KLINGER
EDUCATIONAL PRODUCTS
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2022-23

X-ray Teaching Apparatus

For Physics, Chemistry, Biology and Medical Imaging Lab Courses

Experiments Include

*Transillumination and **X-ray photography***
Ionization** and **dosimetry
Material-dependent and thickness-dependent attenuation of X-rays
Continuum and characteristic lines, investigating the X-ray source
X-ray tubes with different anode materials for investigation of the influence on the characteristic lines
Energy-dependent absorption and K-edges
***Moseley's law** and determining the Rydberg frequency*
***Compton effect**, Bragg*
*Quantitative Compton effect with the **X-ray energy detector***
***Duane-Hunt relation** (determination of **Planck's constant** from the limit wavelength)*
***Bragg reflection** for determining the lattice plane spacing of various crystals*
*Investigating crystal structures by means of **Laue diagrams** and **Debye-Scherrer photographs***
*Direct recording of the **X-ray spectrum** using the X-ray energy detector*
*Comparison of **Bragg-spectroscopy** and X-ray fluorescence spectroscopy using the X-ray energy detector*
***X-ray fluorescence** analysis of arbitrary samples (non-destructive material analysis)*
*Investigation of X-ray fluorescence **spectra of K- and L-lines** and much more...*

The fluorescent screen is ideal for carrying out simple transillumination experiments

Apparatus for the Advanced Lab, Physics & Life Sciences

KLINGER NOW OFFERS LEASING FOR TEACHING EQUIPMENT
Please call to ask about our new leasing program for the X-ray

Toll Free 800 522-6252

86 Glen Cove Road • Roslyn Heights, NY 11577

LEYBOLD®

with LabVIEW™ driver

LabVIEW™ is a registered trademark of National Instruments

554 801 **$26,835.**

X-ray apparatus Mo, complete

Fully-featured, microprocessor-controlled device with x-ray tube Mo and goniometer designed for conducting a wide variety of experiments in x-ray physics. The high-voltage system, x-ray tube and experiment chamber are all within a radiation-proof housing. German type approval as school x-ray apparatus and full-protection device. The type approval is also valid for further x-ray tubes (Fe, Cu, Ag, W). The x-ray tubes are delivered completely adjusted and allow thus an easy and user-friendly exchange. Highest safety and operation comfort by an automatic door locking, which unlock the doors automatically, when no x-ray radiation is generated.
Two large displays show all relevant information on the current experiment. The tube voltage and tube current can be set in the ranges 0 to 35 kV and 0 to 1 mA respectively. The built-in rate meter including counter-tube voltage supply enables direct measuring in conjunction with a Geiger-Müller counter tube. The x-ray apparatus can also be connected to a PC via the USB-port (software included) for recording Bragg spectra. Alternatively, the two analogue outputs (counting rate and angular position) permit data acquisition using a chart recorder.
The goniometer (⋯› 554 831) enables precise setting of any angular position of the sensor and the target as well as coupled 2:1 sensor and target motion, both manual and automatic angular scans are possible.
Two screened coaxial lead-ins and one free access duct provide access to set-ups in the experiment chamber, e.g. for connecting an x-ray energy detector.
Device fully assembled and adjusted, ready for operation.

554 800 **$24,255.**

X-ray apparatus

Basic device fully assembled and adjusted for all tubes, however, without tubes and goniometer.

Scope of delivery: X-ray apparatus without tube, cover for fluorescent screen, dust cover, USB cable, software for Windows 98/2000/XP/Vista

Including Windows software for recording and evaluating data

554 980 en **$179. (free online version)** NEW!

