5/1990 -Di/Sf-

Instruction Sheet **559 56/54/52**

Scattering Chamber after Rutherford
Gold Foil in Holder
Aluminium Foil in Holder

The scattering chamber after Rutherford is a vacuum chamber by which it is especially simple to demonstrate the scattering of α-particles caused by thin metal foils in a qualitative and quantitative manner ('Rutherford scattering'). The alpha particles are recorded via a semiconductor detector with counter.

Moreover, the chamber can be used for experiments on alpha spectroscopy, together with the film holder for alpha scattering (559 55).

Examples of Experiments

Qualitative

- Deflection of alpha particles when passing through a gold foil
- Backscattering of alpha particles
- Scattering of alpha particles in air

Quantitative

- Dependency of scattering rate N on scattering angle ϑ in the case of Rutherford scattering
- Dependency of scattering rate N on atomic number Z
- Alpha spectroscopy

Principle

A beam of monoenergetic alpha rays is directed onto a thin metal foil (gold or aluminium). Besides those α-particles which penetrate the foil virtually without changing their direction, there are such α-particles which are scattered by the also positively charged nuclei of the foil material. These are deflected by different angles ϑ. Measurement of the scattering rate N (ϑ) allows to draw conclusions with respect to nuclear diameter and atomic number of foil material.

Bibliography :
Physics Experiments, Volume 3 (Optics - Atomic and Nuclear Physics - Solid-state Physics) 599 942

1 Safety Notes

- Never touch the metal foil!
- Very carefully vent scattering chamber (see Section 3.4) as otherwise the delicate foils will be damaged!
- Project only for a short time (max. 5 mins.) by the overhead projector!
- Only slightly tighten the knurled screws on clamping fixture (11) or swivel holder (6) !

2 Standard Equipment, Description, Technical Data
(559 56)

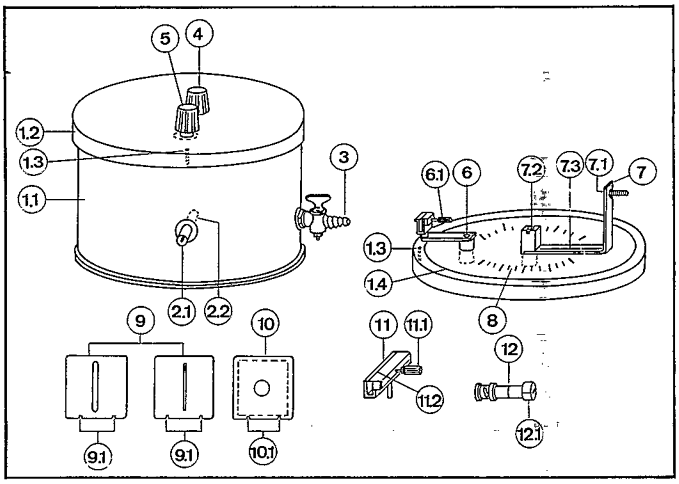


Fig. 1 Standard equipment

(1) Chamber, consisting of lower part (1.1) and lid (1.2), sealed by a rubber ring (1.4) (Spare Part No. 239 50 184), with positioning pin and borehole (1.3) for correct positioning of the lid

(2) BNC dual socket
 (2.1) for BNC cable (501 02) connected to discriminator preamplifier (559 93)
 (2.2) for alpha detector (12)

(3) Stop-cock with built-in air filter, for evacuating and venting, with hose nozzle for vacuum tubing of 8 to 10 mm I.D. (e. g. 307 68)

(4) Rotary knob for swivel arm (7)

(5) Rotary knob for swivel holder (6)

(6) Swivel holder for foil (in qualitative experiments), with knurled-head screw (6.1) to fasten the foil

(7) Swivel arm with 4-mm socket (7.1) for fitting the preparation, and with socket (7.2) for inserting the clamping fixture (11), with slit (7.3) for reading angles on scale (8)

(8) Angle scale, graduated in 5 degree steps, for adjustment of scattering angle

(9) Collimator slit, 1 mm (5 mm) wide, in plastic plate (5 cm x 5 cm), with guide grooves (9.1) for correct positioning in clamping fixture (11)

(10) Gold foil on plastic plate (5 cm x 5 cm) with 12 mm opening,
foil thickness: 2 μm,
Spare Part No. 559 54

interchangeable with:
Aluminium foil (559 52)
foil thickness 7 μm, on plastic plate (5 cm x 5 cm),with 12 mm opening(not included in standard equipment)

