554 801
X-ray apparatus
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. Alternative the two analogue outputs (counting rate and angular position) permit data acquisition using a chart recorder.

The goniometer (l 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 (l 554 831)
NaCl crystal (l 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 l 554 800 or l 554 801:
End-window counter with cable . . . . . . . . . . . . . . . . . . . . . . . . . . . 559 01

Including Windows software for recording and evaluating data

LabVIEW™ is a registered trademark of National Instruments
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

<table>
<thead>
<tr>
<th>X-ray tube</th>
<th>Mo</th>
<th>Cu</th>
<th>Fe</th>
<th>W</th>
<th>Ag</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anode material</td>
<td>Molybdenum</td>
<td>Copper</td>
<td>Iron</td>
<td>Tungsten</td>
<td>Silver</td>
</tr>
<tr>
<td>characteristic radiation</td>
<td>$\lambda_{Kα} = 71.1$ pm (17.4 keV)</td>
<td>$\lambda_{Kα} = 154$ pm (8.04 keV)</td>
<td>$\lambda_{Kα} = 194$ pm (6.40 keV)</td>
<td>$\lambda_{Lα} = 148$ pm (9.39 keV)</td>
<td>$\lambda_{Kα} = 56.1$ pm (22.1 keV)</td>
</tr>
<tr>
<td>$\lambda_{Kβ} = 63.1$ pm (19.6 keV)</td>
<td>$\lambda_{Kβ} = 139$ pm (8.91 keV)</td>
<td>$\lambda_{Kβ} = 176$ pm (7.06 keV)</td>
<td>$\lambda_{Lβ} = 128$ pm (9.67 keV)</td>
<td>$\lambda_{Kβ} = 49.7$ pm (24.9 keV)</td>
<td></td>
</tr>
<tr>
<td>Absorber foil (to generate monochromatic radiation)</td>
<td>Zirconium (Zr)</td>
<td>Nickel (Ni)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

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

- Bragg-spectrum (NaCl) of a molybdenum tube
- Bragg-spectrum (NaCl) of a copper tube
- Bragg-spectrum (LiF) of a iron tube with fine structure of the $K_{α}$-line in 2nd order resolved
- Energy spectrum (LiF) of a tungsten tube, in 2nd order 4 $L_{β}$-lines are well resolved
- Bragg-spectrum (NaCl) of a silver tube
**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:** $K_{\alpha}$ radiation (1st order): 10.2°
- **Crystal structure:** face-centered cubic
- **Surface:** parallel [100]

**NaCl crystal for Bragg reflection**

Design as (→ 554 77)

- **Lattice-plane spacing:** 282 pm
- **Reflection angle for molybdenum:** $K_{\alpha}$ radiation (1st order): 7.24°

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**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

**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):**
- **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

**Set of absorber foils for X-ray apparatus (→ 554 800/801)**

- **Materials:**
  - Polystyrene: Z = 6
  - Aluminum: Z = 13
  - Iron: Z = 26
  - Copper: Z = 29
  - Zirconium: Z = 40
  - Silver: Z = 47
  - Indium: Z = 49

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

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**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
Film capacitor 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...554 885
- 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

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 cm³
Plate width: 8.5 cm/14 cm
Plate spacing: 3.5 cm
Dimensions: 19 cm x 14 cm x 17 cm

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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:
- 672 6610 potassium iodide, 100 g

Implant model (without picture)

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

Additionally required:
- Film holder X-ray...554 838

X-ray film Agfa Dentus M2 (without picture)

X-ray film welded in light proof plastic foil for use in daylight. 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

Developer for X-ray film (without picture)

Pack of 10 portions of 125 ml

Fixative for X-ray film (without picture)

Pack of 10 portions of 125 ml

Development tank 500 ml (without picture)

For developing the x-ray film (554 896) and for up to two 35 mm films.

Changing bag for the developer tank (without picture)

Made of double-layer special material. For putting a film in the (554 893) developer tank during daylight hours.

Dimensions: 55 cm x 65 cm

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

**X-ray energy detector**

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)

For the insert in the X-ray apparatus (→ 554 801) for recording of energy dissolved X-ray spectra in connection with Sensor-CASSY (→ 524 010) and MCA box (→ 524 058). The detector contains a thermolectric cold silicon PIN-detector as well as the electronics for amplification and preparation of the voltage impulses. The amount of the output impulse is proportional with the energy of the X-ray photon.

Photosensitive area: 0.8 mm Ø
Cooling of the detector: thermolectric (Peltier element)
Enterance 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 Kα line): 0.4 keV half-width value
Distribution voltage: ±15 V, +5 V (via plug-in power supply, 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
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

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

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

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

Direct determination of the energy loss of the scattered molybdenum Kα-radiation (Compton effect).

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

Excitation of the L-line fluorescence of lead

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