Book: X-ray apparatus hard copy

24 Experiments from the series “LD Physics Leaflets”, english

School x-ray apparatus and full-protection device with German type approval for school use (approval No. BFS 05/07 V/SchRöV) (suitable for the operation with the exchangeable tubes: Fe, Cu, Mo, Ag, W)
Dose rate at a distance of 10 cm: <1 µS/h
Two independent safety circuits for doors, high voltage and emission current
Automatic door locking : doors can be opened only, when no high voltage is present i.e. no x-ray radiation can be generated
High voltage: 0 ... 35.0 kV (regulated DC voltage)
Tube current: 0 ... 1.00 mA (independent regulated DC)
Visible x-ray tube with molybdenum anode for characteristic short-wave radiation: K_α = 17.4 keV (71.0 pm), K_β = 19.6 keV (63.1 pm)
Fluorescent screen for transillumination experiments: d = 15 cm
Built-in rate meter including voltage supply for GM counter tube
Loudspeaker: as an acoustic ratemeter
Two 4-digit displays (25 mm high) for displaying the following as desired: high voltage, anode current, counting rate, target/sensor angle, scanning range, step width, gate time
Goniometer (⋯› 554 831), stepping-motor controlled
Operating modes: manual control and automatic scan for sensor only, target only, 2:1 coupling
Angular range:
target unlimited (0° ... 360°)
sensor -10° ... +170° Step width: 0.1°
Exposure timer, gate time: 0.5 s ... 9999 s
Bushings in the experiment chamber: high-voltage coaxial cable, BNC coaxial cable, empty channel for e.g. tubing, cable etc.
Analog outputs: each proportional to target angle and to counting rate for chart recorder connection
USB port for connecting a PC to control the x-ray apparatus, data recording and evaluation by the delivered Windows software
LabVIEW™ driver for Windows and Linux available free of charge at http:/www.ld-didactic.com for user defined controlling and measuring
Input voltage: 230 V (±10 %) / 47 - 63 Hz
Power consumption: 120 VA
Dimensions: 67 cm x 48 cm x 35 cm
Weight: 41 kg

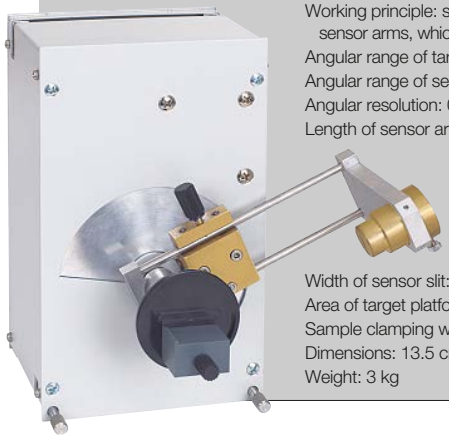
Scope of delivery
X-ray apparatus with X-ray tube Mo
Goniometer (⋯› 554 831)
NaCl crystal (⋯› 554 78), Lattice-plane spacing: 282 pm
Zirconium foil
Cover for fluorescent screen
Dust cover
USB cable
Software for Windows 98/2000/XP/Vista

Additionally required for ⋯› 554 800 or ⋯› 554 801: **$699.**
End-window counter with cable 559 01

554 831 **$4,540.**

Goniometer

With two independently controllable stepping motors which move the sensor and target arm. The motion is defined using the keys in the control panel of the X-ray apparatus (⋯› 554 800 and ⋯› 554 801) and initiated manually or automatically. Included in the scope of supply of the X-ray apparatus (⋯› 554 801).



Working principle: stepping motors for target and sensor arms, which can be electronically coupled
Angular range of target: unlimited (0° … 360°)
Angular range of sensor: approx. -10° to +170°
Angular resolution: 0.1°
Length of sensor arm: approx. 40 -110 mm
Width of sensor slit: 1 mm
Area of target platform: 25 mm x 28 mm
Sample clamping width: 3 - 9 mm
Dimensions: 13.5 cm x 22.5 cm x 12.5 cm
Weight: 3 kg

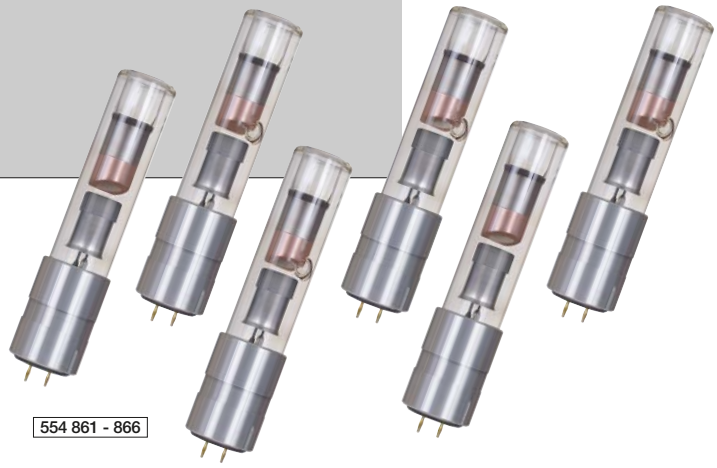
SIX interchangable tubes available!