⑪ Clamping fixture for fitting into (7.2), for collimator slit ⑨ and – for quantitative experiments – foil ⑩, with fastening screw (11.1) and guide edge (11.2) cutting the rotational axis

⑫ Alpha detector with BNC plug for plugging into socket (2.2), with slit diagram (12.1) 2 mm x 6 mm and marking on the circumference for perpendicular alignment of the slit

Dimensions of chamber: dia. 19 cm, height 11 cm
Weight: 1.8 kg

3 Use

> *Important:* When venting the chamber after the experiment, it is imperative to proceed according to Section 3.4.

3.1 Additionally required:

Americium-241 preparation	559 82
Vacuum pump, ultimate pressure < 100 Pa (≙ 1 mbar), e. g. Rotary vane vacuum pump S 1.5	101 01 S
Vacuum tubing	307 68
Discriminator preamplifier	559 93
Plug-in power supply unit	530 88
BNC cable, 1 m long (2x)	501 02
Counter, e.g.	
LH-digital counter	575 40
counter P	575 45
stopclock	313 05
screened cable BNC/4mm	575 24
Recommended: overhead projector, e.g.	
Overhead Projector NV-A4/315	452 11

3.2 Preparing the experimental set-up

Connect scattering chamber, discriminator preamplifier and counter as shown in Fig. 2. Set discriminator to zero (potentiometer fully anticlockwise). Connect detector ⑫ to socket (2.2) and fit vacuum tubing to hose nozzle ③.

3.3 Experiments

3.3.1 Deflection of alpha particles by a gold foil (qualitative)

Remove the lid. Push americium-241 preparation into socket (7.1) down to the stop. Bring swivel arm ⑦ to the +15° position by means of rotary knob ④ and insert clamping fixture ⑪ into (7.2). Insert 5-mm slit ⑨, grooves first (slit engages in mid position), and arrest it by **slightly** securing the knurled-head screw. Align clamping fixture so that the rays fall vertically on to the slit plane. Move swivel holder ⑥ toward the clamping fixture ⑪ as shown in Fig. 3. Insert gold foil ⑩ into the swivel holder ⑥ so that 5-mm slit and gold foil are positioned in parallel, close to each other.

Carry out vertical alignment of entrance slit (12.1) of the detector (marking on top). Place lid on to the chamber making sure of correct positioning (positioning pin in borehole (1.3)). Firmly press it on, if necessary. Then evacuate the chamber.

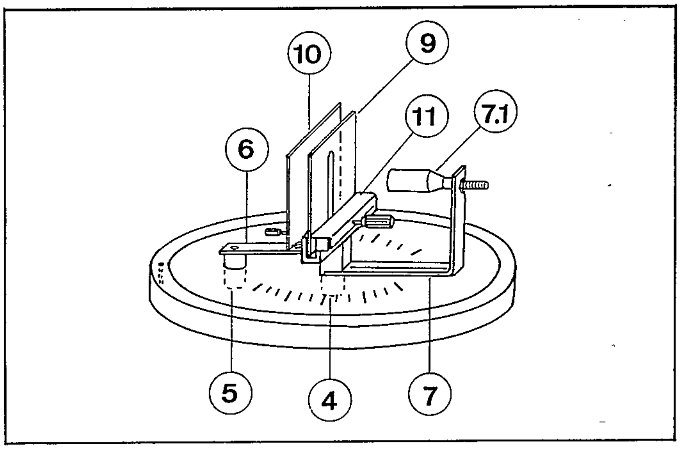


Fig. 3 Positioning of foil and collimator slit during sidescattering

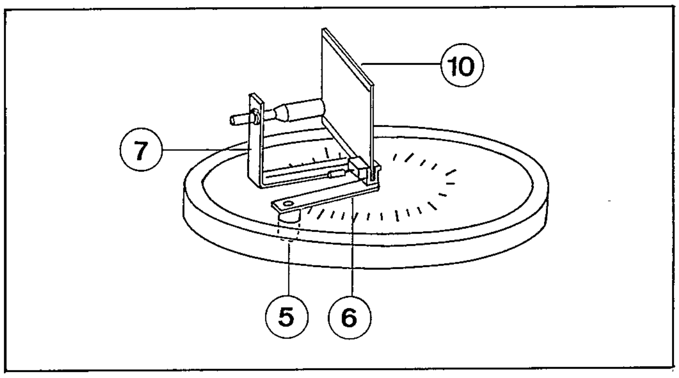


Fig. 4 Positioning of preparation and foil during backscattering

Carrying out the experiment:

Move the gold foil ⑩ to the side via rotary knob ⑤, and move swivel arm ⑦ to the 0° position. Observation: high counting rate.

