different experiment at the same time on 2 frames.

##### Equipment and technical data

- 2 Frames for complete experiments (45500-00)
- 2 Panels for complete experimental setups (45510-00)
- 2 Rear-covers for complete-experiments panel (45501-00)
- 2 Shelves with hanging device (45505-00)
- 3 Clamping holders,18-25mm (45520-00)
- 2 Clamping holders, turnable, 18-25 mm (45521-00)
- 2 Clamping holders, turnable, 8-10mm (45522-00)
- 1 Apparatus holder, variable (45526-00)
- 1 Apparatus carrier with fixing magnets (45525-00)
- 1 Spring plugs, 50 pcs. (45530-00)
- 1 Fixing bands,universal,100 pcs. (45535-00)
- 2 G-clamps (02014-00)

45561-00

#### Complete experiments, holder set

##### Function and Applications

##### Equipment and technical data

- 6 Clamping holders,18-25mm (45520-00)
- 3 Clamping holders, turnable, 18-25 mm (45521-00)
- 4 Clamping holders, turnable, 8-10mm (45522-00)
- 1 Apparatus holder, variable (45526-00)
- 1 Apparatus carrier with fixing magnets (45525-00)

45562-00

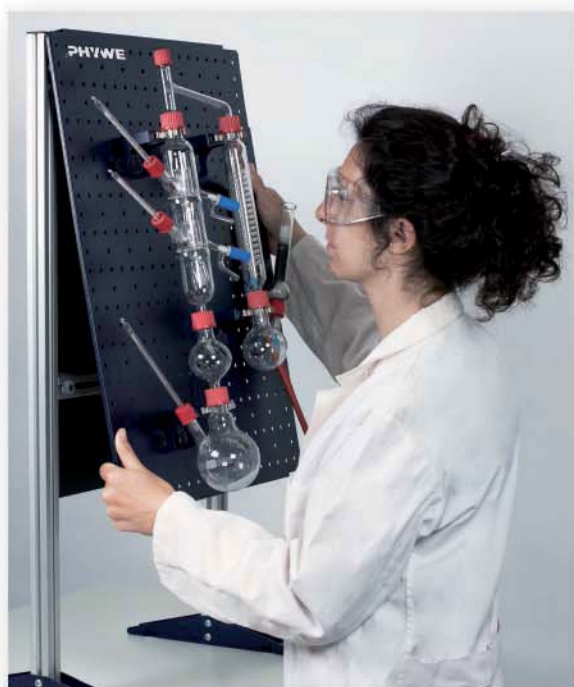




**Clear explanation.**

**Demo** | PHYWE

## Demonstrations system for teaching

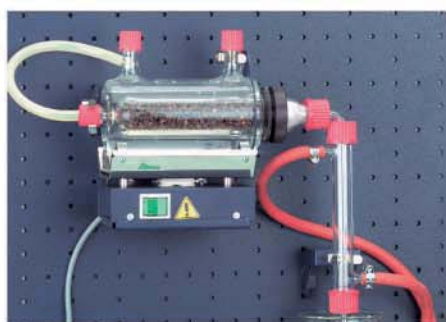


Additional to our TESS expert experiments, there are also our demonstration sets for teachers and lecturers. The innovative system opens up new dimensions for science classes and lecture halls. The particularly useful double-board system shifts the experiments from the horizontal to the vertical and convinces with unlimited possible set-ups, flexible positioning, and ease of installation.

The basis of these experiments is an extensive collection comprising the experiment literature, equipment collection, and storage system.

### Your advantages at a glance

- Minimum preparation time
- Clearly visible demonstration experiments
- Easy set-up and trouble-free changing of experiments
- Customised to your needs



## 12 Demonstration Equipment

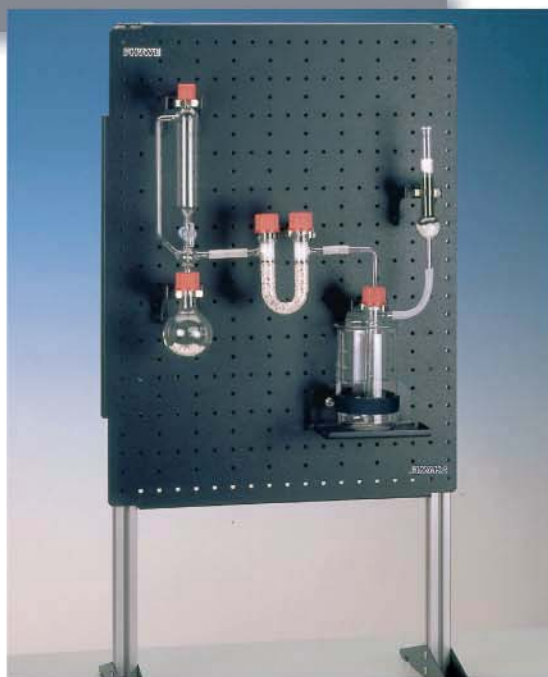
### 12.1 Demonstration sets and corresponding experiments

Demo | PHYWE

## Two board systems one idea in common

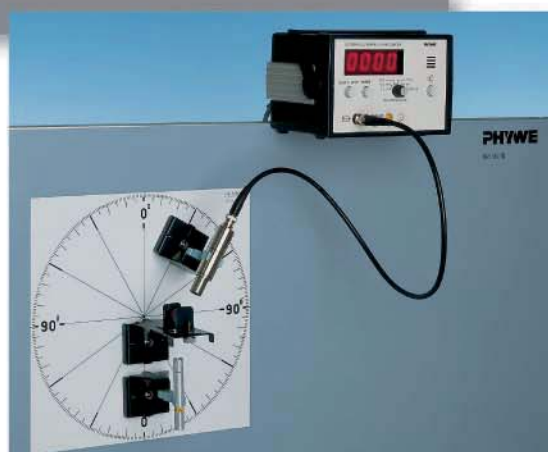
### Chemistry board system

- frame with a hole matrix plate for the secure fastening of equipment with special holders with hooks or with magnetic holders
- easy exchange of hole matrix plates with complete experiment set-ups



### Physics board system

- double-sided board for all physical fields: one-colour coated side, optics side with a white film and grid pattern
- quick positioning and modification of the experiment set-ups by way of magnetic holders



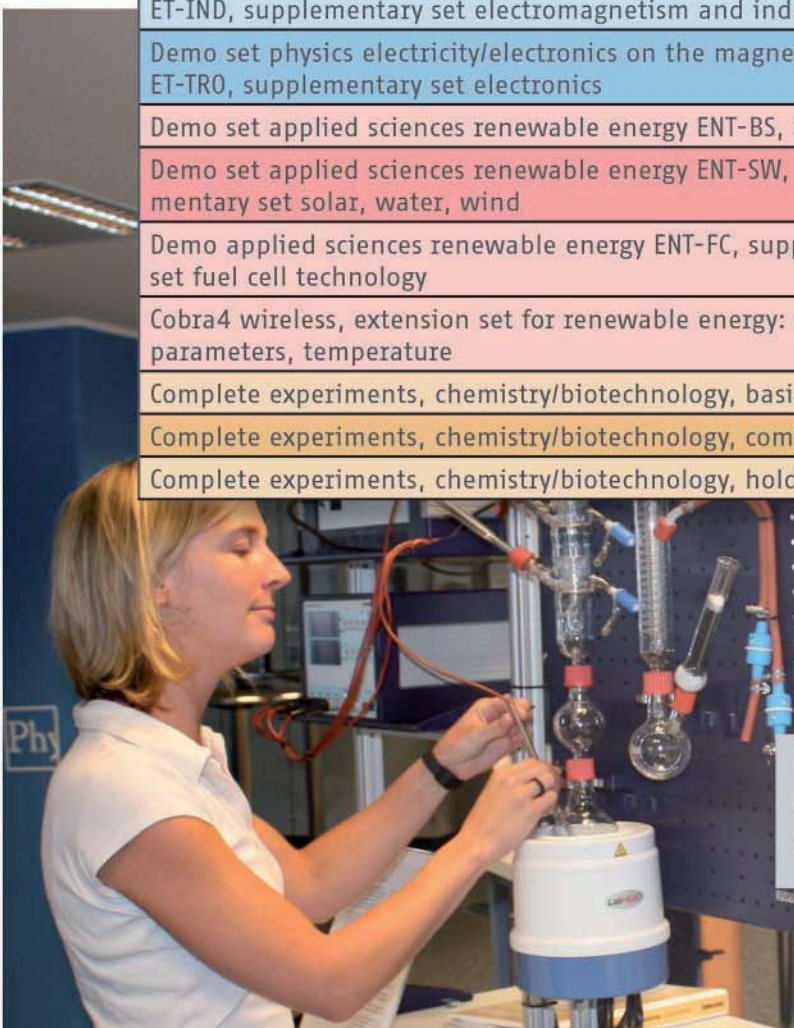
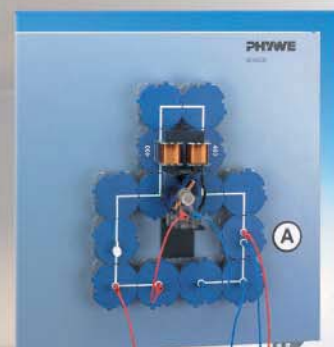
### One idea in common

- vertical, clear set-up
- flexible positioning
- easy installation
- minimum preparation time



### All of the Demo sets at a glance

Demo sets	
Demo set physics mechanics on the magnetic board MT1, basic set	15510-88
Demo set physics mechanics on the magnetic board MT2, supplementary set	15511-88
Demo set physics thermodynamics on the magnetic board WT, complete set	15530-88
Demo set physics optics on the magnetic board OT, complete set	15550-88
Demo set physics radioactivity on the magnetic board RT, complete set	15590-88
Demo set physics electricity/electronics on the magnetic board ET-BS, basic set	15570-88
Demo set physics electricity/electronics on the magnetic board ET-IND, supplementary set electromagnetism and induction	15571-88
Demo set physics electricity/electronics on the magnetic board ET-TR0, supplementary set electronics	15572-88
Demo set applied sciences renewable energy ENT-BS, basic set	15580-88
Demo set applied sciences renewable energy ENT-SW, supplementary set solar, water, wind	15581-88
Demo set applied sciences renewable energy ENT-FC, supplementary set fuel cell technology	15582-88
Cobra4 wireless, extension set for renewable energy: electrical parameters, temperature	12608-88
Complete experiments, chemistry/biotechnology, basic set	45560-00
Complete experiments, chemistry/biotechnology, comfort set	45561-00
Complete experiments, chemistry/biotechnology, holder set	45562-00