X-ray tubes

Directly heated hot cathode tube with screw thread for heat sink and two-pin plug socket for cathode heating for X-ray apparatus (⋯› 554 800/801)

Max. emission current: 1 mA
Max. anode voltage: 35 kV
Size of focal spot: approx. 2 mm²
Minimum service life: 300 hours
Diameter: 4.5 cm
Length: 20 cm
Weight: 0.3 kg

NEW! Gold Tube



554 861 - 866

	$4,265. 554 861	**$4,265.** 554 862	**$4,265.** 554 863	**$4,265.** 554 864	**$4,265.** 554 865	**$5,265.** 554 866
X-ray tube	**Mo**	**Cu**	**Fe**	**W**	**Ag**	**Au**
Anode material	Molybdenum	Copper	Iron	Tungsten	Silver	Gold
characteristic radiation	K_α = 71.1 pm (17.4 keV) K_β = 63.1 pm (19.6 keV)	K_α = 154 pm (8.04 keV) K_β = 139 pm (8.91 keV)	K_α = 194 pm (6.40 keV) K_β = 176 pm (7.06 keV)	L_α = 148 pm (8.39 keV) L_β = 128 pm (9.67 keV)	K_α = 56,1 pm (22.1 keV) K_β = 49.7 pm (24.9 keV)	L_α = 128 pm (9.71 keV) L_β = 108 pm (11.4 keV)
Absorber foil (to generate monochromatic radiation)	Zirconium (Zr)	Nickel (Ni)	-	-	-	-

NEW!

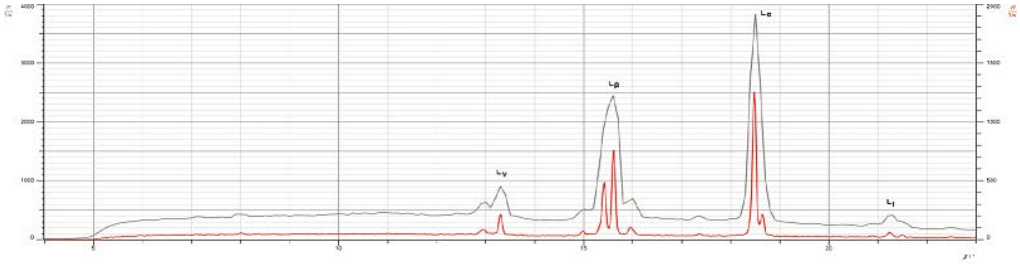
554 835 **$2,410.**

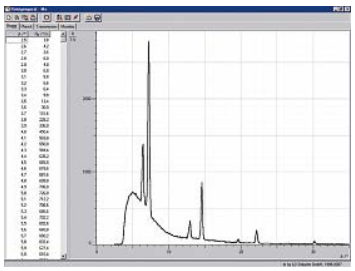
HD Accessory X-ray

HD upgrade kit for the X-ray apparatus (⋯› 554 800) with a Goniometer (⋯› 554 831).
Collimator slit widths: 0.3 mm
Counter tube holder column width: 0.3 mm
Angular resolution of the Goniometer: 0.01° (with supplied software)

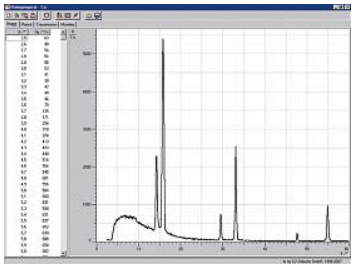
Scope of delivery
High-resolution Collimator
High-resolution Counter tube holder
Software for high-resolution control of the Goniometer

Comparison scan using the HD accessory - red line shows the additional peaks achieved using this accessory.

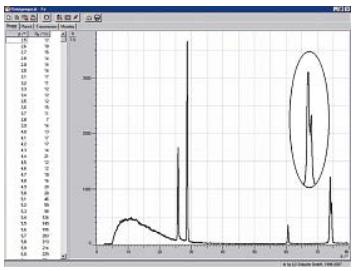




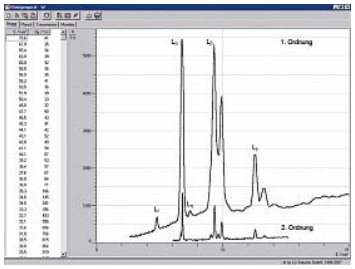
Bragg-spectrum (NaCl) of a molybdenum tube



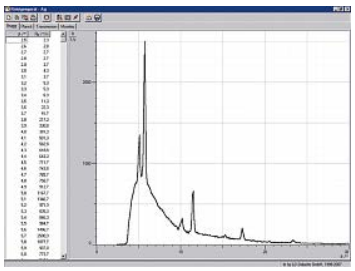
Bragg-spectrum (NaCl) of ac opper tube



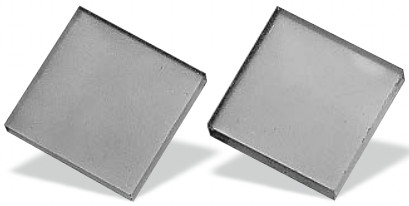
Bragg-spectrum (LiF) of ai ron tube with fine structure of the K_α-line in 2nd order resolved