Slowly bring swivel arm ⑦ to the +15° position. Observation: counting rate drops zo zero.

Again move the gold foil into the path of rays. Observation: counting rate is distinctly different from zero.

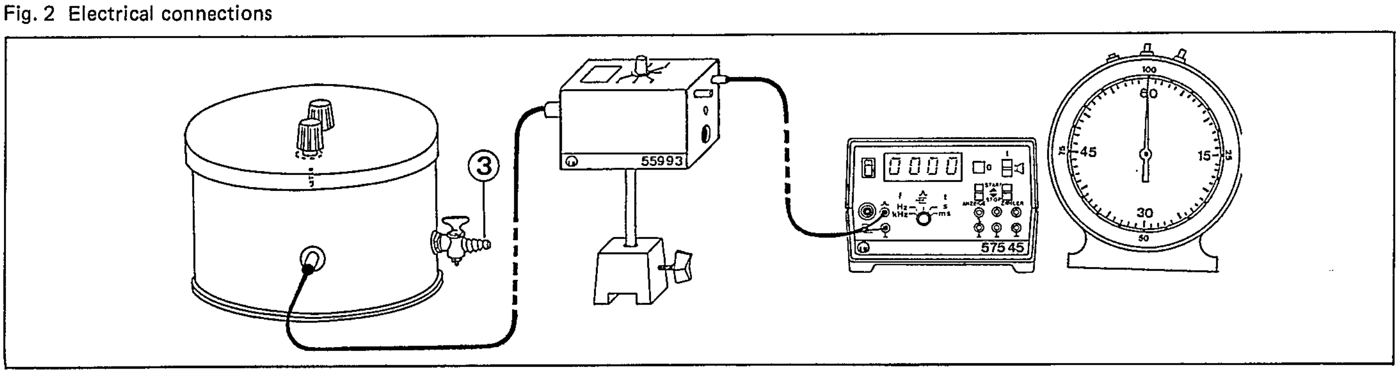
Result:

When passing through the gold foil, the alpha particles are deflected from their straight path and partly directed to the detector.

3.3.2 Backscattering of alpha particles (qualitative)

Insert Americium-241 preparation into socket (7.1) down to the stop. Bring swivel arm ⑦ to 150° position. Move swivel holder ⑥ to centre of chamber according to Fig. 4. Fasten gold foil ⑩ in the swivel holder so that the gold layer is at the outside and, after closing the chamber, in front of Americium-241 preparation and detector. Apply lid and evacuate the chamber.

Fig. 2 Electrical connections



Performing the experiment and result:

When the gold foil is positioned in front of detector and Americium-241 preparation, approx. 1 to 2 alpha particles per minute are scattered back from the foil into the detector (backscattering). After moving the gold foil (knob ⑤) to the chamber's edge, the counting rate is zero.

3.3.3 Measuring the angle dependency N (ϑ) in the case of Rutherford scattering

Setting up and performing the experiment:

Insert americium-241 preparation into socket (7.2) of the swivel arm down to the stop.

Insert the gold foil ⑩ and the 1-mm slit ⑨ – grooves first – together into the clamping fixture ⑪ (allow it to engage in mid position), so that the gold foil is flush with the guide edge (11.2) and the rotational axis runs precisely through the foil (Fig. 5). Align the clamping fixture ⑪ so that the rays fall vertically on to the slit plane. Move swivel holder ⑥ to the chamber's edge so that the measurements are not disturbed. Align slit diaphragm ⑫ of the detector vertically (marking on diaphragm circumference on top). Close and evacuate the chamber.

> *Important:* During measurements avoid direct exposure of the delicate detector to rays, particularly from fluorescent lamps. If necessary, cover the chamber during measurement with a black cloth or similar.

Count at least ten particles ($n(\vartheta) > 10$) each at $\vartheta = 0°$, $\pm 10°$, $\pm 20°$ and $\pm 30°$ and note down the required time Δt.

