Contrast medium experiment with a blood vessel model (Item No.: P2541901)

Curricular Relevance

Area of Expertise:	Education Level:	Topic:	Subtopic:	Experiment:
ILIAS	Physik	Hochschule	Moderne Physik	Röntgenphysik

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Difficult	1 Hour	2 Hours	2 Students

Additional Requirements:

Experiment Variations:

Keywords:

Bremsstrahlung, characteristic X-radiation, law of absorption, mass absorption coefficient, contrast medium

Overview

Short description

Principle

When a blood vessel model is irradiated with X-rays, the blood vessels themselves are not visible at first. It is only after the injection of a contrast medium that the blood vessels become visible.

This experiment is included in the upgrade set “XRI 4.0 X-ray imaging”.

Fig. 1: P2541901

Equipment

Position No.	Material	Order No.	Quantity
1	XR 4.0 expert unit, X-ray unit, 35 kV	09057-99	1
2	XR 4.0 X-ray plug-in unit W tube	09057-81	1
3	XR 4.0 X-ray Blood vessel model for contrast fluid	09058-06	1
4	Potassium iodide 50 g	30104-05	1
5	Glass beaker DURAN®, short, 250 ml	36013-00	1
6	Reagent bottle,scr.cap,cl.,250ml	46213-00	1
7	Glass rod, boro 3.3, l=200mm, d=6mm	40485-04	1
8	XR 4.0 X-ray fluorescent screen	09057-26	1
9	Slide mount for optical bench expert, h = 30 mm	08286-01	2
10	Table with stem	09824-01	1
11	XR 4.0 X-ray optical bench	09057-18	1

Tasks

Inject a 50% potassium iodide solution into the blood vessel model and observe the fluorescent screen of the X-ray basic unit to follow the flow of the injected solution in the blood vessel model.

Setup and Procedure

Procedure

In order to prepare the contrast medium, dissolve 10 g of potassium iodide in 20 ml of water.	
Place the blood vessel model in the small safety trough that is provided. Then, position the trough directly in front of the fluorescent screen that should be located as far to the right as possible on the optical bench (Fig. 2).	 Fig. 2: set-up in the experiment chamber
Lead the tubes through the working channel to the outside (Fig. 3).	 Fig. 3: Tubes laid through the working channel
Fill one of the two syringes with the contrast medium.	
Connect the two syringes to the ends of the tubes: Ensure that the filled syringe is connected to the lower inlet of the model (Fig. 4).	 Fig. 4: Procedure
Set the X-ray tube to operate with an acceleration voltage of U_a = 35 kV and an anode current of I_a = 1 mA.	
The irradiation is performed without any diaphragm tube. Anode voltage U_A = 35 kV and anode current I_A = 1 mA.	
Darken the experiment room so that the flow of the contrast medium can be observed on the fluorescent screen. Then, inject the contrast medium in the filled syringe slowly into the blood vessel model.	

Reduce the anode current and/or voltage in order to demonstrate the effect of these two parameters on the luminous intensity.
For comparison, it is also interesting to fill the blood vessel model with water.
If you would like to document the effect of the contrast medium in a photographic way, we recommend following the procedure described in P2542001.
The contrast medium must be removed from the blood vessel model before the model is taken out of the experiment chamber:

Remove the syringe that is connected to the lower inlet of the blood vessel model and lead the free end of the tube into the storage container.
Press the contrast medium out with the aid of the other syringe.
Seal the free tube ends with the plastic stoppers.

It is only then that the tubes may be pulled through the working channel and that the blood vessel model may be flushed several times with water with the aid of a syringe. Ensure to remove any residual water from the model to the maximum possible extent.

Caution!

Take great care to ensure that no contrast medium can flow out into the experiment chamber. To do so, ensure that the tubes are always tightly connected and that the tube ends are always sealed with stoppers prior to removing the blood vessel model from the experiment chamber.