Energy spectrum (LiF) of at ungsten tube, in 2nd order 4L β-lines are well resolved



Bragg-spectrum (NaCl) of as ilver tube



554 77 **$975.**

LiF crystal for Bragg reflection

Designed to fit the goniometer of the x-ray apparatus (⋯› 554 801). For experiments in Bragg's configuration, e.g. diffraction (up to the 5th order), x-ray spectra, wavelength determination, Duane and Hunt's displacement law, determining Planck's constant, dependence of absorption on wavelength, determination of lattice plane spacings.

Dimensions: 25 mm x 25 mm x 4 mm
Lattice-plane spacing: 201 pm
Reflection angle for molybdenum K_α-radiation (1st order): 10.2°
Crystal structure: face-centered cubic
Surface: parallel [100]

554 78 **$265.**

NaCl crystal for Bragg reflection

Design as (⋯› 554 77)

Lattice-plane spacing: 282 pm
Reflection angle for molybdenum K_α-radiation (1st order): 7.24°

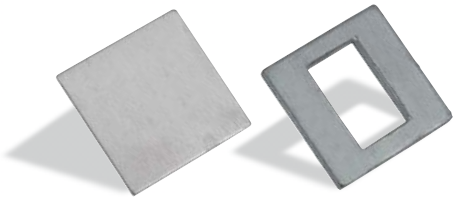
Picture of the blood vessel model (⋯› 554 839) on fluorescent screen

554 8391 **$320.**

Implant model

Wood quader with inserted hidden steel pin for the transillumination in the x-ray apparatus.

Additionally required: **$289.**
Film holder X-ray. 554 838



554 842 **$79.**

Set of 2 crystal powder holders

For pressing a crystal powder and then measuring the X-ray diffraction spectrums with powder samples in the X-ray apparatus (⋯› 554 801).

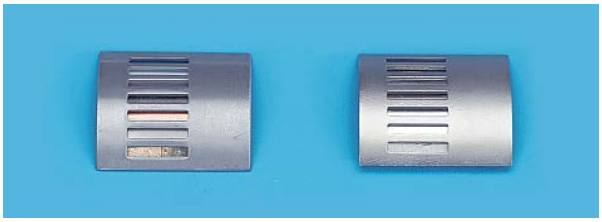
Dimensions: 25 x 25 x 3 mm each
Weight: 10 g

554 836 **$160.**

Compton accessory X-ray

For x-ray apparatus (⋯› 554 801) for investigating the Compton effect by means of wavelength-dependent transmission as a function of the placement of the Cu filter in front of or behind the aluminum scattering body; with aluminum scattering body and copper filter in frame.

Aluminum scattering body: 25 x 25 x 4 mm
Copper filter:
Frame: Ø 24 mm x 11 mm
Foil: 10 mm x 0.07 mm



554 834 **$450.**

Absorption accessory X-ray

For x-ray apparatus (⋯› 554 801). Two absorbers for quantitative investigation of the attenuation of x-rays as a function of the thickness and the atomic number of the absorber.

Thickness graduation of aluminum absorber: 0.5/ 1.0/1.5/ 2.0 / 2.5 and 3.0 mm
Material and atomic number for absorbers of constant thickness (0.5 mm):
polystyrene: Z = 6, aluminum: Z = 13, iron : Z = 26, copper : Z = 29,
zirconium : Z = 40, silver : Z = 47
Dimensions of diaphragm: 2.5 x 15 mm
Diaphragm spacing: 5 mm (approx. 10°)
Dimensions : 40 mm x 35 mm x 8 mm each

Scope of delivery: Absorber set I: varying thickness, same material
Absorber set II: varying materials, constant thickness

554 832 **$545.**

Set of absorber foils for X-ray apparatus (⋯› 554 800/801)

e.g. for experiments on the λ^3 relationship and Moseley's law; foils mounted in frame for attaching to slit diaphragm collimator or counter-tube holder.

Frame: 24 mm Ø x 11 mm, Foils: 10 mm Ø.

