State Examination Commission – Physics Higher Level, 2005

Question 8

Nuclear disintegrations occur in radioactivity and in fission.
Distinguish between radioactivity and fission. (12)
Give an application of (i) radioactivity, (ii) fission. (6)
Radioactivity causes ionisation in materials. What is ionisation? Describe an experiment to demonstrate the ionising effect of radioactivity. (15)
Cobalt−60 is a radioactive isotope with a half-life of 5.26 years and emits beta particles.
(i) Write an equation to represent the decay of cobalt−60.
(ii) Calculate the decay constant of cobalt−60.
(iii) Calculate the rate of decay of a sample of cobalt−60 when it has 2.5×10^{21} atoms. (23)

Distinguish between radioactivity and fission. (12)

Radioactivity is the spontaneous disintegration of an unstable nucleus with the emission of α, β or γ radiation, whereas fission is the splitting of a large nucleus into two smaller nuclei of comparable size, accompanied by the release of energy as well as often producing several free neutrons.

Give an application of (i) radioactivity, (ii) fission. (6)

(i) smoke detectors
(ii) generating electricity

Radioactivity causes ionisation in materials. What is ionisation? (3)

Ionization is the process of converting an atom or molecule into an ion (a charged particle) by adding or removing charged particles such as electrons or other ions

Describe an experiment to demonstrate the ionising effect of radioactivity. (12)

Dry air is normally a good insulator, thus a charged electroscope will stay that way, as the charge cannot escape. When an electroscope is charged, the gold leaf sticks out, because the charges on the gold repel the charges on the metal stalk.

When a radioactive source comes near, the air is ionised, and starts to conduct electricity. This means that the charge can "leak" away, the electroscope discharges and the gold leaf falls.

Cobalt−60 is a radioactive isotope with a half-life of 5.26 years and emits beta particles.
(i) Write an equation to represent the decay of cobalt−60 (9)

$$^{60}Co_{27} \rightarrow {}^{60}Ni_{28} + {}^{0}\beta_{-1}$$

(ii) Calculate the decay constant of cobalt−60. (8)

$$\lambda T_{1/2} = \ln 2$$

$$T_{1/2} = 5.26 \text{ y} = 1.66 \times 10^{8} \text{ s and } \ln 2 = 0.693$$

So, $\lambda = \ln 2 / T_{1/2} = 4.18 \times 10^{-9} \text{ s}^{-1}$

(iii) Calculate the rate of decay of a sample of cobalt−60 when it has 2.5×10^{21} atoms. (6)

$$\frac{dN}{dt} = -\lambda N$$
$$= 4.18 \times 10^{-9} \text{ x } 2.5 \times 10^{21}$$
$$= 1.04 \times 10^{13} \text{ Bq}$$