Further information  
available just one  
click away – [www.phywe.com](http://www.phywe.com)

WEB@ PHYWE

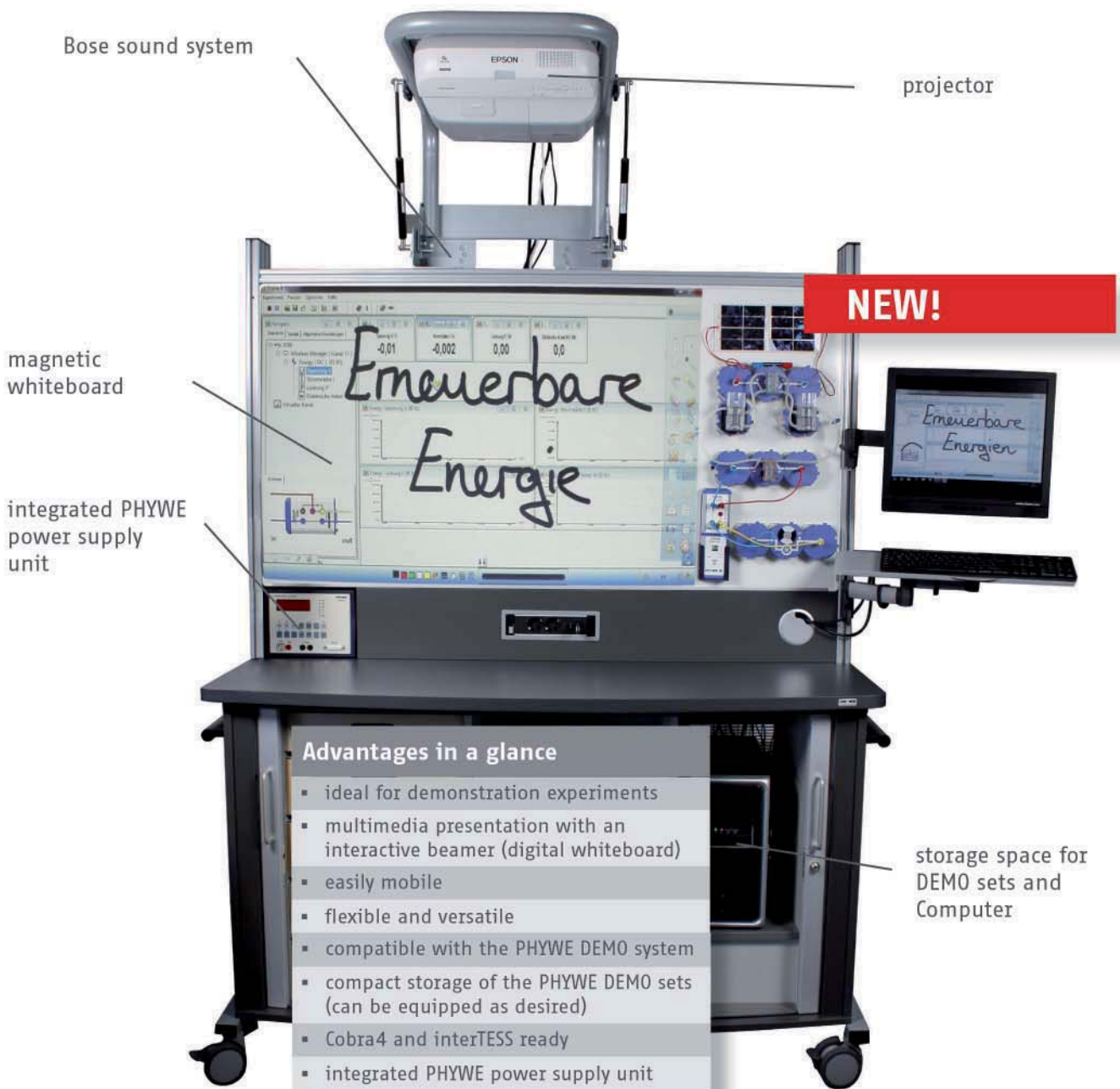
## 12 Demonstration Equipment

### 12.1 Demonstration sets and corresponding experiments

# Multimedia Demo Lab



Demonstration experiments in every room



#### Advantages in a glance

- ideal for demonstration experiments
- multimedia presentation with an interactive beamer (digital whiteboard)
- easily mobile
- flexible and versatile
- compatible with the PHYWE DEMO system
- compact storage of the PHYWE DEMO sets (can be equipped as desired)
- Cobra4 and interTESS ready
- integrated PHYWE power supply unit

storage space for DEMO sets and Computer

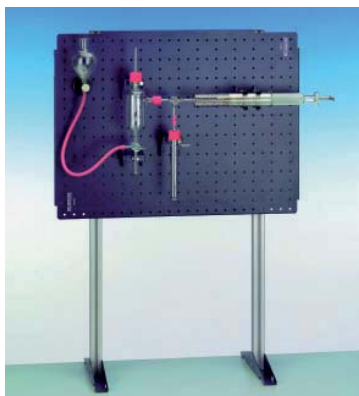
**NEW: The Mobile Demo Lab.**  
Transform any room into a science laboratory

02190-93



### Determination of the molar masses of metals

P1309400



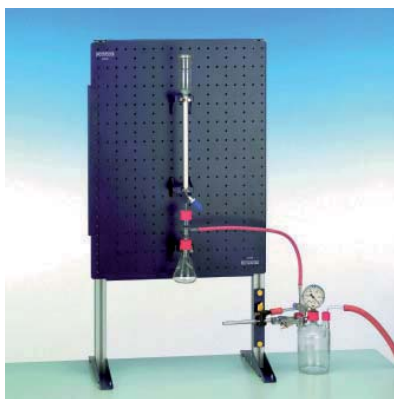
#### Principle

A piece of metal is weighed and placed in the insert of the reaction cylinder, whereafter an acid is added to the cylinder through the three-way valve until it is about half full. The metal is made to react with the acid by lowering the insert. The gas syringe connected to the reaction cylinder is used to collect the hydrogen which is generated. The mass of the metal and the volume of the hydrogen generated are used to calculate the desired molar mass. The reaction can also be used to determine the valency of the metal.

For more details refer to [www.phywe.com](http://www.phywe.com)

### Column chromatography - separation of leaf pigments

P3120300



#### Principle

In this investigation, a uniformly green raw extract of fresh leaves is first separated into different fractions by means of column chromatography. To do so, the extract is added to a column filled with starch and drawn through the column under slightly reduced pressure with ligroin as the eluent. A separation occurs in a clearly recognisable, broad, yellow area and in a narrow, green band. This means that the xanthophylls are separated from the chlorophylls. Each of the separation fractions can be collected individually and characterised by recording their absorption spectra, if necessary, or examined for fluorescence by radiation with UV light.

For more details refer to page 56.

### PEM fuel cell

P1312000



#### Principle

PEM (proton exchange membrane) technology refers to the type of fuel cell favoured by car makers and companies that build combined heat and power plants. The demonstration set-up depicted here produces hydrogen using the classic method by reacting hydrochloric acid with zinc in a gas generator and passing it through distilled water for purification. In the PEM fuel cell, it is then reacted with oxygen to produce water and electrical energy directly. That electrical energy produced from the fuel cell is used to drive a small motor. The advantage of the set-up shown here is that neither an external power supply nor a compressed gas cylinder is required in order to generate the hydrogen.

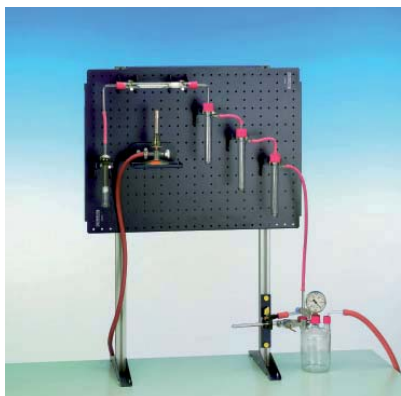
For more details refer to [www.phywe.com](http://www.phywe.com)

## 12 Demonstration Equipment

### 12.1 Demonstration sets and corresponding experiments

#### Model experiment on the desulphurisation of flue gas

P1310000



##### Principle

German coal contains an average of one tonne of sulphur per 100 tons of coal. During combustion, this generates in about two tonnes of sulphur dioxide. Thus, a large 700 megawatt power plant which burns about 200 tons of coal per hour produces about 100 tons of sulphur dioxide per day. These days of course, such a large quantity of a pollutant can no longer be simply released into the air, therefore these flue gases have to be desulphurised. This model experiment provides a simple demonstration of the chemical processes of flue gas desulphurisation as it is carried out in power plants today. The clear, compact setup and the simplifications undertaken relative to industrial scale desulphurisation make it easy to understand the process.

For more details refer to [www.phywe.com](http://www.phywe.com)

#### Electrostatic flue gas cleaning

P1309200



##### Principle

Smoke consists of particles of solid substances suspended in gas. Fog is made up of suspended droplets. In cigarette smoke, as in many industrial processes, smoke and fog are frequently present together. The removal of particles contained in gases - predominately waste gases - is increasingly gaining in importance, both in everyday life and industrially, because frequently the particles and the substances absorbed on them are toxic. The deposited filter dusts are highly toxic, and must be treated as hazardous waste. The experimental set-up used here also enables constituents of cigarette smoke to be semi-quantitatively deposited even in quite large amounts, so that they can be extracted with light petrol and be examined.

For more details refer to page 179.

#### Faraday's laws

P1309500



##### Principle

Passing an electric current through a solution can cause chemical reactions. Here the current is the driving force of the redox reactions that occur.

If ions are added to water to make it conductive and that water is then electrolysed, hydrogen collects at the cathode and oxygen collects at the anode. If these two gases are collected separately, such as with a Hofmann voltameter, the reaction can be followed quantitatively, making it possible to derive two laws ascribed to Faraday.

For more details refer to [www.phywe.com](http://www.phywe.com)

**Fermentation of molasse to ethanol with yeast****P1313600****NEW****Demo****Principle**

As a result of the need to save energy and the increased consciousness of environmental problems, biotechnological production methods are on the advance. Fermenters are used for the biotechnological production of enzymes and other products using bacteria, yeast and cell cultures. For educational purposes a bubble bioreactor used in this experiment is a more convenient and economical alternative to commercial fermenters. To demonstrate how fermenters work, in this experiment molasse which is a waste product of sugar production is fermented in the so-called batch process.