Z	element		thickness	
13	Al	aluminium	0.5	mm
26	Fe	iron	0.5	mm
29	Cu	copper	0.07	mm
40	Zr	zirconium	0.05	mm
42	Mo	molybdenum	0.1	mm
47	Ag	silver	0.05	mm
49	In	indium	0.3	mm

554 840 **$645.**

Plate capacitor X-ray

For x-ray apparatus (⋯› 554 800/801) for measuring the ionization current and determining the ion dose rate; electrical connections via 4 mm safety sockets and BNC socket. 3 plug-in mounting pins for defined setup of plate capacitor in the experiment zone.

Input voltage: 0 to 500 V DC
Saturation current: max. 3 x 10^{-9} A
Saturation voltage: approx. 100 V DC
Ionizable volume of air: 121 cm^3
Plate width: 8.5 cm/14 cm
Plate spacing: 3.5 cm
Dimensions: 19 cm x 14 cm x 17 cm

554 839 **$700.**

Blood vessel model for contrast medium

For the demonstration of the effect of contrast media. Plastic plate with covered channels, via screw connections the contrast medium can be injected from outside the x-ray apparatus and its penetration can be observed on the fluorescence screen of the x-ray apparatus. By variation of the distance, magnification effects can be demonstrated.

Scope of delivery:
Plate with blood vessel model on magnet support
Hose
2 plastic syringes
2 stoppers

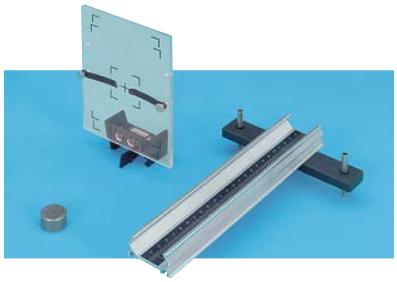
Necessary accessories: **$51.**
Potassium iodide, 100g. 672 6610

554 838 **$365.**

Film holder X-ray

For x-ray apparatus (⋯› 554 800/801), with printed scale for defined positioning of films for transillumination, Laue diagrams and Debye-Scherrer photographs; includes experiment rail with millimeter scale and pinhole diaphragm D = 1 mm for attaching to slit-diaphragm collimator.
Suitable X-ray films:
X-ray film 554 895
X-ray film Agfa Dentus M2. . . . . 554 896

Dimensions:
Film holder: 12 cm x 16.5 cm
Experiment rail: 25 cm x 16 cm x 6 cm
Pinhole diaphragm: 1 mm Ø



554 896 **$235.**

X-ray film Agfa Dentus M2 (without picture)

X-ray film welded in light proof plastic foil for use in day light. The film must be removed from the foil for development, for example with the aid of the changing bag (⋯› 554 899).

Packet contents: 25 films
Film size: 5 cm x 7 cm

554 804 **$2,750.** NEW!

Drawer for X-ray Apparatus

For storage of accessories including X-ray tubes, crystals, absorbers, filters, Geiger counter with holder and target table, X-ray energy detector, MCA box and film holder. Thanks to the padded, device-shaped storage system, your accessories can be stored optimally, clearly and in just one place. The lockable drawer is made of stable steel and fits under the X-ray apparatus and also under a tabletop as an alternative.

Dimensions: 67 cm x 10 cm x 35 cm

554 824 **$2,755.** NEW!

Drawer for Computer Tomography Module

For storage of accessories for the Computer Tomography Module including X-ray tubes, samples, object holder and Lego-Adapter. Thanks to the padded, device-shaped storage system, your accessories can be stored optimally, clearly and in just one place. The lockable drawer is made of stable steel and fits under the Tomography Module and also under a tabletop as an alternative.

Dimensions: 53 cm x 10 cm x 35 cm

Crystals for Laue diagrams

554 87 Lithium fluoride crystal **$245.**
554 88 Sodium chloride crystal **$175.**

554 8972 **$469.**

Developer and fixer for X-ray film (without picture)

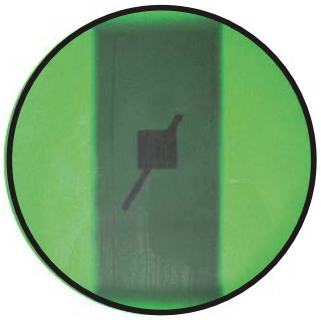
Pack of 10 portions of 125 ml each

554 8931 **$395.**

Changing bag with developer tank
(without picture)

For developing the x-ray film (⋯› 554 896) and for up to two 35 mm films. Changing bag made of double-layer special material. For putting a film in the development tank during daylight hours.

Dimensions of the changing bag: 55 x 65 cm
Volume of the developer tank: 500 ml



Picture of the implant model (⋯› 554 8391) on fluorescent screen

X-ray energy detector

The energy detector is designed for use with the X-ray apparatus (⋯› 554 801), recording energy separated measurements within the X-ray spectrum. The detector expands the range of experiments possible in quantum and atomic physics, and will also perform non-destructive material analysis.