Theory and Evaluation

Theory

In radiological diagnostics, many organs and tissues can only be distinguished from each other with great difficulty. For this reason, contrast media are used in order to make the gastrointestinal tract or blood vessels, for example, visible in an X-ray image. In roentgenologic examinations of blood vessels, concentrated solutions of iodine are used for this purpose. They absorb radiation to a higher extent than the surrounding tissues, which results in high-contrast X-ray images.
If X-rays with intensity I_0 penetrate the matter of the layer thickness d, then, in accordance with the law of absorption, the intensity I of the radiation that passes through the matter is given by (see P2541101):

$$I = I_0 e^{-\mu(\lambda,z)\cdot d} \qquad (1)$$

The so-called linear absorption coefficient $\mu[cm^{-1}]$ is dependent on the wavelength λ of the radiation and on the atomic number Z of the absorber. Since the absorption is proportional to the absorbing mass, the so-called mass absorption coefficient $\mu/\rho[cm_2/g]$ is often used, with ρ as the density of the absorber.
The following processes are responsible for the attenuation:

1. Photoelectric effect
2. Scattering
3. Pair production

Absorption through pair production, however, can be excluded in this case, since X-rays do not have the level of energy that would be required.
As a result, the absorption coefficient for X-rays only comprises the following two components:

$$\mu = \tau + \sigma$$

τ = absorption coefficient of the photoelectric effect
σ = scattering coefficient

For the wavelength range that is used here, the photoelectric effect dominates $(\tau > \sigma)$.

In this case, the absorption can be described with the aid of the following empiric relationship:

$$\frac{\tau}{\rho} \approx \frac{\mu}{\rho} = k(\lambda^3 \cdot Z^3) \qquad (2)$$

In accordance with (2), the absorption increases drastically with an increasing wavelength as well as with an increasing atomic number of the absorber.
As iodine has a much higher atomic number $(Z = 53)$ than the elements in organic tissue, it has a very high absorption power and is very well suited for use as a contrast medium.

Figures 5a and 5b show the effect of the contrast medium.

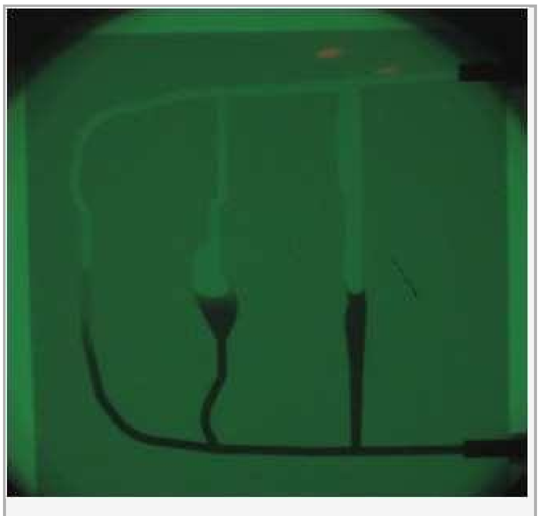

Fig. 5a: Blood vessel model with the contrast medium; half filled

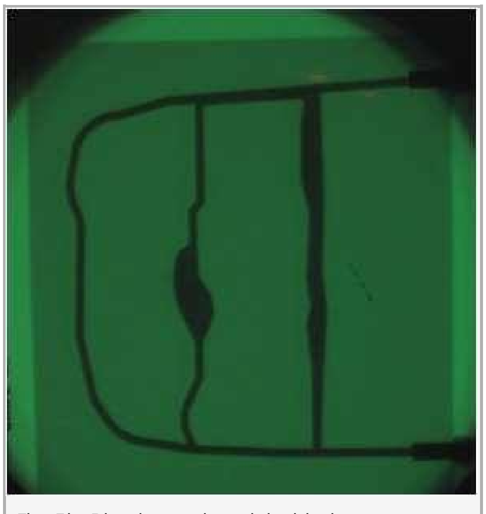

Fig. 5b: Blood vessel model with the contrast medium; completely filled