For more details refer to [www.phywe.com](http://www.phywe.com)**Microbial synthesis of ethanol by *Zymomonas mobilis* subsp. *mobilis* with Cobra4** **P1313762****NEW****4  
Cobra****Demo****Principle**

The properties of the microorganism *Zymomonas mobilis* have been used in the production of alcohol for centuries. *Zymomonas* was found to synthesise ethanol much more effectively than yeast does. In this experiment, *Zymomonas mobilis* is grown in a bioreactor.

The cell density can first be determined photometrically in the samples taken and the cell count can be determined in the counting chamber, and those data can be used to generate a growth curve. Chemical and enzymatic tests show the consumption of glucose and the production of ethanol.

For more details refer to [www.phywe.com](http://www.phywe.com)**Production of amino acids by fermentation of *Corynebacterium glutamicum* with Cobra4** **P1313862****NEW****4  
Cobra****Demo****Principle**

A bacteria culture of *Corynebacterium glutamicum* is used in a bioreactor at a constant temperature of 30 °C to produce amino acids. Under these conditions the fermentation of *Corynebacterium glutamicum* takes place in a so-called batch process for 7 to 10 days.

For more details refer to [www.phywe.com](http://www.phywe.com)

## 12 Demonstration Equipment

### 12.1 Demonstration sets and corresponding experiments

#### Osmosis - dependence of the osmotic pressure on the concentration

P1135700



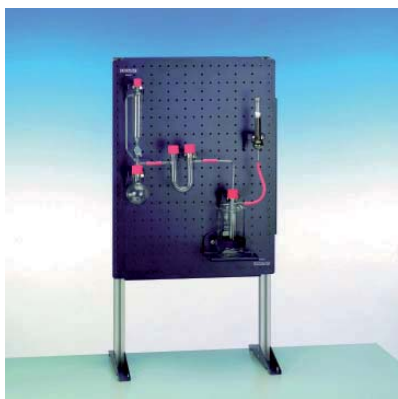
##### Principle

Osmosis describes the phenomenon that solvent molecules move through a partially permeable membrane into a region of higher solute concentration. Thus, the concentration of solute is equalized on both sides. The experimental set-up consists of seven chambers that are filled with solutions of sugar with different concentrations. The liquid column in the capillaries is determined and the dependence of the osmotic pressure on the concentration can easily be shown.

For more details refer to [www.phywe.com](http://www.phywe.com)

#### Reaction of aldehydes with ammonia

P1308700



##### Principle

Aldehydes are not only easily oxidised, they are also capable of addition reactions. In this way, the addition of dried gaseous ammonia to an ethereal solution of acetaldehyde forms 1-amino-ethanol, which precipitates out of the solution as a solid.

For more details refer to [www.phywe.com](http://www.phywe.com)

#### Synthesis of ethyl acetate and butyl acetate

P1309100



##### Principle

Carboxylic acids and alcohols can react with esters under suitable conditions. Water forms as a by-product and, under the properly selected reaction conditions, it can be continuously separated by means of a distilling trap (Dean-Stark apparatus). The progress of the reaction can be followed very clearly based on the quantity of water separated. The set-up depicted here with components from the comprehensive chemistry/biotechnology experiment set enables optimum visibility of the glass equipment and can be set up rapidly.

For more details refer to [www.phywe.com](http://www.phywe.com)



### Plunger eudiometer



#### Function and Applications

The plunger eudiometer consists of a glass cylinder with a movable plunger and is used to determine the ratio of volumes in explosive gas reactions.

#### Benefits

- Two 4-mm sockets connect the ignition spark generator.
- This device can be used to cause gas mixtures to react at room temperature, which lead to gaseous reaction products or in which residual quantities of the reaction gases remain in the cylinder (e.g. mixtures of air and hydrogen, of carbon monoxide and oxygen).
- The gas mixtures are simply injected into the eudiometer using an injection syringe.
- If the plunger eudiometer is assembled in the glass jacket, the ratio of volumes of gas reactions can also be investigated at temperatures other than room temperature, such as the reaction of a stoichiometric mixture of hydrogen and oxygen at above 100°C.

02611-00

### Electrolysis apparatus-Hofmann



#### Function and Applications

For electrolysis of water with measuring device for 2 volumes of produced gas. Particularly suitable to demonstrate Faraday's law and to be used as Coulombmeter.

44518-00

### Leclanche cell, c.be dismantled



#### Function and Application

Demountable demonstration model of a Leclanché element (bag element, dry battery), the electrodes have 4-mm connection sockets. The element is supplied without filling.

#### Equipment and technical data

- Glass beaker
- Porous ceramic vessel
- Zinc electrode (Cylinder) Ø 75 x H 152 mm
- MnO<sub>2</sub> - Carbon electrode (rod) Ø 50 x H 100 mm
- Voltage approx. 1.5 V
- Content of vessel approx. 1 l

#### Required filling:

- Solution of ammonium chloride (NH<sub>4</sub>Cl) 20%

06637-00

### Daniell cell, can be dismantled



#### Function and Application

Demountable demonstration model of a Daniell element, the electrodes have 4-mm connection sockets. The element is supplied without filling.

#### Equipment and technical data

- Glass beaker
- Porous ceramic vessel
- Zinc electrode (Cylinder) Ø 75 x H 152 mm
- Copper electrode (rod) 145 x 42 x 18 mm
- Voltage approx. 1.1 V
- Content of vessel approx. 1 l

#### Required filling:

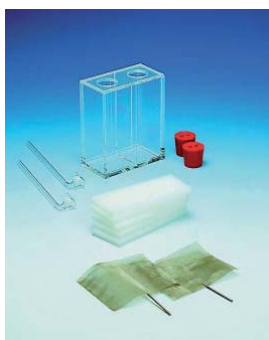
- Solution of copper sulfate (CuSO<sub>4</sub>) 10%
- Solution of zinc sulfate (ZnSO<sub>4</sub>) 10%

06631-88

## 12 Demonstration Equipment

### 12.2 Models and measuring devices

#### Fuel cell, complete



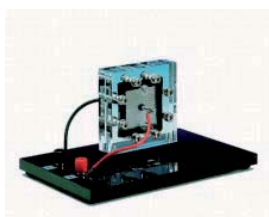
##### Function and Applications

##### Equipment and technical data

- Chamber with cover for fuel cell (44536-10)
- Partitions, plastic foam (44536-02)
- Electrode, nickel wire gauze (2x) (44532-00)
- Gas diffuser tube (2x) (44455-00)
- Rubber stopper (2x) (39260-02)

44536-88

#### PEM fuel cell



##### Function and Applications

For the production of electrical energy from hydrogen and oxygen, whereby even air can be used as the source of oxygen.

##### Equipment and technical data

- Fuel cell mounted on a stable base plate.
- The cell is optimised for high gas utilisation and a good efficiency.
- Without the use of caustic lyes or acids.
- Incl. operating instructions with detailed description of experiment.
- Electrode surface area:  $16 \text{ cm}^2$ .
- Output: 1.2 W.
- No-load voltage: 0.9 V.

06747-00

#### PEM electrolyser



##### Function and Applications

For the production of hydrogen and oxygen through electrolysis.

##### Equipment and technical data

- Electrolyser and storage container for distilled water mounted on a stable baseplate.
- Without use of caustic lyes or acids.
- Only distilled water is used for operating it.
- Voltage input protected against polarity reversal.
- Operating instructions with detailed description of experiment.
- Electrode surface:  $16 \text{ cm}^2$ .
- Output: 4 W.
- Voltage required: 1.7...2 V.

06748-00

#### Critical point apparatus



##### Function and Applications

Critical point apparatus with transparent compression chamber on three legged base, pressure measurement-, generation- and cooling system, two gas valves.

##### Equipment and technical data

- Temperature range: 0...55 °C
- Pressure range: 0...50 bar, 0.5 bar division
- Volume range: 0...4 ml, 0.05 ml division

04364-10

### Gas liquefier



#### Function and Applications

Gas liquefier, for demonstrating isothermal condensation and evaporation due to changes in pressure and volume.

#### Equipment and technical data

- Plastic-coated glass tube, piston with handle.
- Length: 270 mm.
- Diameter: 27 mm.

08173-00

### Compressed-air lighter



#### Function and Applications

To demonstrate the temperature increase of a gas (air) during adiabatic compression through ignition of a combustible material.

#### Equipment and technical data

- DURAN® coated glass cylinder closed at one end.
- Adapted metal piston with handle and eye to introduce cotton wool.
- Length: 230 mm.
- Standard accessories: non-slipping support block, cleaning reamer, 50 g Ramsay grease, combustible material: membrane filters, 5pcs.

04360-00

### Bologna flask



#### Function and Applications

Thick walled flask to demonstrate interior tension of a fast cooled glass, where interior tension and surface tension are in equilibrium. The flask bursts when a hard splinter shaped object with sharp edges is thrown in, e.g. a piece of flint or a nail.

#### Equipment and technical data

- Height: 25cm.
- Weight: 1 kg.

03609-00

### Capillary tube



#### Function and Applications

To demonstrate the capillary effect.

#### Equipment and technical data

- 5 communicating glass tubes of different interior diameters on a round base.
- Capillary diameters (mm): 0.4; 0.8; 1.2; 2.2.
- Diameter of filling tube: 19 mm.
- Height of filling tube: 185 mm.

03611-00

## 12 Demonstration Equipment

### 12.2 Models and measuring devices

#### Multimeter ADM1, demo., analog



##### Function and Applications

Switchable, overload protected moving coil instrument for measuring direct and alternating voltage and current. Passive instrument.

##### Benefits

- Independent of a mains, battery or accumulator supply of power.
- Separate selection measuring range and type of current for clear settings.
- Reading of measured values made easy by automatic call-up of a scale with 30 or 100 divisions when the measuring range is selected.
- Scale is clearly visible from a distance, scale length 200 mm, digit height 20 mm.

13810-00

#### Multimeter ADM2, demo., analogue



##### Function and Applications

Electronic analogue multimeter for measuring direct and alternating voltage and current, and for measuring resistance.

##### Benefits

- Eight demonstrative scales with a total of 66 measuring ranges.
- Measures direct or alternating current from 1 mikroA to 10 A.
- Measures direct or alternating voltage from 1 mV to 10 kV.
- Measures resistance up to 1 MΩ.
- Scale with zero in the middle with automatic middle positioning of pointer.
- Automatic switch-off of battery after approx. 50 min.
- Operatable and readable also from the back. Extensive overload protection in all measuring ranges even when line voltage is falsely applied.
- Eliminates the need for fuses and cutouts.

13820-01

#### Thermite process, demonstr. set



##### Function and Applications

For the simple and safe demonstration of the thermite process. After melting the liquid steel flows down through the steel closing platelet of the reaction crucible into the receiving crucible below.

##### Equipment and technical data

- Supplied completely, including all material necessary.

