

Workshop Tutorials for Introductory Physics

QI6: Radiation and the Body

A. Review of Basic Ideas:

Use the following words to fill in the blanks:

brain, atmosphere, lead, radiation, X-raying, radioisotopes, 10 km, inhaled, cosmic, charge, background, exposure, radon, γ , ultraviolet, energy, positron, annihilate, radioactive, photons

Radiation and the body

Everybody is exposed to _____ all the time, from radioactive materials in the ground, the air, and inside us, and _____ radiation from space. This naturally occurring radiation is called _____ radiation. The normal dose from the background radiation is very low, and not dangerous.

However some people are exposed to more background radiation than others. For example airline pilots and stewards spend a lot of time 10 km above the earth. Normally the _____ shields us from a lot of cosmic background radiation, but when you're _____ up, the background level is somewhat higher. Smokers also have a higher _____ to radiation than non-smokers. When tobacco leaves are dried they accumulate small amounts of the _____ dust which settles on them. The radon and its daughter products are then _____ by the smoker.

People who work with radiation may also be exposed to higher levels of radiation than the normal background. People working with _____ may wear lead aprons to protect them from radiation, and carry a badge which senses the amount of radiation they are exposed to. The sorts of safety precautions used depend on the type of radiation present.

The most difficult radiation to shield against is _____ radiation. The high energy photons have no mass or _____, and hence are highly penetrating. Dentists and radiologists who use X-ray machines have to be careful to use _____ shielding. Even _____ radiation from the sun can be dangerous, which is why it's important to wear sunscreen if you're outside for any length of time. It is this penetrating nature of high energy photons that makes them so useful for imaging, such as _____.

Other sorts of radiation are also used for imaging. A PET (_____ emission tomography) scan uses β^+ radiation. The patient is injected with a radioisotope which emits positrons. When a positron is emitted it will not travel very far before it encounters an electron. A positron is the anti-matter particle of an electron, so when the two collide they _____ each other and some _____ is released. The energy is released as two _____ of a specific energy (the mass energy of the particles, from $E = mc^2$), which move off in opposite directions. By recording where the photons come out, we can work out where they must have come from, and hence where the original decay occurred. If the positron was emitted from _____ glucose, for example, we can tell which parts of the body are most active and hence using the most energy. This is extremely useful for looking at the _____, which only uses glucose for energy.

Discussion question

The radiation levels inside the reactor building of the HIFAR research reactor at Lucas Heights are lower than those outside the building. How is this possible?

B. Activity Questions:

1. X-ray pictures

Examine the X-ray films.

Why are some areas light and others dark? In which areas are more X-rays absorbed?

Why are more X-rays absorbed in these regions?

2. Measuring Radiation

Several different means of measuring radiation are shown.

Explain how they work.

Which ones would be suitable monitoring devices for persons working in a radiation area?

C. Qualitative Questions:

1. There are three main types of radiation, α , β and γ .

a. Of these three types of radiation, which particle is the most penetrating? Explain your answer.

b. Which has the greatest ionising power?

c. Why are α emitters not considered dangerous unless inhaled or ingested?

d. Why are dense materials, such as lead, the best materials for shielding against radiation?

e. Nuclear reactors produce a lot of neutrons. How do you think the penetrating and ionising power of a neutron compares to α and β radiation?

2. After the Chernobyl nuclear accident, which gave off significant amounts of the radioactive isotope ^{90}Sr , many European countries immediately imposed a ban on the sale of milk, why was this?

D. Quantitative Question:

The proportion of radiation penetrating a material decreases exponentially with the thickness of the material. A shielding material is rated according to its attenuation coefficient, $\mu = \ln 2/\text{HVL}$. The HVL is the half-value layer, which is the thickness which stops one half of the incident radiation. This thickness depends on the material, and also on the radiation. It will be greater for more penetrating radiation.

a. Write an equation which gives the radiation level at a distance d through some material.

b. Sketch the intensity of the radiation as a function of distance.

c. Name another process which follows this form.

There are several isotopes of potassium which are radioactive. They emit γ and β radiation. The half value layers for the γ radiation from ^{40}K for several materials are shown below.

material	HVL (cm)
Lead	1.2
Iron	1.8
aluminium	5.0
water	12
air	10,000
concrete	5.6

d. By what fraction would the radiation be decreased by 25 cm of aluminium?

e. How much lead would you need to reduce exposure by 75%?

f. How much air would you need to reduce exposure by 75%?