SL Paper 2

This question is about radioactivity.

Caesium-137 $\left({}^{137}_{55}\mathrm{Cs}\right)$ is a radioactive waste product with a half-life of 30 years that is formed during the fission of uranium. Caesium-137 decays by the emission of a beta-minus (β^-) particle to form a nuclide of barium (Ba).

a. State the nuclear equation for this reaction. [2]

$$^{137}_{55}\mathrm{Cs} \rightarrow {}^{\cdots}_{\cdots}\mathrm{Ba} + {}^{0}_{-1}\beta^{-} + \cdots\cdots$$

b. Determine the fraction of caesium-137 that will have decayed after 120 years. [2]

c. Explain, with reference to the biological effects of ionizing radiation, why it is important that humans should be shielded from the radiation emitted by caesium-137. [2]

This question is in **two** parts. **Part 1** is about nuclear reactions. **Part 2** is about thermal energy transfer.

Part 1 Nuclear reactions

Part 2 Thermal energy transfer

a. (i) Define the term *unified atomic mass unit.* [2]

(ii) The mass of a nucleus of einsteinium-255 is 255.09 u. Calculate the mass in $\mathrm{MeV}c^{-2}$.

c. When particle X collides with a stationary nucleus of calcium-40 (Ca-40), a nucleus of potassium (K-40) and a proton are produced. [6]

$$^{40}_{20}\mathrm{Ca} + \mathrm{X} \rightarrow {}^{40}_{19}\mathrm{K} + {}^{1}_{1}\mathrm{p}$$

The following data are available for the reaction.

Particle	Rest mass / MeV c^{-2}
calcium-40	37 214.694
X	939.565
potassium-40	37 216.560
proton	938.272

(i) Identify particle X.

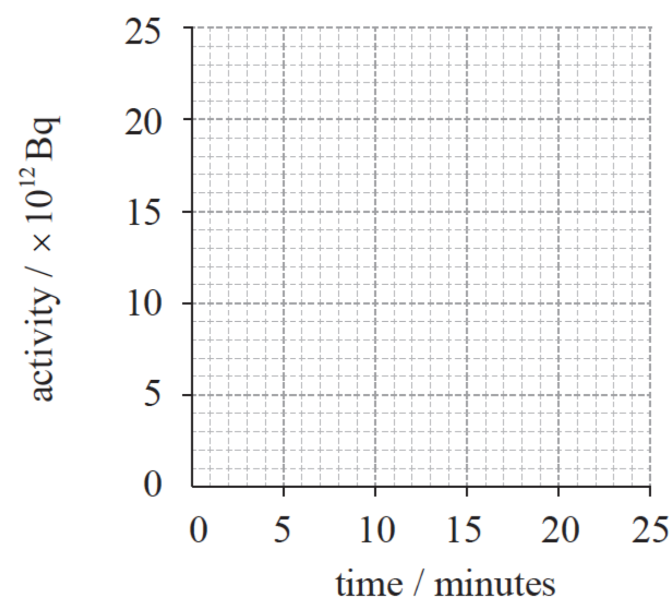
(ii) Suggest why this reaction can only occur if the initial kinetic energy of particle X is greater than a minimum value.

(iii) Before the reaction occurs, particle X has kinetic energy 8.326 MeV. Determine the total combined kinetic energy of the potassium nucleus and the proton.

d. Potassium-38 decays with a half-life of eight minutes. [5]

(i) Define the term *radioactive half-life*.

(ii) A sample of potassium-38 has an initial activity of 24×10^{12}Bq. On the axes below, draw a graph to show the variation with time of the activity of the sample.



(iii) Determine the activity of the sample after 2 hours.

e. (i) Define the *specific latent heat* of fusion of a substance. [5]

(ii) Explain, in terms of the molecular model of matter, the relative magnitudes of the specific latent heat of vaporization of water and the specific latent heat of fusion of water.

f. A piece of ice is placed into a beaker of water and melts completely. [5]

The following data are available.

Initial mass of ice = 0.020 kg
Initial mass of water = 0.25 kg
Initial temperature of ice = 0°C
Initial temperature of water = 80°C
Specific latent heat of fusion of ice = 3.3×10^5 J kg^{-1}
Specific heat capacity of water = 4200 J $kg^{-1}K^{-1}$

(i) Determine the final temperature of the water.

(ii) State **two** assumptions that you made in your answer to part (f)(i).