36685-00

#### Hydrometers, set of 6



To measure the density of liquids; length 180 mm; subdivision 0.005 g · cm<sup>-3</sup>; consisting of 1 piece each, numbered 1?6.

38254-88



### UV analysis lamp 254/366 nm



#### Function and Applications

Switchable UV-hand-held lamp for the detection of fluorescent or substances that absorb in the UV range in paper, thin layer and column chromatograms.

#### Equipment and technical data

- dual wave length: short wave and long wave (254 nm and 366 nm)
- lamp output each 4W
- current supply 230 V WE / 40 VA
- dimensions (mm): 205 x 70 x 55

33972-93

### Gas chromatograph, 2-column



#### Function and Applications

For the separation of undecomposed vaporisable substances up to 250 °C.

#### Benefits:

- fixed in the furnace chamber of the gas chromatograph at the injection and detector block
- signals can be registered via the recorder output with a tY recorder or a computer

#### Equipment and technical data:

- 2 exchangeable separating columns
- Length: 1 m
- Diameter: 5 mm
- Column I polar mobile solvent (polyethylene glycol adipate)
- column II anon-polar mobile solvent (apiezone fatl).
- separate gasinlet (via a coupler hose connection ) and gas outlet
- thermal conductivity detector, which is switched on according to the separating column used.
- Heating output approx. 180Watt.

36657-93

### Isotope table, wall-chart



#### Function and Applications

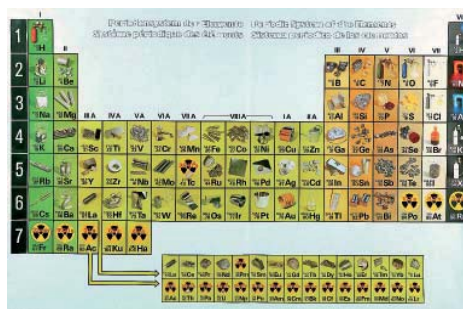
The Karlsruhe Nuclide Chart provides structured, accurate informations of more than 2950 experimentally observed nuclides and 690 isomer.

- symbol of the elements
- standard atomic weights
- isotopic abundances
- decay modes of radionuclides
- half-lives
- energies of emitted radiation
- cross sections

An important characteristic of the Chart is its great didactic value in education and training in the nuclear sciences. It has been used in training programmes worldwide.

39790-00

### Periodic system with colour pictures



#### Function and Applications

Wall map in multicoloured offset printing on flexible Pretex-foil with rods.

#### Benefits

- The elements are shown with an application, the commercial form, radioactive elements with the radioactivity symbol and the half-life.
- The photos supply informations about appearance and aggregate state, metal or nonmetal character, modifications, storage and reactivity of the elements.
- Important correlations of the periodic table can be recognized immediately, basic properties of the elements are memorized.

47310-02

# 12 Demonstration Equipment

## 12.2 Models and measuring devices

### Molecular model construction kit, basic set



#### Function and Application

With these big elements (Atoms) for molecular models structures of chemical compounds can be presented especially vividly also to a greater number of observers

#### Benefits

- structural elements of shockproof plastic
- diameter of the elements: 38 mm (ostentatious)
- chemical elements characterized by internationally usual colors
- angularity of the connections by precisely rivetted push-buttons according to the valences of the elements
- transparent connectors: straight for single bond and scurved for double and triple bonds
- push-buttons for a secure connection of the elements even after years of use

**Molecular model construction kit, polymer chemistry**  
39818-88

**Molecular model construction kit, organic chemistry**  
39821-88

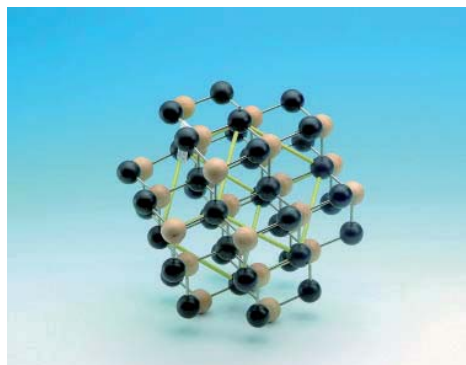
**Molecular model construction kit, Supplement set organic chemistry**  
39822-88

**Molecular model construction kit, Supplement set for inorganic chemistry**  
39823-88

**Supplementary set metals**  
39824-88

**Molecular model construction kit, basic set**  
39820-88

### Crystal-lattice model diamond



#### Function and Applications

High quality crystal-lattice model consisting of colored wooden balls and metallic links; the model will be delivered completely fixed.

#### Equipment and technical data

- Scale to real crystals: 1 : 250 million
- Diameter of the balls: approx. 20 mm

**Crystal-lattice model diamond**  
40010-00

**Crystal-lattice model graphite I**  
40011-00

**Crystal-lattice model sodium chloride**  
40014-00

**Crystal-lattice model cesium chloride**  
40015-00

**Crystal-lattice model sphalerite**  
40016-00

**Crystal-lattice model ice**  
40022-00

### Mobile Demo Lab for demonstration experiments with a magnetic board



**NEW** Demo

#### Function and Applications

This complete mobile system is designed for teaching natural sciences and is ideally suitable for demonstration experiments. All equipment for the experiments can be organized in 4 storage boxes for a quick and easy set-up. Everything belonging to modern teaching methods is incorporated into this new mobile teacher system. The vertical board allows writing with a pen and beamer projection, set-up of experiments with magnetic holders. Beamer, teacher desk and laboratory bench are included. It is ideal for all teaching environments and its modular design guarantees flexibility and adaptability for all of your purposes.

#### Benefits

- flexibly usage in different rooms: no need for a fixed installation of presentation equipment in the rooms
- the system combines techniques of the modern multi media presentation methods and modern demonstration experimentation with thousand fold used robust mobile desks
- preparation can be done in the separate preparation room before the lesson starts
- minimum preparation time for lessons
- ideal for PC based experimentation by using of the Cobra4 interface system
- fast and flexible positioning and modification of the experiment set-ups using magnetic holders
- easy assembly and clearly visible vertical set-up of the experiments

#### Equipment and technical data

- magnetic adhesive board; dimensions: 68 cm x 142 cm
- for vertical set-up of experiments and as a projection screen
- interactive projector, mounted above the board in a hinged manner
- free space under the board for a low-voltage power supply
- 2 easily accessible power sockets and 2 USB ports
- USB connection mounted on top of the board for Cobra4 Wireless manager

02190-93

### Mobile Science Cart



**NEW**  
Demo

#### Function and Applications

The Mobile Science Cart offers all functions to run science teaching classes via integrated access to water, gas, electricity and computer technology.

Cabinets with lockable doors are designed to store PHYWE student science sets (TESS), or teacher science sets (DEMO).

The acid resistant work surface is robust, so chemistry experiments may be conducted safely.

#### Equipment and technical data

- Fully mobile science teaching cabinet
- Integrated access to water, gas, electricity and computer
- Access to vacuum by water jet pump
- Fully lockable
- Storage adapted to all 50 TESS students science sets / 10 DEMO teacher science sets
- Acid resistant work surface
- Dimensions: 1420 x 690 x 1060 mm (W x D x H)
- Weight: 45 kg

02195-93

## 12 Demonstration Equipment

### 12.3 Furniture

#### XR 4.0 Mobile X-ray Lab



#### Function and Applications

Teaching and performing experiments with the mobile X-ray lab. The mobile X-ray lab saves valuable time by making the set-up and dismantling of experiments in the classroom or lecture hall redundant. All of the important parts, such as X-ray tubes, goniometer, or multi-channel analyser, can be stored safely in the lockable cabinet. Prepare your experiments unhurriedly ahead of time before pushing them into the room at time of the lecture. Cluttered set-ups and tangled cables are a thing of the past: The most important connectors are located on the desktop. The screen is fixed in place on the desktop in a permanent manner in order to protect it against damage and theft. The extra-large castors easily surmount any edges or bumps. Any type of room can be instantly transformed into an X-ray science lab!

#### Benefits

- Ideal for experiments in the classroom or lecture hall
  - Preparation of the experiment outside the classroom or lecture hall and easy to move
- Firm set-up of the X-ray unit
- Room for all of the accessories: protected against shock and dust
- Connectors such as USB, VGA, and HDMI integrated in the desktop
- Space-saving: PC stored in the lockable cabinet

#### Equipment and technical data

- Storage compartments for four X-ray tubes, goniometer, etc.
- Recesses in the desktop ensure the firm set-up of the XR 4.0
- Integrated power supply connection with distribution outlets at the back, on the desktop, and in the PC compartment
- Connectors on the desktop: 4 x USB, 1 x HDMI, 1 x triple power socket, 1 x VGA for connecting a beamer or monitor
- Dimensions: 1400 x 1500 x 800mm (W x H x D); Weight: 117kg
- Three layers of melamine-faced high-quality chipboard
- Plastic shutters with groove-mounted runners; lockable handle
- 4 castors with a diameter of 75 mm, two of them with brakes

**XR 4.0, accessories, PC, and screen not included**

09057-48

#### Moveable experimental table 75, 40 mm table top with PP edge



#### Function and Applications

Moveable experimental table.

#### Equipment and technical data

consisting of :

- Experimental table 75 75
- Oval ducted rack
- Colour: dove blue
- 4 castors, 2 lockable
- 1 shelf
- Tabletop: 40 mm thick, Synthetic material, perl; with PP-edge, grey
- Dimensions (mm): 750 x 600 x 908

#### Moveable experimental table 75, 40 mm table top with PP edge 54080-00

#### Moveable experimental table 75, 40 mm table top with PP edge and with intermediate bottom 54080-01

#### Moveable experimental table 75, 40 mm table top with PP edge intermediate bottom and socket board 54080-03





PHYWE Headquarter and Production in Goettingen, Germany

## About PHYWE

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## Traditional yet modern 100 years of quality

Those who know nothing must believe everything.

Marie von Ebner-Eschenbach

With a 100-year tradition of excellence, PHYWE Systeme GmbH & Co. KG stands for technical capability, innovation, quality and customer satisfaction. As a leading supplier of premium quality teaching and learning materials, nearly all made in Germany, PHYWE is one of the world's largest providers of system solutions for the instruction of the natural sciences.

The product range comprises scientific equipment, experiments and solution systems along with modern blended learning systems, literature and software for the areas of physics, chemistry, biology, medicine, material science and earth science. A broad spectrum of services such as training programmes, installation and comprehensive consulting services completes the portfolio.

PHYWE solutions can be individually adapted to the specific curricula in each country and provide ideal coverage for the full spectrum of performance specifications and requirements. Ask us to prepare a customised equipment offering to suit your special needs!

