**Q1.**(a) Which ionizing radiation produces the greatest number of ion pairs per mm in air? Tick (✓) the correct answer.

| | |
|---|---|
| $\alpha$ particles | |
| $\beta$ particles | |
| $\gamma$ rays | |
| X−rays | |

**(1)**

(b) (i) Complete the table showing the typical maximum range in air for $\alpha$ and $\beta$ particles.

| Type of radiation | Typical range in air / m |
|---|---|
| $\alpha$ | |
| $\beta$ | |

**(2)**

(ii) $\gamma$ rays have a range of at least 1 km in air.

However, a $\gamma$ ray detector placed 0.5 m from a $\gamma$ ray source detects a noticeably smaller count-rate as it is moved a few centimetres further away from the source.

Explain this observation.

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**(1)**

(c) Following an accident, a room is contaminated with dust containing americium which is an $\alpha$−emitter.

Explain the most hazardous aspect of the presence of this dust to an unprotected human entering the room.

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**(2)**
**(Total 6 marks)**

**Q2.** (a) In a radioactivity experiment, background radiation is taken into account when taking corrected count rate readings in a laboratory. One source of background radiation is the rocks on which the laboratory is built. Give **two** other sources of background radiation.

source 1 .....

source 2 .....

**(1)**

(b) A γ ray detector with a cross-sectional area of $1.5 \times 10^{-3}$ $m^2$ when facing the source is placed 0.18 m from the source.
A corrected count rate of 0.62 counts $s^{-1}$ is recorded.

(i) Assume the source emits γ rays uniformly in all directions.
Show that the ratio

$$\frac{\text{number of } \gamma \text{ photons incident on detector}}{\text{number of } \gamma \text{ photons produced by source}}$$

is about $4 \times 10^{-3}$.

**(2)**

(ii) The $\gamma$ ray detector detects 1 in 400 of the $\gamma$ photons incident on the facing surface of the detector.
Calculate the activity of the source. State an appropriate unit.

answer = ..... unit .....

**(3)**

(c) Calculate the corrected count rate when the detector is moved 0.10 m further from the source.

answer = ..... counts $s^{-1}$

**(3)**
**(Total 9 marks)**

**Q3.** (a) $^{212}_{83}Bi$ can decay into $^{208}_{82}Pb$ by a $\beta^-$ followed by an $\alpha$ decay, or by an $\alpha$ followed by a $\beta^-$ decay. One or more of the following elements is involved in these decays:

$_{80}Hg$ , $_{81}Tl$ , $_{84}Po$ , $_{85}At$ .

Write out decay equations showing each stage in both of these decays.

| First decay path | Second decay path |
| --- | --- |

**(6)**

(b) (i) Describe how you would perform an experiment that demonstrates that gamma radiation obeys an inverse square law.

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(ii) Explain why gamma radiation obeys an inverse square law but alpha and beta radiation do not.

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**(9)**
**(Total 15 marks)**

**Q4.** (a) Calculate the radius of the $^{238}_{92}$U nucleus.

$r_0 = 1.3 \times 10^{-15}$ m

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**(2)**

(b) At a distance of 30 mm from a point source of $\gamma$ rays the corrected count rate is *C*. Calculate the distance from the source at which the corrected count rate is 0.10 *C*, assuming that there is no absorption.

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**(2)**

(c) The activity of a source of $\beta$ particles falls to 85% of its initial value in 52 s. Calculate the decay constant of the source.

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**(3)**

(d) Explain why the isotope of technetium, $^{99}Tc_{m}$, is often chosen as a suitable source of radiation for use in medical diagnosis.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

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**(3)**
**(Total 10 marks)**