Atomic and nuclear physics

X-ray physics

Detection of X-rays

Influence of a contrast medium on the absorption of X-rays

Experiment objective

- Investigation of how a contrast medium affects the absorption of X-rays

Principles

During X-ray investigations of living creatures, on first sight only the bones are clearly visible because, on account of their composition, they absorb a considerable amount of the X-rays. The imaging and distinction of individual organs is a lot more difficult because they usually have an X-ray absorption very similar to that of the surrounding tissue. A gall bladder or kidney is not visible on the X-ray image, likewise the coronary arteries

The way out of this is to fill the organs to be recorded in the X-ray image with a strongly absorbing material. Such a material is called a contrast medium because in the X-ray image it ensures clear contrast between the investigated organ and the other tissues.

Elements with a high atomic number Z are particularly suitable for this, provided they are available in a form which is not toxic. Many elements are excluded on account of the toxicity of their compounds, and essentially there are only two groups of substances which are in practical use.

There is non-soluble barium sulphate which can be drunk in the form of a suspension and is used for imaging the digestive tract while it moves through it.

Other organs such as the kidneys or the gall bladder can only be filled with a contrast medium from the outside with great difficulty. For this reason an attempt was made to find a contrast medium which can be injected into the bloodstream and which is then excreted by either the kidneys or the liver. Most usually iodine compounds are used for such purposes as they are biologically relatively harmless compared to compounds made up of heavier elements. Typically, contrast media based on tri-substituted aromatic iodine compounds are used. Depending on the remaining side chains, one distinguishes between ionic and non-ionic contrast media which have different pharmacokinetics. Some are preferably excreted by the kidneys, others via the liver.

When imaging blood vessels, e.g. the coronary arteries, the contrast medium is injected directly into the blood vessels, if required via a catheter close to the organ, and it should then be quickly excreted again.

This experiment investigates the effect of a contrast medium on the absorption of X-rays. Because for the model of blood vessels described here the contrast medium only flows through plastic tubes and between plastic plates, a simple and cheap iodine compound such potassium iodide can be used instead of the tri-substituted aromatic iodine compounds used with people.

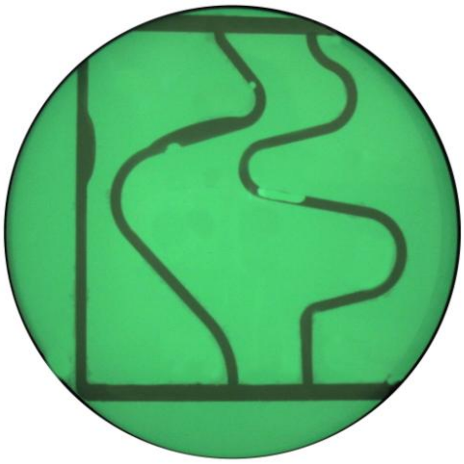

Fig. 1: Picture of a model blood vessel with a contrast medium on a fluorescent screen, taken with a digital camera.

The model blood vessel consists of a channel 2 mm deep covered by a plastic plate. Liquids such as water or a contrast medium can be injected from outside the X-ray apparatus while the tube is switched on.

Initially the model is filled with pure water. After the apparatus is switched on, the fluorescent screen will simply display a uniform green and the course of the channels inside the model remains invisible. Next, the water is replaced with a solution of potassium iodide. Then the parts of the equipment with the potassium iodide solution in them appear as dark areas on the screen (see Fig. 1).

Equipment

1 X-ray apparatus	554 800
1 X-ray tube, Mo	554 861
1 Blood vessel model for contrast medium	554 839
1 Potassium iodide, 100 g	672 6610
1 Beaker, 150 ml	602 023
1 Glass rod, 200 mm, 6 mm diam.	602 783
1 Wide-necked flask, brown glass, 250 ml	602 295

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Safety instructions

The X-ray apparatus meets all regulations applicable to the design of an X-ray tube for use in schools and the demands for fully protected equipment. It is certified as fully protected and approved for use in schools under Germany's X-ray protection legislation (BfS 05/07 V/Sch RöV).

The factory-fitted protective equipment and shielding leads to dosage outside the apparatus being reduced to less than 1 μSv/h, a figure of the same order of magnitude as recorded for ordinary background radiation.

- Before using the X-ray apparatus, check that it is undamaged and make sure that the anode lead is inserted into the heat sink of the X-ray tube (see instruction manual for X-ray apparatus).
- Prevent unauthorised persons from gaining access to the X-ray tube

Avoid overheating of the anode in the molybdenum X-ray tube.

- When you turn on the X-ray apparatus, make sure the fan is turning.

Observe the instruction manual for the X-ray apparatus (554 800) and the molybdenum Y-ray tube (554 861).

Observe all valid stipulations for working with chemicals.

Preparations for experiment

Dissolve about 25 g of potassium iodide in 50 g of water. The solubility of potassium iodide is 72 g per 50 g of water. To prevent it crystallising out, a 50% solution is employed.