Calculate the counting rate $N = \frac{n(\vartheta)}{\Delta t}$ and plot a graph of log $N = f(\vartheta)$ (Fig. 6).

For plotting curves beyound $\pm 30°$ angles (long measuring times due to low counting rates; see Fig. 7), replace the 1-mm slit by the 5-mm slit; again determine the counting rate for 30° and calculate the conversion factor k:

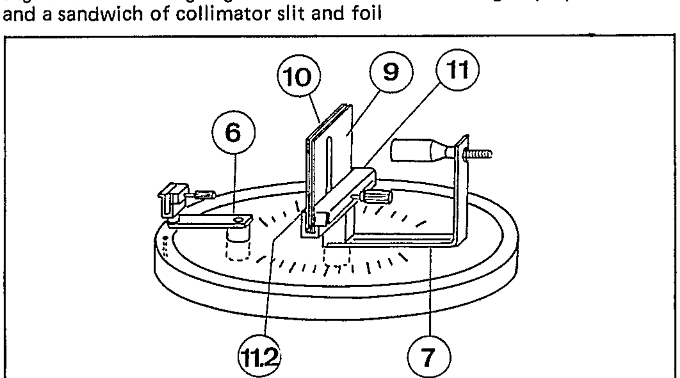
$$k = \frac{N(30°) \text{ with 5-mm slit}}{N(30°) \text{ with 1-mm slit}}$$

For adaptation to the measured values for $\vartheta \leqslant 30°$, divide the counting rates determined for $\vartheta = 40°, 50° \ldots$ by the conversion factor k.

Notes:

Inaccuracy of the collimator adjustment or non-centrical distribution of the radiation of the americium preparation in the holder may cause a shifting of the curve along the abscissa (angle shift < 3°; if necessary, displace the system of coordinates).

Fig. 5 For recording angular distribution: Positioning of preparation and a sandwich of collimator slit and foil



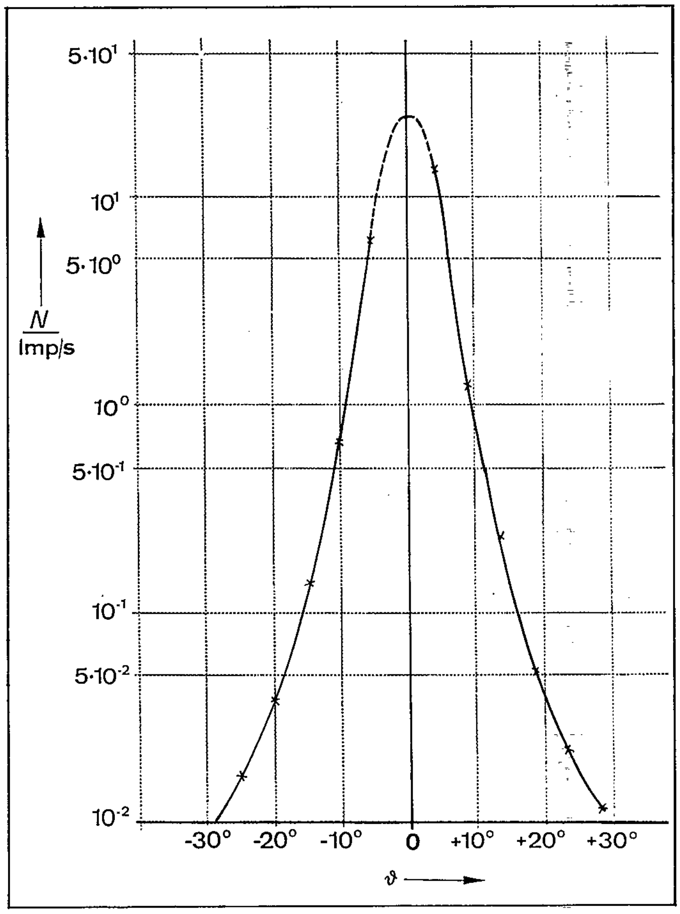
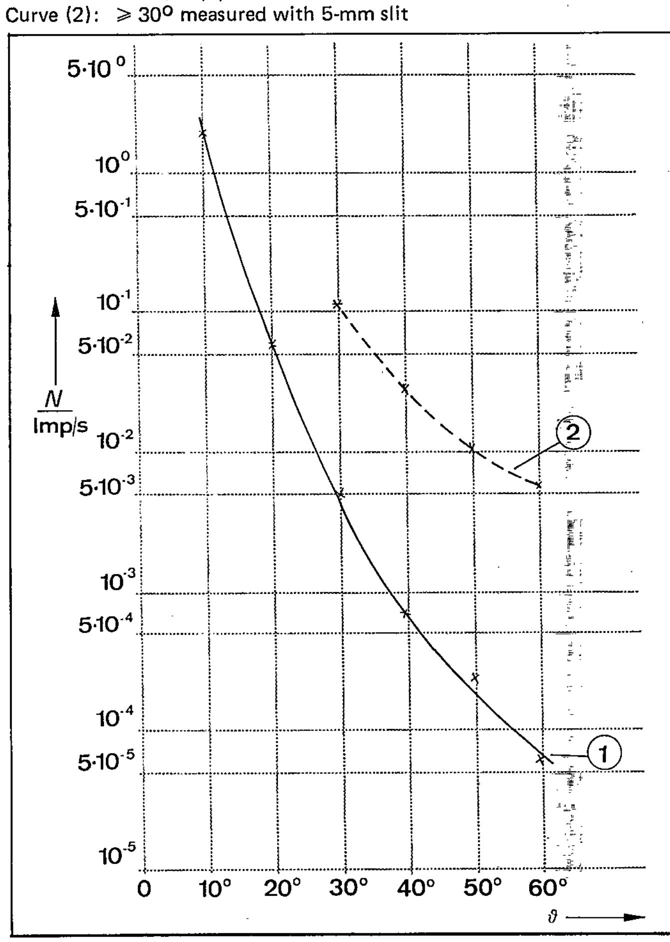