Topics

Recording the spectrum of an x-ray tube and dependency on current and voltage
Quantitative investigation of the Compton effect
X-ray fluorescence and recording fluorescence spectra of different elements
Verification of Moseley's law using fluorescence spectra
Non-destructive material analysis

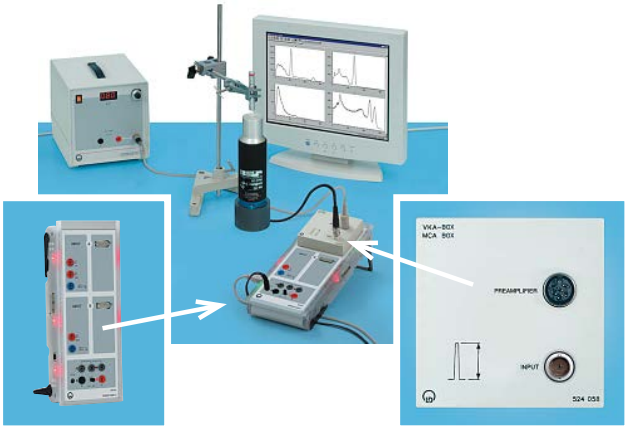
Material Analysis:
Geography (rock analysis)
Ecology (detection of heavy elements in nature)
Biology (chemical elements in food)
Chemistry (chemical analysis)

559 938 **$5,699.**

X-ray energy detector

For the insert in the X-ray apparatus (⋯› 554 801) for recording of energy dissolved X-ray spectra in connection with Sensor-CASSY (⋯› 524 013) and MCA box (⋯› 524 058). The detector contains a thermoelectric cold silicon PIN-detector as well as the electronics for amplification and preparation of the voltage impulses. The amount of the output impuls is proportional with the energy of the X-ray photon.

Photosensitive area: 0.8 mm Ø
Cooling of the detector: thermoelectric (Peltier element)
Entrance window (plastics): absorption equivalent to graphite with d = 40 µm
Detectable energy field: approx. 2 keV to 60 keV
Energy resolution at E = 6.40 keV (Fe K_α-line): 0.4 keV half-width value
Distribution voltage: ±15 V, +5 V (via plug-in power supply 100...250V, 50...60 Hz, in scope of delivery)
Output: BNC socket for connection to the MCA box
Dimensions: 60 mm x 120 mm x 60 mm
Weight: 450 g



524 013 524 058

524 013 **$2,460.**

Sensor-CASSY 2

Cascadable interface device for recording measurement data via connection to the USB-port of a computer, to another CASSY module or to the CASSY display.

5 Analog inputs
2 Analog voltage inputs A and B: 4-mm safety sockets (electrically isolated)
Resolution: 12 bits
Measuring ranges: ±0.1/0.3/1/3/10/30/100/250 V
Sampling rate: up to 1 MHz per input
1 Analog current input A on 4-mm safety sockets (alternatively to voltage input A)
Measuring ranges: ±0.03/0.1/0.3/1/3 A
Sampling rate: up to 1 MHz per input
2 Analog inputs at sensor box connector sites A and B
(All CASSY sensor boxes and sensors can be connected)
Sampling rate: up to 500 kHz per input
4 Timer inputs with 32-bit counters at sensor box sites A and B
Counting frequency: max. 1 MHz
Time resolution: 20 ns
5 LED status indicators for analog inputs and USB-port
Colors: red and green, according to the current status
Light intensity: adjustable
1 Changeover relay (switching indication via LED)
Range: max. 250 V / 2 A
1 Analog output (LED switching state indicator)
Variable voltage range: max. 16 V / 200 mA (load ≥8 0Ω)
For further details please have al ook at our website

524 220 **$1,260.**

CASSY Lab 2

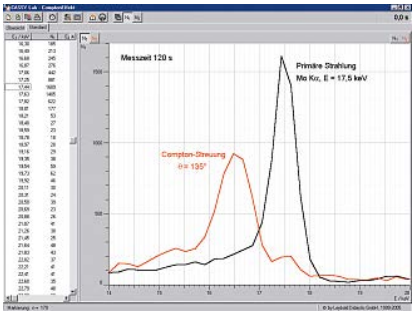
School (site) license CASSY Lab 2 for computer with Windows XP/Vista/7.

