A Level · OCR · Physics

31 mins 3 questions

Structured Questions

Radioactivity

Radioactive Decay / Alpha, Beta & Gamma Radiation / Alpha & Beta Decay Equations / Activity & The Decay Constant / Half-Life / Radioactive Decay Equations / Modelling Radioactive Decay / Radioactive Dating

Medium (2 questions)	/16
Hard (1 question)	/15
Total Marks	**/31**

Scan here to return to the course
or visit savemyexams.com

Medium Questions

1 (a) An isotope of polonium-213 ($^{213}_{84}\text{Po}$) first decays into an isotope of lead-209 ($^{209}_{82}\text{Pb}$) and this lead isotope then decays into the stable isotope of bismuth (Bi). Fig. 24 shows two arrows on a neutron number *N* against proton number *Z* chart to illustrate these two decays.

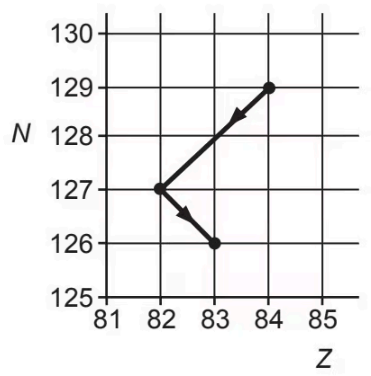

Fig. 24

Complete the nuclear decay equations for

i) the polonium isotope $^{213}_{84}\text{Po} \rightarrow\ ^{209}_{82}\text{Pb} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots$

[1]

ii) the lead isotope

$$^{209}_{82}\text{Pb} \rightarrow\ ^{\ldots\ldots}_{83}\text{Bi} +\ ^{0}_{-1}\text{e} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

[2]

....

....

(3 marks)

(b) A pure sample of polonium-213 is being produced in a research laboratory. The half-life of $^{213}_{84}\mathrm{Po}$ is very small compared with the half-life of $^{209}_{82}\mathrm{Pb}$.

After a very short time, the ionising radiation detected from the sample is mainly from the beta-minus decay of the lead-209 nuclei.

i) Briefly describe and explain an experiment that can be carried out to confirm the beta-minus radiation emitted from the lead nuclei.

[2]

ii) The activity of the sample of $^{209}_{82}\mathrm{Pb}$ after 7.0 hours is 12 kBq.

The half-life of $^{209}_{82}\mathrm{Pb}$ is 3.3 hours.

Calculate the initial number of lead-209 nuclei in this sample.

number of nuclei = ... **[4]**

(6 marks)

2 (a) Fig. 20 illustrates a device used to determine the relative abundance of charged rubidium ions.

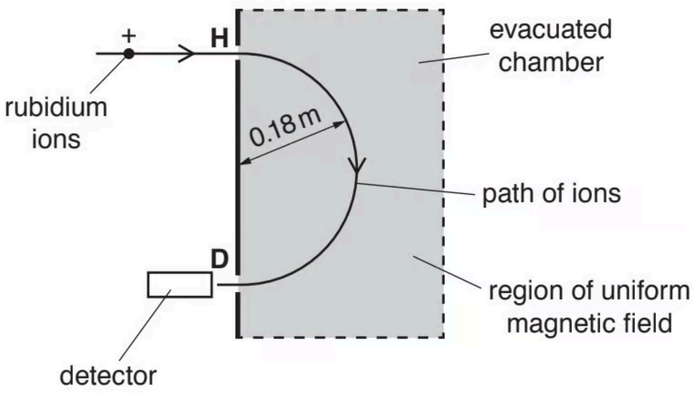

Fig. 20

A uniform magnetic field is applied to an evacuated chamber. The direction of the magnetic field is perpendicular to the plane of the paper.

A beam of positive rubidium ions enters the chamber through a hole at **H**. The ions travel in a semi-circular path in the magnetic field. The ions are detected at point **D**.

Each rubidium ion has charge $+1.6 \times 10^{-19}$ C and speed 4.8×10^{4} ms^{-1}. The radius of the semi-circular path of the ions is 0.18 m. The mass of a rubidium ion is 1.4×10^{-25} kg.

Calculate the magnitude of the magnetic flux density *B* of the magnetic field.

B = ... T **[3]**

....

....

....

(3 marks)

(b) The chemical composition of ancient rocks found on the Earth can be used to estimate the age of the Earth. Nuclei of rubidium-87 ($^{87}_{37}\mathrm{Rb}$) decay spontaneously into nuclei of strontium-87 ($^{87}_{38}\mathrm{Sr}$).

The half-life of rubidium-87 is 49 billion years.

i) Name the two leptons emitted in the decay of a rubidium-87 nucleus.

[1]

ii) The percentage of rubidium **left** in a sample of an ancient rock is 95%. Estimate the age of the Earth in billion years.

age = ... billion years **[3]**

....

....

....

....

(4 marks)

Hard Questions

1 (a) $^{60}_{27}\mathrm{Co}$ is produced by irradiating the stable isotope $^{59}_{27}\mathrm{Co}$ with neutrons.

Each nucleus of $^{60}_{27}\mathrm{Co}$ then decays into a nucleus of nickel (Ni) by the emission of a low energy beta-minus particle, one other particle and two gamma photons.

Complete the nuclear equations for these two processes.

$$^{59}_{27}\mathrm{Co} + ^{\cdots\cdots}_{\cdots\cdots}\mathrm{n} \rightarrow ^{60}_{27}\mathrm{Co} \rightarrow ^{\cdots\cdots}_{\cdots\cdots}\mathrm{Ni} + ^{\cdots\cdots}_{\cdots\cdots}\mathrm{e} + \cdots\cdots\cdots + 2\gamma$$

[3]

....

