Name of the Student:_____
Max. Marks : 17 Marks **Time : 17 Minutes**

Mark Schemes

Q1.

(a) U-235 (absorbs) a neutron with added information ✔1

1 *Possible added information :*
To become U-236
absorbs a slow moving neutron
absorbs a thermal neutron
If no marks awarded but the first two marking points are made without identifying the isotope give one mark

U-235/6 then divides/splits and gives out more neutrons ✔2

U-238 absorbs/scatters <u>neutrons</u> ✔3

3 *If the answer implies that U-238 in any way is involved in fission this mark is lost*

3

(b) Substitution into or manipulation of the equation $N_t = N_0 e^{-\lambda t}$ to give the ratio $\frac{N_0}{N_t}$

with N_t for the present day and N_0 being in the past ✔1a

$$\left(\frac{N_0}{N_t} = e^{+\lambda t} = e^{+\left(1.54 \times 10^{-10} \times 2.0 \times 10^{9}\right)} = 1.36\right)$$

Mass of U-238 (= 1.36 × 0.993) = 1.35 kg (3 sf) ✔2a

OR working with half-lives

(Half life = 4.50×10^9 year)

Number of half-lives = 4/9 or 0.44 ✔1b

$$\left(\frac{N_0}{N_t} = 2^{(4/9)} = 1.36\right)$$

Mass of U-238 (= 1.36 × 0.993) = 1.35 kg (3 sf) ✔2b

Must be to 3 sig figs
Calculation may be in grams
1b *Half life = $\ell n 2 / 1.54 \times 10^{-10}$*
= 4.50×10^9 (year)
Number of half-lives = $2.00 \times 10^9 / 4.50 \times 10^9$

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2

(c) Ratio $\left(\frac{N_{235}}{N_{238}+N_{235}}\right)$ = 3.6% to 3.7%

so yes ✔ A valid calculation must be performed to gain the mark eg with an ecf from (b)

$$\left(\frac{N_{235}}{N_{238}+N_{235}}=\frac{52}{1400+52} \text{ using (b) data } = \frac{52}{1350+52}\right)$$

Condone using ratio $\frac{N_{235}}{N_{238}}$

$$\left(\frac{N_{235}}{N_{238}}=\frac{52}{1400} \text{ using (b) data } = \frac{52}{1350}\right)$$

= 3.7% to 3.9%

1

[6]

Q2.

(a) To increase the probability/chance of fission (when neutron collides with fissile material/U-235)
Or
To allow the neutron to be absorbed by the <u>fuel/U-235</u> ✔

Condone because thermal/slow moving neutrons are needed for fission to take place

'fuel' but not 'fuel rod' to be used in the alternative.

Reject inaccurate descriptions for example ones that imply the neutrons are undergoing fission.

1

(b) E_{final} = (1 – 0.63) $E_{incident}$ or E_{final} = 0.37 $E_{incident}$ ✔$_1$
(continuing this idea, E_1 = (1 – 0.63) E_0
E_2 = (1 – 0.63) E_1 so E_2 = (1 – 0.63)^2 E_0
and E_5 = (1 – 0.63)^5 E_0
E_5 = (1 – 0.63)^5 × 2.0 × 10^6))
= 1.4 × 10^4 eV ✔$_2$ (1.39 × 10^4 eV)

If no marks are scored a single mark can be given:

if the final answer that has a power of 10 error possibly by not using the M in the eV.

OR

using 0.63 rather than (1 – 0.63) in the calculation giving the answer 2(.0) × 10^5 (eV)

✔$_2$ *A correct final answer gains full marks*

2

(c) A link made between the change in kinetic energy or momentum to the masses of the (two) particles involved in the collision. ✔$_1$

A consistent argument that results in a statement 'as nucleon number/number of nucleons in the nucleus increases more collisions are required. ✔$_2$

✔$_1$ *Ref. to mass is needed.*

{Essence of marking point: The mass determines how much KE/momentum is lost}

✔$_2$ *Ref to nucleon number or equivalent needed but mass is not.*

{Essence of marking point: If N is high then not much KE is lost so

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more collisions are needed}

An example of an argument could be:

More (kinetic) energy is lost when the mass of the moderator atom/nucleus is closer to the mass of the neutron

So the number of collisions needed increases with nucleon number

2

(d) Mass difference

= ($mass_U$ + $mass_n$) – ($mass_{Xe}$ + $mass_{Sr}$ + 4 $mass_n$)

= (235.044 + 1.0087) – (141.930 + 89.908 + 4 × 1.0087) ✔$_1$

= 0.180 u ✔$_2$ {if no unit present take u as the default unit}

(= 0.180 × 931.5)

= 168 (MeV) ✔$_3$

✔$_1$ Mark for word equation or substitution, one neutron may be cancelled from both parts of the subtraction. Condone any simple slip in transferring the numbers.

Also the mark can be awarded for giving or comparing the mass on the LHS with the RHS.

✔$_2$ Only allow correct answer.

✔$_3$ This mark can stand alone for the conversion of any number of u converted to MeV. 2 sig figs is acceptable.

The conversion mark can come from any part of this question not just the final line.

{1 kg = 6.02 × 10^{26}}

A correct answer gains all 3 marks.

3

(e) 1. (Small amounts of fossil fuel used) so <u>little</u> greenhouse gas emissions/less global warming/less CO_2/less climate change. {not <u>no</u> greenhouse gas}

2. (Less fossil fuel used) so cleaner air.

3. Small amounts of fuel consumed to get the same/large amount of power/energy.

4. Nuclear power can be produced continuously{condone use of constant} (whereas renewables are dependent on sunlight/wind etc).

5. Some (but not all) nuclear power stations can adjust their output quickly.

6. Benefit of producing medical isotopes.

✔ ✔ ✔ any three points

Just one of the examples may be from the following:

At present nuclear fuel is obtained from stable allied countries (as opposed to oil/gas).

Facilitates nuclear weapon production.

(Less fuel used) so less transportation needed.

Examples of rejected ideas because they are incomplete or wrong:

Produces more energy.

There is more uranium than fossil fuel.

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Damages the environment less.
Provides jobs.
More efficient than others.
Reference to cost.
It's a renewable source.

3

[11]

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