 **made**  
 **in**  
 **Germany**



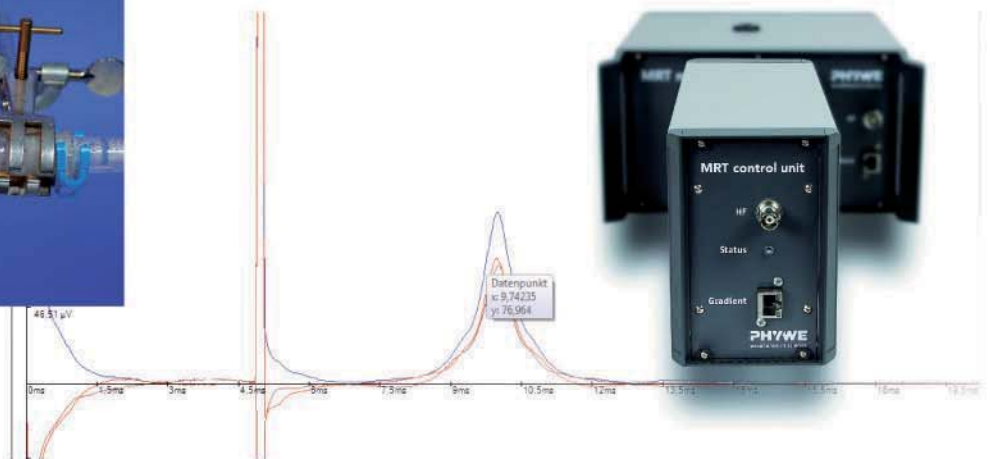
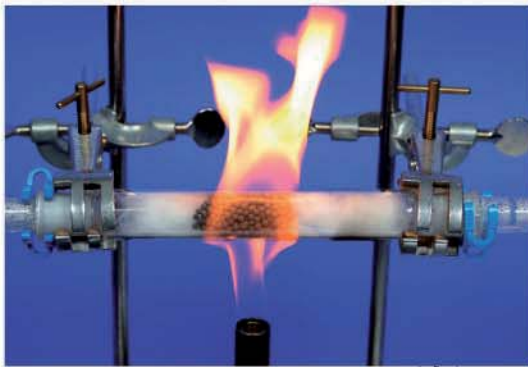




### PHYWE supplies more than 50 Nobel Prize awarded experiments

The Nobel Prize is awarded annually in the disciplines of physics, chemistry, physiology or medicine, literature and peace. For scientists and researchers, it is the highest award.

PHYWE supplies more than 50 Nobel Prize awarded experiments. From Conrad Röntgen to Max Planck or Albert Einstein. Experiments in the footsteps of Nobel Prize winners. PHYWE made Nobel Prize experiments understandable.



#### Nobel Prize awarded experiments (Selection)

##### 1900 ...

- 1901 – Wilhelm Conrad Röntgen
- 1901 – Jacobus Henricus van 't Hoff
- 1902 – Hendrik A. Lorentz, Pieter Zeeman
- 1903 – Henri Becquerel, Pierre Curie, Marie Curie
- 1908 – Ernest Rutherford
- 1909 – Wilhelm Ostwald

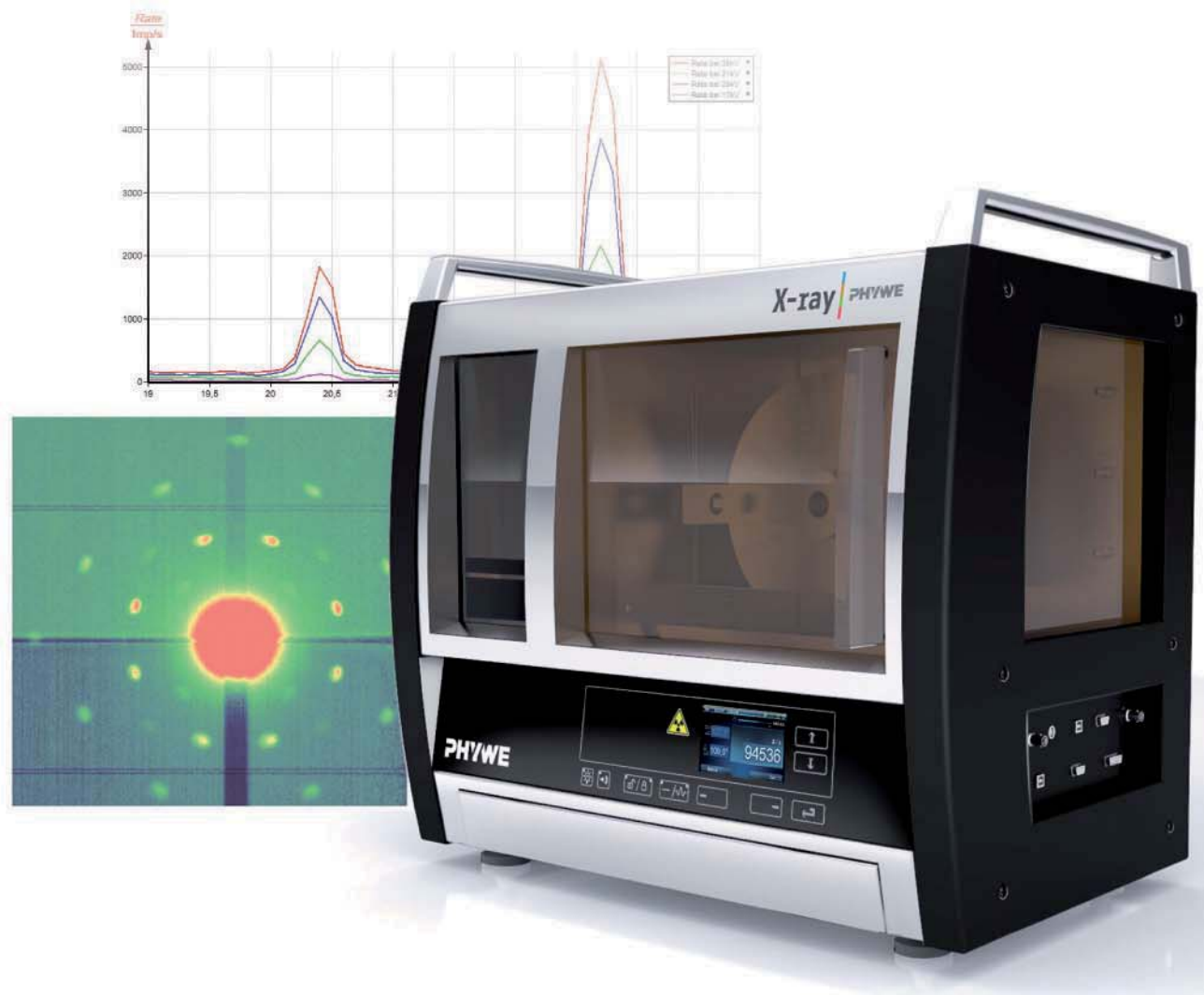
##### 1910 ...

- 1910 – Johannes Diderik van der Wals
- 1914 – Max von Laue
- 1915 – Sir William Henry Bragg, Sir William Lawrence Bragg
- 1912 – F. A. Victor Grignard
- 1918 – Fritz Haber

##### 1920 ...

- 1921 – Albert Einstein
- 1922 – Niels Bohr, Henrik David
- 1924 – Manne Siegbahn
- 1924 – Willem Einthoven
- 1925 – James Franck, Gustav Hertz





### 1930 ...

1931 – Carl Bosch, Friedrich Bergius  
 1932 – Irving Langmuir  
 1936 – Victor Franz Hess,  
 Carl David Anderson  
 1936 – Peter Josephus W. Debye

### 1940 ...

1943 – Otto Stern  
 1952 – Felix Bloch, Edward M. Purcell  
 1952 – Archer John P. Martin,  
 Richard Laurence M. Synge  
 1954 – Max Born, Walther Bothe

### 1970 until today

1971 – Dennis Gabor  
 1979 – Allan M. Cormack,  
 Godfrey N. Hounsfield  
 1986 – Heinrich Rohrer, Gerd Binnig  
 2003 – Paul C. Lauterbur,  
 Sir Peter Mansfield

The PHYWE Nobel Prize experiments  
 are signed with this icon.



### Computer assisted measurement – for your science experiments



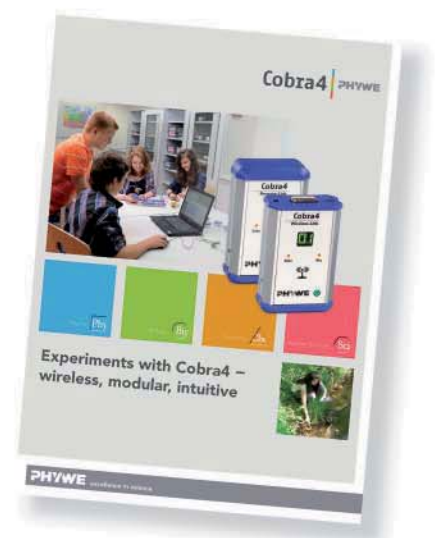
With computer-assisted experiments from PHYWE you rely on a system that perfectly matches the demands of modern scientific education. Approximately 50% of the total number of TESS and Demo expert experiments are computer-based. PHYWE offers the unique Cobra4™ system with completely new experimentation possibilities. Be inspired by more than 300 described experiments with Cobra4™.

The corresponding software “measure” stands for simple and reliable data recording, analysis and further processing – and it is available in 24 languages. Get more information about our Cobra4™ program in the brochure “Experiments with Cobra4”

#### Benefits

- wireless measurements – comfortable and modern
- more than 30 sensors for more than 50 measurands
- time-saving: settings can be saved
- fully automatic sensor identification
- up to 99 sensors can be addressed simultaneously
- can be used as a hand-held measuring instrument

View our Cobra4 catalogue online



#### The Cobra4 interfaces



**Wireless-Link + Wireless Manager + Remote-Link**  
for wireless measurements



**USB-Link**  
for high data rates



**Mobile-Link\***  
for stand-alone measurements

\*registered utility model



**Xpert-Link**  
for special high-performance applications

# The Cobra4™ system

combine interfaces and sensors



**Cobra4 Electricity**

current +  
voltage - +

PHYWE

One of over 30 available sensors!

fast and secure connection of sensors

**Cobra4 Mobile-Link**

GPS

SD card for data storage

2.4" Display 65,536 colors

intuitive operation

One of 4 available interfaces!

USB for charge and data transfer

The Cobra4 system provides over 30 different sensors.