....

....

(3 marks)

(b) Students want to carry out an investigation into gamma photon absorption using a source of $^{60}_{27}\mathrm{Co}$. They add sheets of lead between the source **S** and a radiation detector **T**, to give a total thickness *d* of lead. **S** and **T** remain in fixed positions, as shown in Fig. 2.1.

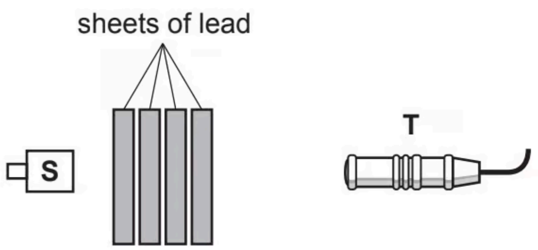

Fig. 2.1

i) The $^{60}_{27}\mathrm{Co}$ source emits beta radiation as well as gamma radiation. Explain why this would not affect the experiment.

[1]

ii) The students record the number N of gamma photons detected by **T** in 10 minutes for each different thickness d of lead. The background count is negligible.

The results are shown in a table. The table includes values of ln N, including the absolute uncertainties.

N	d/mm	ln N
4300 ± 440	0	8.37 ± 0.10
2500 ± 250	10	7.82 ± 0.10
1400 ± 150	20	7.24 ± 0.11
800 ± 90	30	6.68 ± 0.11
500 ± 60	40	6.21 ± 0.12
300 ± 40	50	

N and d are related by the equation $N = N_0 \, e^{-\mu d}$ where N_0 and μ are constants.

1. The students decide to plot a graph of ln N against d. Show that this should give a straight line with gradient = – μ and y-intercept = ln N_0.

[1]

2. Complete the missing value of ln N in the table, including the absolute uncertainty. Show your calculation of the absolute uncertainty in the space below.

[2]

3. In Fig. 2.2, five of the data points have been plotted, including error bars for ln *N*. Plot the missing data point and error bar. Draw a straight line of best fit and one of worst fit.

[2]

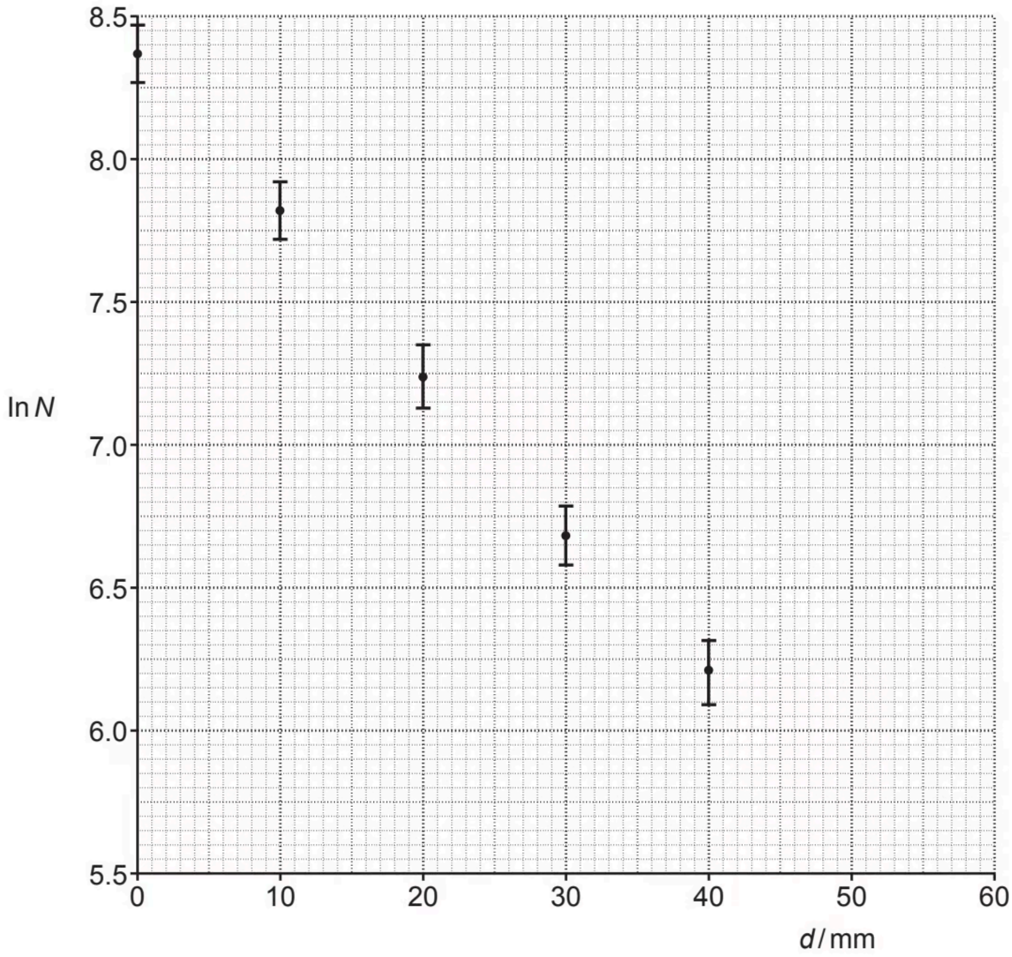

Fig. 2.2

4. Use Fig. 2.2 to determine the value of μ in m^{-1}, including the absolute uncertainty.

μ = ... ± .... m^{-1} **[4]**

5. Determine the thickness, $d_{½}$, of lead which halves the number of gamma photons reaching **T**.

$d_{½}$ = ... m **[2]**

(12 marks)