**3** A radioactive source emits beta radiation and gamma radiation.
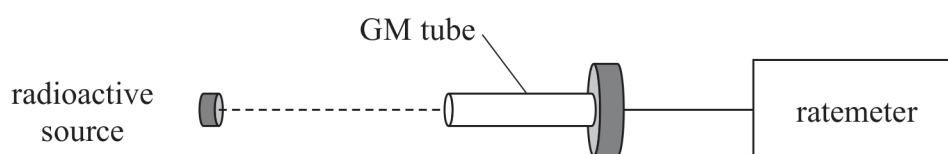
(a) State two precautions that should be taken when using this source.

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(b) The radiation emitted from a radioactive source can be investigated using the apparatus shown. The Geiger-Muller (GM) tube detects beta radiation and gamma radiation.



The ratemeter displays the count rate from all radiation detected by the GM tube.

Explain why the background count rate should be measured.

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(c) The corrected count rate $C$ varies over time $t$ according to the relationship

$$C = C_0 \, e^{-\lambda t}$$

where $C_0$ is the initial count rate and $\lambda$ is the decay constant.

Explain how a graph of $\ln C$ against $t$ can be used to determine a value for $\lambda$.

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(d) The source contained two radioactive isotopes, X and Y. The table below shows the corrected count rate as the isotopes decayed.

| $t$/hours | $C$/s$^{-1}$ | |
|---|---|---|
| 0.00 | 633 | |
| 2.00 | 217 | |
| 4.00 | 167 | |
| 6.00 | 140 | |
| 8.00 | 126 | |
| 10.00 | 107 | |
| 12.00 | 98 | |

(i) Plot a graph of $\ln C$ against $t$ on the grid opposite. Use the additional column in the table to record your processed data.

(5)

(ii) Isotope X has a half-life of approximately 30 minutes.

Determine a value of $\lambda$, in hours$^{-1}$, for isotope Y.

(3)

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$\lambda =$ .................................................... hours$^{-1}$

(iii) Hence determine the half-life $t_{\frac{1}{2}}$ for isotope Y.

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$t_{\frac{1}{2}} =$ ....................................................