**Digital function generator –  
universal and intuitive**



**Features**

- Universal, programmable voltage source with a bandwidth of 1MHz and an output current of 1A
- Can be used with Cobra4 or as a stand-alone device
- Intuitive operation via function keys and a rotary control knob
- Illuminated display for optimum visibility
- Low distortion factor and high signal-to-noise ratio for brilliant signals, especially for acoustics
- $U = U(f)$  output for a particularly easy pick-up of the frequency – ideal for analysing circuits with frequency ramps
- Part of more than 30 TESS and Demo experiments



Faraday effect (P2260106)



Chladni's figures (P2150702)



## New devices – for the Cobra4 family



### Cobra4™ Sensors



Sound level  
(12669-00)



Skin resistance  
(12677-00)



Oxygen  
(12676-00)



Forceplate  
(12661-00)



Colorimeter  
(12634-00)

	Sound level	Skin resistance	Oxygen	Forceplate	Colorimeter
Measuring range:	35...94 dBA/dBC 75...130 dBA/dBC	0 to 10 $\mu$ S	0 to 30% by volume (air) 0...20 mg/l, 0...200 % (liquid)	-2 to 5 kN	4 wavelengths (LEDs), transmission 0 to 100%
Resolution:	0,1 dB	0,01 $\mu$ S	0...20 mg/l, 0...200 %	0,5 N	0,01 %T
Max. sampling rate:	100 Hz	100 Hz	100 Hz	100 Hz	10 Hz

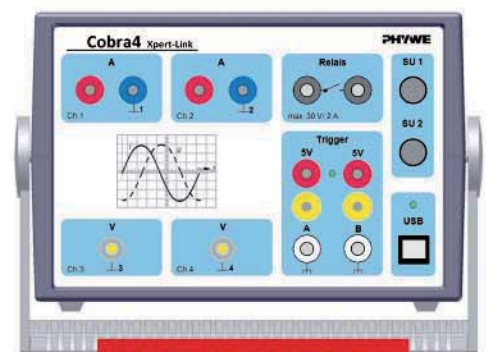
### Cobra4™ Xpert-Link



The high-performance USB interface for high-precision measurements and universal use.

#### Features

- 4 integrated channels (2x current, 2x voltage), electrically isolated
- True RMS converter for all channels, AC and DC functions
- High resolution: up to 10  $\mu$ V, up to 2  $\mu$ A
- High sampling rates: > 1 MHz for current channels and > 5 MHz for voltage channels
- 2 trigger in and 1 trigger out (programmable control relays)
- 2 Cobra4 sensors can be connected



**NEW 2014**

# PHYWE – your partner for turn-key projects

YOU have a vision – WE have the solution

Labs and classrooms for all science disciplines with complete fulfilment by PHYWE. Support by experienced project managers.



## From your drawing...



From your vision of the future we provide a step by step tangible project.

Complete projects according to your curricula topics including:

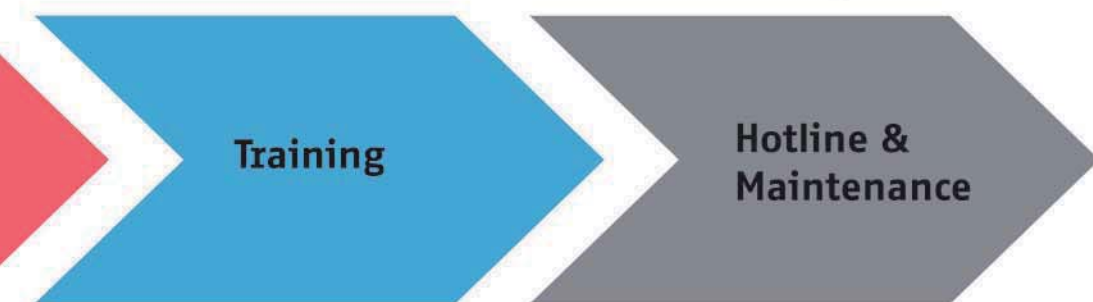
- Solution for science experiments
- Solution for infrastructure & furniture
- Services, e.g. training

Your PHYWE equipment:

- Unpacking
- Inventory
- Installation of hardware
- Installation of software



### ...to the running lab



- Your staff is the key:
- Training of operation
  - Training of maintenance and handling

- Your partner for decades:
- Inquiries of application
  - Spare parts

■ made  
■ in  
■ Germany



## Service at PHYWE –

Professional care from A to Z



### Individual Service for individual needs

By choosing a PHYWE product you decide for a comprehensive service at the same time. We support you with our multi-level service concept. From planning through to installation and up to our extensive after sales service. Rely on our strengths: rugged and long-lasting products made in Germany, customized for your needs.

### We offer

- ✓ Installation and training
- ✓ Seminars at PHYWE or on-site
- ✓ Repair & spare parts delivery
- ✓ Technical hotline



## PHYWE Service team



"...very friendly, flexible and helpful staff. Everything is well organized." Uwe Löding, Head of the collection (Natural sciences) at the Felix-Klein-Gymnasium, Goettingen/Germany

### You can reach the service team by

Phone +49 (0) 551 604-196\*  
 Fax +49 (0) 551 604-106  
 E-Mail [service@phywe.de](mailto:service@phywe.de)

\* on weekdays 8 am – 4 pm (German local time)

## Services

### On-site placement service - inventory taking, per day:

We organize and inventory your collection.

On-site placement service

03333-10

### On-site placement service - project settlement, per day:

We control the supply and put them away in cabinets and organization systems.

On-site placement service

03333-05

### On-site installation, per day:

We install your equipment and do a function test at your site.

On-site installation

03333-06

### On-site training, per day

We train the handling of equipment and experiments at your site.

On-site training

03333-02

### Training & Presentation, per day at Phywe site:

We train the handling of equipment and experiments at PHYWE site.

Training & Presentation at Phywe site

03333-03

## Cooperations – Reliable partner for education

There's a way to do  
it better – find it.

Thomas Edison

The share of ideas and transfer of knowledge between academia and PHYWE is one of our major attempts in R&D. Our network is spread out worldwide and comprises cooperation projects, research assignments, and the education of expert staff.

Some breathtaking novelties of our new XR 4.0 platform are one by one the result of fruitful cooperation in this regard - thank you!



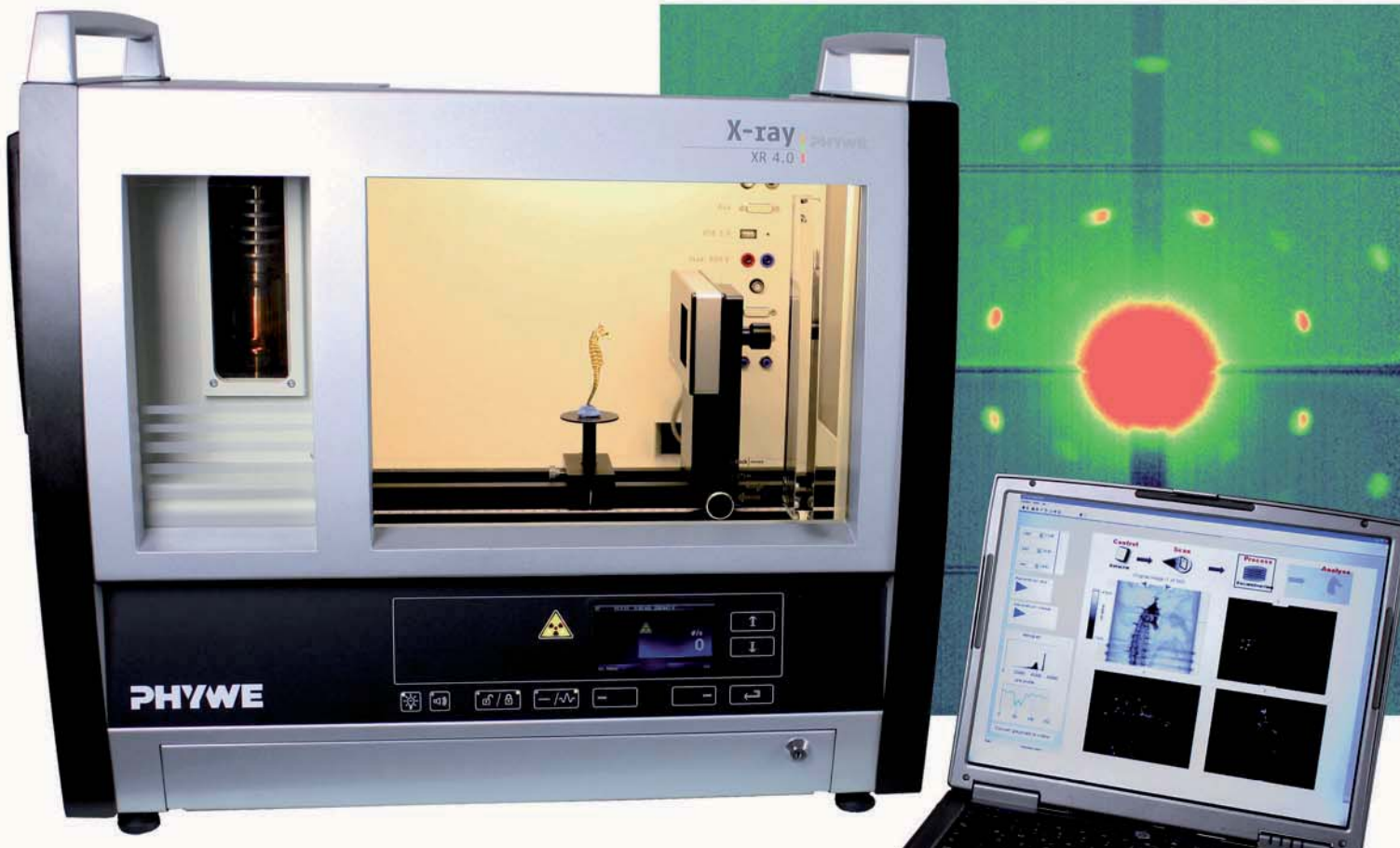
GEORG-AUGUST-UNIVERSITÄT  
GÖTTINGEN

HOCHSCHULE FÜR ANGEWANDTE WISSENSCHAFT UND KUNST  
HILDESHEIM/HOLZMINDEN/GÖTTINGEN  
FACULTY OF NATURAL SCIENCES AND TECHNOLOGY

**HAWK**



XLAB  
Göttinger Experimentallabor  
für junge Leute e.V.



## General notes on safety

### Notes on safety

The regulations for dealing with electrical devices, lasers, radioactive materials and hazardous materials are not uniform worldwide. Before any experimentation, it is essential that you become familiar with the national and local laws, directives and ordinances regarding the handling of the-

se appliances and materials, as well as their storage and transport.