524 058 **$1,500.**

MCA Box

The MCA (multichannel analyzer) box is used in conjunction with the CASSY computer-assisted measurement system. It may be used for pulse height spectroscopy in general, and particularly for energy resolving measurements of radioactive radiation and X-ray emissions with a scintillation counter or a semiconductor detector.

Resolution: from 256 to 2048 channels (8-11 bits) per spectrum
Storage depth: 2 x 10^9 events per channel (31 bit)
Dead time: approx. 60 µs
Energy linearity: < 3% of final value
Coincidence window: 4 µs
Operating limit for external sensors: 0.5 V to 5 V according to the adjustment of the attenuator, positive or negative. Internal attenuator and polarity adjustable via software.



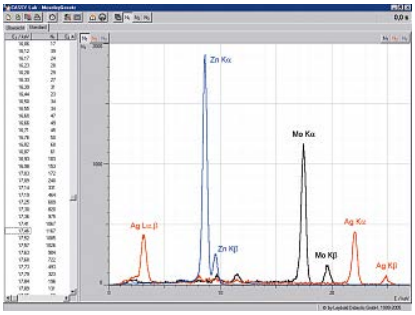
Direct determination of the energy loss of the scattered molybdenum K_α-radiation (Comptoneffect).

554 8371 **$240.**

Compton accessory X-ray II

For investigating the Compton-effect on X-ray radiation in combination with the X-ray energy detector (⋯› 559 938) and the X-ray apparatus (⋯› 554 801). Consists of a circular collimator and a Plexiglas radiation body.

Dimensions: 25 mm x 25 mm x 6 mm



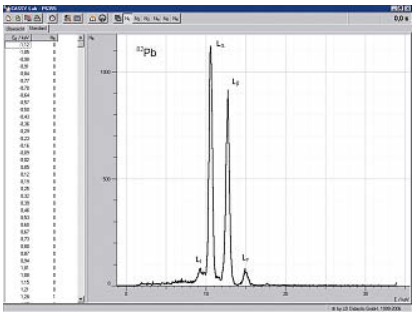
Energy loss of K-line as a function of the atomic number (Moseley law)

554 844 **$505.**

Set of targets K-line fluorescence

For recording the X-ray fluorescence spectrum of different elements in the X-ray apparatus (⋯› 554 801) in connection with the X-ray energy detector (⋯› 559 938), Sensor-CASSY (⋯› 524 010) and MCA box (⋯› 524 058).

Materials: Ti, Fe, Ni, Cu, Zn, Zr, Mo, Ag
Dimensions: 25 mm x 25 mm



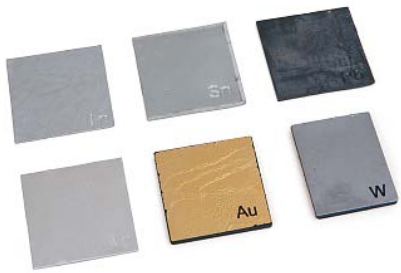
Excitation of the L-line fluorescence of lead

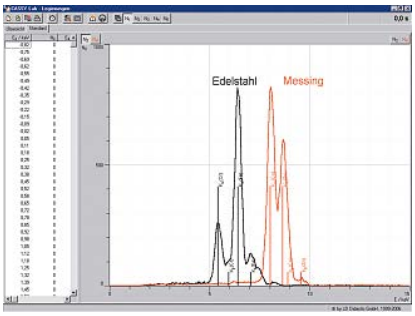
554 846 **$770.**

Set of targets L-line fluorescence

For recording the X-ray fluorescence spectrum of different elements in the X-ray apparatus (⋯› 554 801) in connection with the X-ray energy detector (⋯› 559 938), Sensor-CASSY (⋯› 524 010) and MCA box (⋯› 524 058).

Materials: Ag, In, Sn, W, Au, Pb
Dimensions: 25 mm x 25 mm





Determining the chemical composition of alloys by means of x-ray fluorescence analysis

554 848 **$230.**

Set of targets alloys

For recording the X-ray fluorescence spectrum of different alloys in the X-ray apparatus (⋯› 554 801) in connection with the X-ray energy detector (⋯› 559 938), Sensor-CASSY (⋯› 524 010) and MCA box (⋯› 524 058).