Note:

Initially the potassium iodide solution will not contain any free iodine but only iodide radicals, and therefore remains clear. Over the course of some days, elementary iodine will develop, which causes the solution to gain a strong yellow coloration. It will also discolour and attack the syringes and tubes used.

After the experiment is finished, the set-up therefore needs to be thoroughly rinsed with water. In addition, potassium iodide can only be reused a limited number of times. Storing the solution in a brown glass jar considerably increases its lifespan.

Set-up

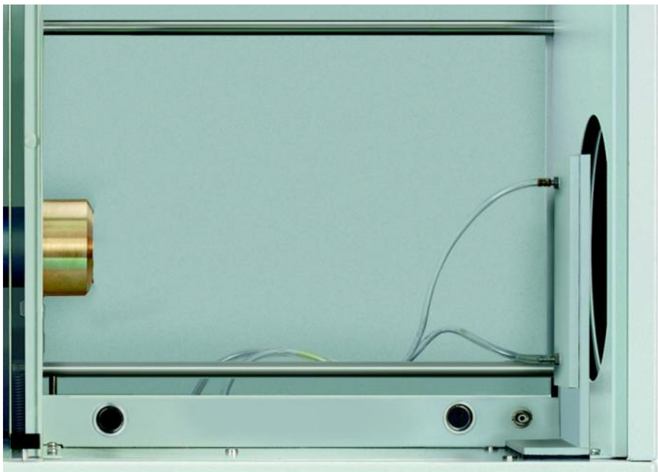

Fig. 2: Experiment set-up

Note:

During the experiment it must be ensured when inserting and removing tubes through the channel of the X-ray device that the tubes are closed by means of the appropriate stopper. If any liquid escapes, the power supply is to be cut off IMMEDIATELY and the device is to be taken out of use. Only then may the device be cleaned. If a considerable quantity of iodine solution has escaped into the device, it is best to send it to the manufacturer for cleaning.

The experiment set-up is shown in Fig. 2.

- If the goniometer is present, remove it from the experiment chamber of the X-ray apparatus and take out the collimator.
- The blood vessel model should be set up in the experiment directly in front of the fluorescent screen, with the tubes **equipped with stoppers** running through the X-ray apparatus' channel to the outside of the unit.
- Close the leaded glass sliding door.

Procedure and conclusions

Note:
Carry out the experiment in a darkened room.

a) Water

- Fill one of the syringes with water and connect it to the tube on the lower nozzle of the blood vessel model.
- Connect the empty syringe to the top nozzle of the blood vessel model.
- Set the high voltage for the tube to U = 35 kV and set up an emission current I = 1.0 mA. Turn on the power using the HV ON/OFF button. The fluorescent screen should light up green.
- By alternately pulling on the empty syringe and pressing on the full one where necessary, water is then "injected" into the model.

The fluorescent screen continues to be lit up uniformly in green. The paths of the channels inside the blood vessel model remain invisible.

The injected water, like the surrounding plastic model, is made up of light elements. The absorption cross-sections for X-rays do not differ by very much. That is why there is no contrast on the fluorescent screen between the channels filled with water and the surrounding plastic.

b) Contrast medium

- Empty the blood vessel model back along the path by which it was filled.
- Remove the syringe from the end of the tube from the lower nozzle and seal the end of the tube with a stopper.
- Empty the syringe that was filled with water and draw potassium iodide into it. Connect the syringe once again to the tube on the lower nozzle of the blood vessel model.
- By alternately pulling on the empty syringe and pressing on the full one where necessary, the contrast medium is then "injected" into the model.

On the fluorescent screen it can now be seen how the contrast medium slowly rises up the channels. The iodine contained in the medium has a much greater absorption spectrum than the surrounding plastic due to its higher atomic number Z and therefore looks dark on the fluorescent screen (see Fig. 1). Air bubbles contained in the channels have very poor contrast, though, and they therefore appear bright.

After the experiment is finished, the equipment is emptied back along the direction it was filled and then the syringes can be disconnected from the tubes. After **both tubes have been sealed with stoppers**, they are pulled back through the channels and removed from the model. The blood vessel model, the tubes and the syringes should then all be rinsed in water one more time in order to clean out any residual iodine. When rinsing, use water with no lime content where possible, to avoid limescale being deposited within the model or the tubes.

Note:

Instead of viewing a direct image of the model blood vessel on the fluorescent screen, there are a number of other alternatives, as follows:

- Imaging the model using X-ray film

  Additionally required:

  1 X-ray film 554 895/6

- Photographing the fluorescent screen with a digital camera

  Additionally required:

  1 Camera holder for X-ray apparatus 554 891

  1 Suitable digital camera

  If the camera has an option to show a preview in the form of a live video signal, this too can be displayed on a screen.

- Imaging the fluorescent screen using the camera from the computer tomography set

  Additionally required:

  1 Computer tomography module 554 821

You can find more detailed instructions on the set-up and procedure of the experiment in the instruction manuals for the blood vessel model and the other equipment used.