You can refer as an example to our notes on safety, which correspond to the high German and EU standards. The laws in the respective country are binding, however.

### 1.) Experiments using electrical energy

**The utilisation of the electrically operated devices (mains power supply) that are offered herein is only allowed in science rooms of educational institutions, schools, universities, and laboratories, but NOT in residential areas.**

Experiments at school usually use non-hazardous extra-low voltages (< 25 V~ / < 60 V-). The following safety notes provide information about the existing legal regulations. In addition, they include rules of conduct for the responsible teacher for the execution of experiments with hazardous voltage levels.

When performing experiments with electrical energy, it must be absolutely sure that the persons involved in the experiment cannot come into contact with hazardous voltage. The professional (teacher) who supervises/conducts the experiment is responsible for this.

In the "Safety requirements for electrical equipment for measurement, control, and laboratory use" (DIN EN 61010-1, VDE 0411 part 1) of the European Union, non-hazardous voltage is defined as voltage < 33 V~ or < 70 V- or, in the case of higher voltage, with a limited current of 0.5 mA~ and 2 mA- maximum.

Other restrictions for schools providing general education have been decreed by the standing conference of the minister of education and cultural affairs of Federal Republic of Germany in the "Directives concerning safety during lessons" (GUV-SI 8070) with reference to the standard VDE 0105 part 12 ("Operation of power installations - Particular requirements for experiments with electrical energy in lecture rooms"). In these directives, the voltage limits for students up to the German class level 10 (age approximately 16 years) have been fixed at 25 V~ and 60 V- maximum.

Professionals (usually teachers) and students of class levels higher than level 10 may work with hazardous voltages in exceptional cases, if the teaching objective cannot be reached with non-hazardous voltage. In this case, the teacher must be present during the experiment.

The following rules and regulations should be observed:

#### 1. Electrical safety

(DIN EN 61010-1, VDE 0105 part 12, GUV-SI-8070)

Prior to the first experiments of students, trainees, or apprentices with electrical energy in a laboratory or classroom, the students, trainees, and apprentices must be informed in detail about the hazards of the electrical current and about the applicable safety instructions.

Prior to using the electrical devices, they must be checked for signs of damage! Do not use the device if it is damaged!

The operating instructions of the equipment that is used for the experiment must be followed!

Do not use hazardous voltages (> 25 V~ and > 60 V-) in student experiments!

The professional must re-check the experiment set-up (circuit) prior to the start of the experiment and inform the user of any potential hazards!

Modifications of the experiment set-up (set-up, conversion, and take-down) must only be performed when the set-up is completely disconnected from the power supply and when all poles of the supply voltage are switched off!

If measurements or adjustments are unavoidable during an experiment with hazardous voltage, work only with one hand and hold the other behind the back or put it in a pocket!

Ensure that there is a sufficient number of emergency OFF switches in the laboratory.

Use only 4-mm safety cables that are protected against accidental contact (e.g. PHYWE ref. no. 07336-01) when performing experiments with hazardous voltages!

After the completion of the experiment, it should be taken into consideration that component parts, such as capacitors, may supply hazardous voltage even some time after the equipment has been switched off!



Experiments with set-up transformers require special safety measures. Even if the primary side of the transformer is supplied with extra-low voltage ( $< 25\text{ V}\sim$ ), very high hazardous voltages may be generated on the secondary side by the transformation, e.g. if the coils get mixed up!

If demonstration experiments are performed with hazardous voltages, the teacher or lecturer must ensure a sufficient safety distance from the students. In addition, these kinds of experiments must be marked with the danger sign "High voltage!" (PHYWE ref. no. 06543-00)!

Experiments that are directly supplied with mains power must not be performed unless a residual current circuit breaker ( $< 30\text{ mA}$ ), e.g. a safety plug/socket assembly (PHYWE ref. no. 17051-93) or a variable isolating transformer (PHYWE ref. no. 13535-93), has been installed before the set-up. Do not plug the 4-mm connecting cables directly into the earthing contact socket outlet (SCHUKO socket)!

If power supply units (e.g. power supply unit for students, PHYWE ref. no. 13505-93) are used that do not produce hazardous voltages (extra-low voltages  $< 25\text{ V}\sim$  and  $< 60\text{ V}\sim$ ), simple, unprotected 4-mm connecting cables and other non-insulated components may also be used for student experiments.

### 2. EMC (electromagnetic compatibility) (Technical recommendation concerning the application of the EMC Act on electrical teaching equipment, Reg TP 322 TE01)

Experiment set-ups for the demonstration of physical processes must only be used in science rooms at schools, universities, and other educational institutions!

The teacher (expert) who sets up and performs the experiments is responsible for the compliance with the requirements for the EMC Act on the electromagnetic compatibility of equipment! The experiment set-ups do not require a CE mark or declaration of conformity, but the teacher as an expert must take all the necessary measures in order to avoid interferences in the environment!

Possible EMC measures:

- Ensure shielding and equipotential bonding!
- Keep a sufficiently large distance from sensitive equipment!
- Use short connecting cables (in order to reduce RF emission)!
- Floor coverings that may lead to static charges should be avoided and the body should be discharged prior to touching any sensitive experiment equipment!
- RF emitters, e.g. mobile phones, should not be used in close vicinity of the experiment set-up!
- Critical experiment set-up and devices (e.g. Van de Graaf generator, Ruhkoeff induction coil, transmitter), which can cause interferences even at a distance of several 100 metres should be switched on as briefly as possible.

## 2.) Experiments using lasers

In general, the "Directives concerning safety during lessons" (GUV-SI 8070) are applied at schools. In accordance with these directives, the following points must be observed when working with lasers:

1. Only lasers of class 1, 1 M, 2, and 2 M1 in accordance with DIN EN 60 825 may be used at schools.
2. Lasers of class 1 M, 2, and 2 M must be kept under lock and key.
3. Prior to setting up and performing experiments with lasers of class 1 M, 2, and 2 M, the students who observe or are involved in the experiment must be informed as to the risk to the eyes that is caused by the laser light.

These lasers must only be used under the supervision of the teacher.

4. The area in which experiments with lasers of class 1 M, 2, and 2 M are performed must be marked with laser warning signs during the operation of the laser. This laser area of experiment set-ups must be secured against accidental access by some form of delimitation.
5. The set-up and performance of experiments with lasers of class 1 M, 2, and 2 M must ensure that looking into the direct laser beam or into the reflected beam is avoided, e.g. with the aid of some kind of screening. If lasers of class 1 M and 2 M are used, the beam cross-section must not be reduced, i.e. these lasers must not be used



- in combination with converging components (e.g. magnifying glasses).
6. The use of laser devices of class 3 B or 4 in other educational institutions (universities etc.) must be reported to the responsible accident insurer and to the responsible occupational safety and health authority prior to the first start-up of the lasers.
- For the use of laser systems of class 3 B or 4, a competent person must be appointed the laser safety officer in writing.
- Additional information concerning the use of lasers can be found in the documents of the German Social Accident Insurance "GUV-V B – Laser radiation" and "GUV-I 832 – Use of laser systems". These documents are mainly based on the EU standard "DIN EN 60825-1 – Safety of laser products".

### 3.) Handling of radioactive products

In Germany, the handling of radioactive substances is controlled by the German Radiation Protection Ordinance (Strahlenschutzverordnung, StrlSchV). The legal bases of this ordinance are articles 25 to 27 combined with appendix V of the ordinance dated 20 July 2001, last amended by article 2 of the law of 02/08/2008. Substances within the exemption limits (see Appendix V of the German Radiation Protection Ordinance (StrlSchV) for the exemption limits) can be supplied to schools without any conditions. If the exemption limits are exceeded, the school will need a special handling permit issued by the responsible supervisory authority prior to purchasing the substances.

If several substances within the exemption limits are owned and/or purchased, the sum formula that is stated in the German Radiation Protection Ordinance must be observed.

Radioactive substances must be protected against unauthorised persons, which is why they must be stored in a theft-proof manner. In addition, the handling regulations of the German Radiation Protection Ordinance must be observed. Substances that have become unusable must be handed over directly to the responsible collection centre or to a disposal company.

### 4.) Safety instruction for handling hazardous materials

Before any experimentation with hazardous materials, it is essential that you become familiar with the national and local directives and ordinances concerning the handling of hazardous materials, their storage and transport. The basic principle is that all hazardous materials must be dealt with cautiously and carefully. It is of course required that, in case of experiments, neither the students nor the teachers be exposed to any unnecessary dangers to health. The instructions

of the safety data sheets for the individual materials, in the most current version in each case, are to be considered, as well as the accident-prevention specifications and the respective workplace-related operating instructions. The waste disposal of used hazardous materials must be implemented according to recognized methods. The local specifications for the proper removal of chemical residues are to be considered in this case.

## General Terms and Conditions (GTC)

### of PHYWE Systeme GmbH & Co. KG

#### § 1 Application of Conditions

1. These General Terms and Conditions (hereinafter referred to as GTC) shall apply for all goods, services and offers of PHYWE Systeme GmbH & Co. KG (hereinafter referred to as PHYWE) for its customers (hereinafter referred to as Customer). They shall apply equally for all future business between the contract parties without requiring a repeated reference. General Terms and Conditions of the Customer shall apply only if expressly approved by PHYWE in writing.
2. All deviating agreements between PHYWE and the Customer shall be set down in writing; a waiver of the written form does not have any effect on the agreement's validity. In the event of such an agreement these GTC shall be of lesser importance and shall supplement the agreement.
3. PHYWE reserves all rights to PHYWE operational and offer documents. If no order is placed, all documents shall be returned immediately of the Customer's own accord. All information in them and from other transactions shall be treated as strictly confidential.
4. All offers, samples and test products as well as their technical data and descriptions in the respective product information and promotional materials on the PHYWE website are for information only and are not binding. They do not represent a warranty of quality or application.
5. Insofar as PHYWE considers it necessary for the completion of its performances, PHYWE is authorized to exchange job-related data with assistants or trading partners. If the Customer does not desire such an information exchange, the Customer may object to it in writing at any time.

#### § 2 Offer and Contract Conclusion

PHYWE's offers are not binding. PHYWE reserves an acceptance period of two weeks from receipt at PHYWE regarding the Customer's binding orders. Verbal statements of acceptance (by phone) and all Customer orders shall be confirmed by PHYWE in writing or by telex; a waiver of the confirmation does not affect the effectiveness of verbal statements of acceptance and orders (by telephone).