Materials: special steel X5CrNi18-10, brass CuZn36, brass CuZn39Pb3, cobalt samarium magnet
Dimensions: 25 mm x 25 mm

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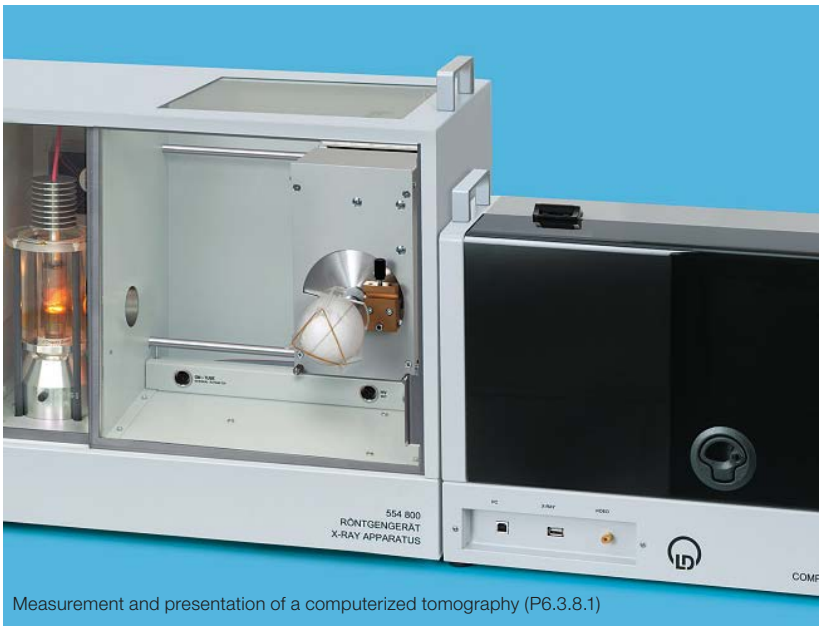
X-ray Tomography

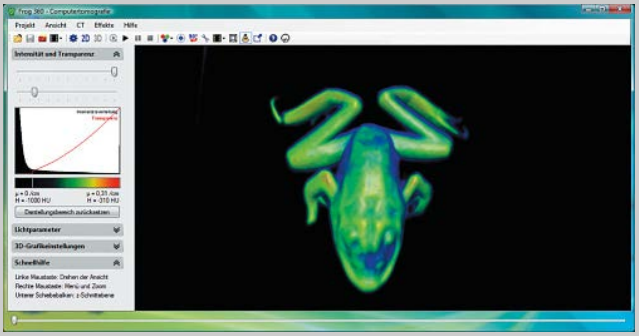


Measurement and presentation of a computerized tomography (P6.3.8.1)

P6.3.8 X-ray Tomography	P6.3.8.1	Measurement and presentation of a computerized tomography	
	P6.3.8.2	Computerized tomography of simple geometrical objects	
	P6.3.8.4	Measuring absorption coefficients in structured media with computerized tomography	
	P6.3.8.5	Computerized tomography of biological samples	
554821	**Computerized Tomography Module** *for use with 554800 X-ray Apparatus, 554831 Goniometer, 554864 W tube*		**$13,640.**

In 1972 the first computed tomographic scanner was built by Godfrey Hounsfield who, together with Allan Cormack, was awarded the Nobel Prize in Physiology or Medicine in 1979. The basic idea of computerized tomography (CT) is the illumination of an object by X-rays from numerous different angles.
Our educational X-ray apparatus allows the illumination of objects by X-rays. The resulting 2D-projections are visualized at the fluorescence screen.
By turning an object using the built-in goniometer of the X-ray apparatus, and recording the 2D-projections from each angular step, the computer can reconstruct the object illuminated by X-rays. Our e-learning software visualizes the back projection (necessary for reconstructing the computed tomography) concurrently with the scanning process. The 3D-model is then displayed on the PC screen.

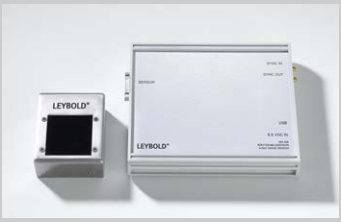
Experiment P6.3.8.4 analyses the absorption coefficient of water inside a plastic body to demonstrate the capabilities of CT in distinguishing different kinds of tissues and discusses hardening effects of the X-rays.
Experiment P6.3.8.5 analyses the CT of real biological specimens and applies to the results of the previous experiments.


Computed tomography of a frog (P6.3.8)

554 820P1 **$39,950.**

Computed Tomography Pro package

Compact high-resolution sensor head with USB module for capturing X-ray images with an X-ray apparatus at daylight conditions (without X-ray film). Together with the precision slide (554 829), the image sensor is a high performance camera for X-ray photography, radiology, material testing, crystallography and computed tomography for use in practical trainings and demonstrations at universities.



Includes: X-ray image sensor, rail, software, power supply