Fig. 6 log N = f (ϑ) in the ± 30° scattering range

Fig. 7
log N = f (ϑ) in the 0 . . . 60° scattering range
Curve (1): 0 . . . 30° measured with 1-mm slit > 30°: measured values of curve (2) converted to 1-mm slit
Curve (2): ⩾ 30° measured with 5-mm slit



Theoretically it applies:

$N(\vartheta) \sim 1/\sin^4(\vartheta/2)$.

It should be possible to bring to coincidence the measured-value diagram with the likewise semilogarithmically plotted function $f(\vartheta) = 1 \sin^4(\vartheta/2)$ by shifting along the ordinate.

Recommended alternatives for plotting the curve over large angle ranges: Recording the α-scattering on nuclear film (559 53) which is to be positioned in the film holder for α-scattering (559 55) as required for the experiment.

3.3.4 Determining the atomic number of aluminium

Compare scattering rates of gold foil and aluminium foil for a scattering angle of 10° (use 1 mm collimator slit).

It applies:

$$\frac{N_{Au}}{N_{Al}} = \frac{Z_{Au}^2 \, d_{Au}}{Z_{Al}^2 \, d_{Al}}$$

where N = counting rate
Z = atomic number
d = thickness of foil

Possible sources of error: faulty counts caused by disturbances from the mains.

Measurement Example:

$N_{Au} = 0.3\ s^{-1}$, $N_{Al} = 0.027\ s^{-1}$

With the values

$d_{Au} = 2\ \mu m$
$d_{Al} = 7\ \mu m$
$Z_{Au} = 79$

one obtains

$$Z_{Al} = \sqrt{\frac{79^2 \cdot 2 \cdot 0{,}027}{0.3 \cdot 7}} = 12{,}7 \qquad (Z_{Al} = 13)$$

3.4 Venting of the chamber

It is imperative for venting to proceed as follows:

Close venting cock ③.

Switch off the pump **and vent** the chamber.

Remove the gold foil (via rotary knob ⑤) from the danger zone of instreaming air, i. e. move it as close as possible to the chamber wall. If the foil is mounted in the clamping fixture ⑪, align the foil so that it is in parallel to the expected air flow.

Only then slowly and carefully open the venting cock ③ until a hissing sound is heard. Leave the cock in that position until the hissing stops and the chamber is completely vented.

3.5 Projection of chamber by the overhead projector

Place the chamber on the projector and focus the light beam so that a sharp image of the detector ⑫ appears. Measurements during projection are not possible due to the luminous sensitivity of the detector. Therefore, switch off the projector during measurements, which is also recommendable in order to avoid excessive heating of the inside of the chamber (there is no heat flow in vacuum!).