3. This question is about the use of enriched uranium

(a) Amount of U in 1 pound = 0.45 kg $\times$ 10^3 g kg^{-1} / 235.0439 g mol^{-1} = 1.91 mol

Energy released from 1 pound = 8.0 $\times$ 4.184 $\times$ 10^{12} J = 3.35 $\times$ 10^{13} J

Energy released in kJ mol^{-1} = 3.35 $\times$ 10^{13} J / 1.91

= 1.8 $\times$ 10^{10} kJ mol^{-1} **1**

(b) (i) Relative Atomic Mass = $m_{235}\,x + m_{238}\,(1 - x)$

$$x = \frac{238.0289 - 238.0507}{235.0439 - 238.0507} = 0.00725$$

% abundance of ^{235}U = 0.725% **1**

If percentage of ^{238}U is calculated first but incorrectly, allow ECF for percentage of ^{235}U, where ECF answer = 100% − ***(b)(ii)***

(ii) % abundance of ^{238}U = 100 − 0.725 = 99.275% **1**

ECF answer = 100% − ***(b)(i)***

(c) **B** Fluorine has only one naturally occurring isotope. **1**

(d) No. **1**

Whilst the individual U–F bonds are polar, the octahedral shape of UF_6 means that these cancel out.

(e) % heavier = (238 − 235) / (235 + 6 $\times$ 19) $\times$ 100 = 0.860% **1**

(f) (i) $UF_6 + H_2 \rightarrow UF_4 + 2HF$ **1**

(ii) $UF_4 + 2Mg \rightarrow U + 2MgF_2$ **1**

(g) (i) +6, +5, (+5) **1**

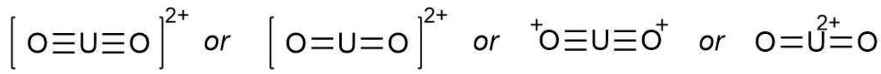
Duplication of +5 oxidation state not required. Do not penalise lack of a + sign. Allow use of Roman numerals.

(ii) +4, +6, (+6) **1**

Duplication of +6 oxidation state not required. Do not penalise lack of a + sign. Allow use of Roman numerals.

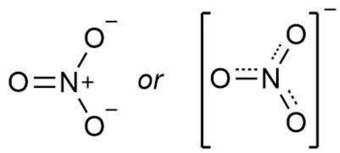
(h) (i) Compound **R**

Structure of cation

 **1**

Accept if dative bonds drawn from oxygen to uranium. The charges drawn must add up to an overall charge of +2.

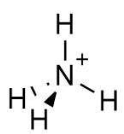
Structure of anion **1**



Accept if a dative bond drawn from nitrogen to oxygen. No credit for any structure where nitrogen has more than four discrete bonds. The charges drawn must add up to an overall charge of −1.

(ii) Compound **T**

Structure of cation

 **1**

Shape does not have to be drawn in three dimensions as students were told the shape in the question. There are two ammoniums per formula unit but it does not matter whether students draw one or two here. Charge must be indicated. Accept if dative bond drawn from nitrogen to hydrogen.

Formula of anionic part

$U_2O_7^{2-}$ **1**

Please note that we did not ask for students to draw the structure here because this is not a simple molecular anion like dichromate. If they have attempted to draw a structure which has this formula then mark as correct.

(iii) Compound **X** UO_2 **1**

Compound **Z** UF_4 **1**

(i) (i) $^{235}U \rightarrow {}^{231}Th + \alpha$ **½**

(ii) $^{238}U \rightarrow {}^{234}Th + \alpha$ **½**

(j) (i) Half-life = 0.704×10^9 years ½

Range allowed: 0.604×10^9 years to 0.804×10^9 years

(ii) Half-life = 4.47×10^9 years ½

Range allowed: 4.07×10^9 years to 4.87×10^9 years

(k) From $\lambda = \frac{\ln 2}{t_{½}}$ and answers in part **(j)**

$\lambda_{235} = 9.85 \times 10^{-10}$ years^{-1} ½

$\lambda_{238} = 1.55 \times 10^{-10}$ years^{-1} ½

$\frac{N_{235}}{N_{238}} = e^{-(\lambda_{235}-\lambda_{238})t}$

as the N_0 values for both isotopes are the same and so cancel out

$\frac{N_{235}}{N_{238}}$ from part **(b)** = 0.725 / 99.275 1

$t = \frac{\ln\left(\frac{0.725}{99.275}\right)}{-(9.85 - 1.55) \times 10^{-10}}$ = 5.92×10^9 years 1

½ mark for each correct λ calculation, 1 mark for correct $\frac{N_{235}}{N_{238}}$ calculations and 1 mark for answer.

*For ECF from part **(b)** and **(j)** use:*

$$Age = \frac{\ln\left(\frac{^{238}U \text{ percentage abundance}}{^{235}U \text{ percentage abundance}}\right)}{\left(\frac{\ln 2}{t_{½}{}^{235}U} - \frac{\ln 2}{t_{½}{}^{238}U}\right)} = \frac{\ln\left(\frac{(\mathbf{b})(\mathbf{ii})}{(\mathbf{b})(\mathbf{i})}\right)}{\left(\frac{\ln 2}{(\mathbf{j})(\mathbf{i})} - \frac{\ln 2}{(\mathbf{j})(\mathbf{ii})}\right)}$$

Question Total 21