#### § 3 Prices

1. The prices given in the PHYWE price list or the PHYWE order confirmation, exclusive of the relevant applicable value-added tax in the respective country, shall be binding. Additional goods and services are charged separately.
2. The prices are "ex work PHYWE" and include PHYWE standard packaging. Special packaging or other requests from the Customer, such as packaging in certain lots, are charged separately. Deviating provisions may be agreed between PHYWE and the Customer or by PHYWE for a region or a country in writing from time to time.

#### § 4 Delivery and Performance Terms

1. Delivery dates or terms that may be agreed upon, both binding and unbinding, shall be set down in writing. Non-binding delivery terms may be exceeded by up to 8 weeks by PHYWE; only after expiration of this term we shall fall into arrears by reminder of the Customer. Delivery terms shall start as of contract conclusion and acceptance of payment details by PHYWE. In the event that changes to the contract are agreed upon, it is subsequently required to agree on a new delivery date at the same time. Claims for damages or recourse of the Customer towards PHYWE shall be excluded in any case.
2. In the event of delivery and performance delays due to force majeure, natural disasters as well as due to labour disputes, traffic or operation disturbances, lack of material through no fault of their own and similar reasons on PHYWE and its suppliers' part, the Customer is not entitled to withdraw from the contract or to assert claims towards PHYWE. The Customer is entitled to withdraw from the contract if the aforementioned reasons cause an extension of the delivery date by more than four months. PHYWE is entitled equally to withdraw from the contract. Claims for damages or recourse of the Customer towards PHYWE shall be excluded in any case.

3. PHYWE is entitled to make partial deliveries and partial performances at any time unless the deliveries and performances are to be made fully and completely in accordance with the contractual arrangements.
4. PHYWE's compliance with delivery and performance obligations requires the Customer's timely and proper compliance with its obligations.
5. If the Customer falls into arrears, PHYWE is entitled to demand reimbursement of the additional expenses it had to make for the unsuccessful offer and storage and maintenance of the owed object; with commencement of default of acceptance the risk of incidental deterioration and accidental loss is transferred to the Customer.

#### § 5 Export Business

PHYWE is entitled to withdraw from the contract regarding delivery of such products (partial withdrawal) that require approval of the federal ministry for economics and export control, the Federal Institute for Medicaments and Medical Products or a similar governmental institution for their export from Germany or their import in their country of destination pursuant to legal provisions in the event that the approval is not issued or probably may not be obtained until the agreed delivery date. PHYWE shall immediately advise the Customer of this and possibly reimburse a compensation for the part of the performance affected by the withdrawal.

#### § 6 Shipping and Transfer of Risk

1. Place of performance is Göttingen. The delivery condition is "ex works PHYWE". Other agreements must be made in writing.
2. The Customer may request PHYWE to ship the goods. It shall bear the costs and risk for it. In the case of a forwarding order the risk is transferred to the Customer as soon as the shipment had been handed over to the person executing the transport. If PHYWE is able to ship the goods at the time determined by contract and the shipment is delayed at the Customer's request the risk is transferred to the Customer at notice of readiness for shipment.
3. At the Customer's request shipments shall be insured in its name and on its account.

#### § 7 Claims for Defects/Guarantee

1. PHYWE is working pursuant to the guarantee claims typical in Germany and the EU. If a PHYWE product shows any other defect already present at delivery, the Purchaser shall advise it immediately and provide evidence. In such an event PHYWE shall repair the defect or deliver a product free of defects (supplementary performance) pursuant to legal provisions. PHYWE shall bear the expenses required for the purposes of supplementary performance, including but not limited to transport, labour and material cost. Additional expenses caused by the sold product being brought to a place other as the domicile or the branch office of the Customer shall not be borne by PHYWE.
2. Insignificant or commercial deviations of the delivered goods in size, shape and colour being in the material's nature do not establish claims for defects by the Customer. Article 377 German Commercial Code applies.
3. PHYWE reserves the right to changes to the PHYWE products required for technical or other reasons not affecting usability and not reducing the service's value and for technical improvements. They do not establish claims for defects, abatement or withdrawal from the transaction by the Customer.
4. If PHYWE's operation or maintenance instructions are not adhered to, changes to the products are made, parts are exchanged or consumables not complying with the original specifications are used, the Customer may not assert claims for defects if the Customer does not refute a substantiated claim to the effect that it was only one of those circumstances that had caused the defect.
5. The Customer must immediately inform customer service management/PHYWE's technical hotline of visible defects in writing, however, the latest within one week after receiving and/or accepting the



delivered goods. Defects that can not be discovered within this period even with careful examination shall be communicated and proven to PHYWE in writing immediately upon discovery.

6. Claims for defects for regular wear and tear are excluded.
7. Only the immediate Customer is entitled to claims for defects towards PHYWE and may not transfer them to third parties.
8. Claims for defects fall under the statute of limitations after 12 months as of delivery of the goods under contracts with the Customer. Retaining payments by the Customer is only admissible if the proportion of the occurred defect is appropriate.

#### § 8 Repairs

If the Customer is not entitled to claims for defects pursuant to § 7 or if the statutory period of limitation pursuant to § 7.8 is expired and PHYWE and the Customer agree on a repair of the products § 7.8 applies equally to the limitation of a defect of the repair.

#### § 9 Reservation of Title

1. PHYWE reserves title to the goods until fulfilment of all claims from the business relation for whatever legal reason including the claims arising in the future or conditional claims. If the realisable value of existing securities (goods subject to reservation of title pursuant no. 3 below and transferred accounts receivable pursuant no. 5 below) exceeds the secured claims by more than 10 % in total PHYWE is obliged insofar to release securities at the seller's discretion at the Customer's request.
2. Joint ownership rights arising from combination or mixing are deemed goods subject to reservation of title. PHYWE has an appropriate right to the reservation of title on these goods as well.
3. The Customer is entitled to process and sell the goods subject to reservation of title in the course of normal business unless it falls into arrears. Pledging or protective conveyance is inadmissible. By way of security the customer shall immediately transfer to PHYWE all claims (including any outstanding balance claims from the current accounts) arising from the resale or another legal reason (insurance, inadmissible action) in connection with the goods subject to reservation of title to their full extent. PHYWE shall give it the revocable authorization to collect the claims transferred to PHYWE for its account in its own name. This authorization for collection may only be withdrawn if the Customer does not properly fulfil its payment obligations.
4. In the event that the Customer behaves contrary to the contract – including but not limited to falling into arrears – PHYWE is entitled to take back the goods subject to reservation of title after expiration of an appropriate additional respite or demand the transfer of the Customer's claims for return towards third parties as the case may be. PHYWE taking back the goods subject to reservation of title does not constitute a withdrawal from the contract unless PHYWE has expressly stated such withdrawal.

#### § 10 Payment

1. All payments exceeding the credit limit of the Customer with PHYWE confirmed by PHYWE in writing shall be made for payment in advance or confirmed with an irrevocable letter of credit from a large European bank accepted by PHYWE or an equivalent bank guarantee.
2. Within or above credit limit invoices shall be payable without deducting a cash discount or other discounts with PHYWE receiving the payment within 20 days as of contract conclusion and receipt of the invoice or an equivalent payment listing by the Customer.
3. In the event of orders with a purchase price surpassing € 25,000.00 the Customer shall make an advance payment of 40% of the purchase price for PHYWE products and 60% of the purchase price for third party products. The advance payment is due on contract conclusion and receipt of an invoice or equivalent payment listing.
4. A payment is only deemed made when PHYWE has the amount at its disposal. In case of cheques the payment is only deemed made when the cheque has been cashed.

5. The Customer shall fall into arrears 3 days after maturity of the claim by PHYWE and receipt of an invoice or delivery without it requiring a written reminder. If the Customer falls into arrears PHYWE is entitled to demand interest of 8% above the relevant basic interest rate of the European Central Bank at the respective point in time. PHYWE may submit evidence of a greater damage
6. If PHYWE becomes aware of circumstances calling the Customer's financial standing into question, including but not limited to not cashing its cheque or stopping its payments, or if PHYWE becomes aware of other circumstances calling the Customer's financial standing in question, PHYWE is entitled to call the complete outstanding debts even if it had accepted cheques.
7. The Customer is only entitled to set off its debts if the counterclaims have been established as final and absolute or are undisputed. The same shall apply for the right of retention pursuant to article 273 German Civil Code, the commercial right of retention pursuant to article 369 German Civil Code and the right of refusal of services pursuant to article 320 German Civil Code.

#### § 11 Copyright Infringements

1. PHYWE shall exempt the Customer and its customers from claims arising from infringements of copyrights, trade marks or patents unless the design of a delivery object had been made by the Customer. PHYWE's exemption obligations shall be limited to the amount of the predictable damage. An additional requirement for exemption is that in case of a legal dispute (article 72 German Code of Civil Procedure) the Customer informs PHYWE of the dispute and that the alleged legal infringement may be ascribed to the construction of PHYWE's delivery items without combination or use with other products.
2. Optionally PHYWE has the right to free itself from the obligations assumed in clause 1 by either
  - a) obtaining the required licences regarding the alleged infringed patents, or
  - b) providing the Customer with a changed delivery item or part of it that rectifies the infringement reproach concerning the delivery item by exchanging it for the infringing delivery items or their parts unless the changed delivery item (or parts of it) falls behind the original performance regarding the usability and/or its value.

#### § 12 Liability

1. PHYWE shall be liable for breaches of contractual and non-contractual obligations, including but not limited to impossibility, delay and unlawful acts, only in cases of malicious intent and gross negligence – of its executive employees as well – limited to damages foreseeable at contract conclusion.
2. Claims for damages of material defects shall fall under the statute of limitation after 12 months as of delivery of the goods – with exception of personal injury or wilful or grossly negligent breaches of duty. The limitation of legal regress claims remains unaffected. The relevant legal provisions apply for claims for damages on account of other legal reasons.

#### § 13 Applicable law, jurisdiction, partial invalidity

1. In addition to these provisions German law with exemption of the provisions of the UN Convention on Contracts for the International Sale of Goods dated 11/04/1980 (CISG) applies.
2. Place of jurisdiction is Göttingen
3. If a provision in these General Terms and Conditions or a provision under other agreements is or becomes ineffective the validity of all other provisions or agreements shall remain unaffected.

General Terms and Conditions of PHYWE Systeme GmbH & Co. KG, last updated on 01/08/2010

After announcement of new General Terms and Conditions all previous General Terms and Conditions lose their validity.



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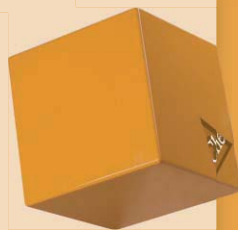
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