Part 2 Nuclear processes

(a) (i) *proton number:* 89;
nucleon number: 222; *[2]*

(ii) 12.5% remains;
3 half lives 4800 years; *[2]*

(b) momentum conserved;
so different speeds as different masses;
opposite directions because momentum zero initially; *[3]*

(c) beta have smaller mass / smaller / have greater speed than alpha;
beta have smaller charge than alpha;
therefore less likely to interact with air molecules; *[3]*

MULTIPLE CHOICE

25 A
27. A

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24. A
26. A

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22. D
23 C
24. B

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22. C
23. A

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23. C
24. B

Part 2 Radioactive decay and binding energy

(a) unstable nuclei/nuclides change spontaneously/randomly/emit energy;
by the emission of <u>alpha particles</u> and/or <u>electrons</u> and/or <u>gamma rays</u>; *(accept α, β and γ particles/radiation)* *[2]*
*To award **[2 max]** reference must be made to nuclei/nuclides and to spontaneously/randomly.*

(b) *Z:* 18 ***or*** 20;
x: neutrino/ ν / ${}^{0}_{0}\nu$ /antineutrino/ $\overline{\nu}$ / ${}^{0}_{0}\overline{\nu}$; *[2]*
***Please note:** that β^{+} decay is not in the SL core, only β^{-} so accept answers in terms of β^{-} decay and mark any combination correct.*

(c) mass of 81 protons $= (81\times938 =) 75978\ \text{MeV c}^{-2}$;
mass of 125 neutrons $= (125\times940 =) 117500\ \text{MeV c}^{-2}$;
mass difference $= 75978 + 117500 - 191870 = 1608\ \text{MeV c}^{-2}$;
binding energy per nucleon $= 7.81\text{MeV}$; *[4]*

(d) energy is released in the decay of Tl-206 / energy released is the difference in binding energies / decay is spontaneous / Pb-206 is more stable than Tl-206; *[1]*

B3. Part 1 Production of energy in nuclear fission

(a) (i) 3; *[1]*

(ii) $\Delta m = 234.99333 - 91.90645 - 140.88354 - [2 \times 1.00867]$;
$= 0.186\,(\text{u})$;
energy released $= 0.186 \times 931 = 173\,(\text{MeV})$;
$173 \times 10^{6} \times 1.6 \times 10^{-19}$;
$(= 2.768) \approx 2.8 \times 10^{-11}\,(\text{J})$ *[4]*

or

$\Delta m = 234.99333 - 91.90645 - 140.88354 - [2 \times 1.00867]$;
$= 0.186\,(\text{u})$;
mass converted $= 0.186 \times 1.66 \times 10^{-27} (= 3.09 \times 10^{-28})$;
(use of $E = mc^2$) energy $= 3.09 \times 10^{-28} \times 9 \times 10^{-16}$;
$(= 2.77) \approx 2.8 \times 10^{-11}\,(\text{J})$
*Award **[2 max]** if mass difference is incorrect.*

*Award **[3 max]** if the candidate uses a value for x inconsistent with (a)(i).*

(iii) greater/higher energy; *[1]*

(b) reduces neutron speed to (thermal) lower speeds;
so that chance of initiating fission is higher; *[2]*
Accept "fast neutrons cannot cause fission" for 2nd marking point.

(c) 40% efficient so 40 (MW) required;
$\frac{40 \times 10^{6}}{2.8 \times 10^{-11}} = 1.43 \times 10^{18}$ per second;
number of fissions per day $= 1.23 \times 10^{23}$;
$\left(= \frac{1.23 \times 10^{23} \times 235}{6 \times 10^{23}} \right) = 48$ g per day; *[4]*

(e) lower amplitude everywhere on graph;
with a much broader resonance peak;
maximum moves to left on graph; ***[2 max]***
*Award **[2]** for a sketch graph.*

Part 2 Rutherford model of the atom

(a) most of the atom is empty space;
most of the mass/(protonic) charge of the atom is concentrated in the nucleus/ nucleus is dense;
nucleus is positively charged;
(most) alphas not close enough to nuclei to be deflected;
(very few) alphas (are) close enough to nuclei to be deflected;
These points can be awarded to a labelled diagram. ***[5]***

(b) (i) mention of Coulomb <u>repulsion</u> between protons;
mention of strong (nuclear) force (between nucleons);
overall balance must be correct (and more neutrons needed for this); ***[3]***
*Award **[0]** for a statement that neutron is negative.*

(ii) anti neutrino / $\bar{\nu}$; ***[1]***

B2. Part 1 Power production and global warming

(a) energy transferred to surroundings/from system; *(do not allow bald "energy lost")*
energy no longer available for use/cannot be used again; ***[2]***

(b) (i) U-235 fissions / neutrons are produced;
nuclei/neutrons have high energy/are fast moving;
nuclei transfer (kinetic) energy to (reactor) core / neutrons transfer (kinetic) energy to moderator;
names energy of moving nuclei/neutrons as <u>kinetic</u>;
core/moderator energy transferred to coolant/named coolant/surroundings; ***[4 max]***

(ii) heat exchanger allows transfer of (thermal) energy between reactor and coolant;
coolant transfers (thermal) energy to steam/other named fluid;
steam/fluid allows turbine to drive generator/dynamo; ***[3]***

(c) *Allow any one of the following.*
heating the working fluid in the exchanger;
the working fluid passing through the turbine;
cooling the working fluid having passed through the turbine;
named dissipative/friction process in power station machinery; *(do not allow "air resistance/friction" unless seat of loss is clear)* ***[1 max]***

(d) energy output of Drax $= \left(4.0\times10^{9}\times3.2\times10^{7} =\right) 1.28\times10^{5}\,\text{TJ}$;

mass of U-235 needed $= \left(\dfrac{1.28\times10^{5}}{82} =\right) 1.6\times10^{3}\,\text{kg}$; ***[2]***

(e) frequency of vibration is close to that of the frequency of infrared radiation;
(atmospheric) carbon dioxide absorbs the infrared radiated by the surface of Earth;
the part of the radiation that is re-radiated back to Earth will cause the temperature of the surface to rise / re-radiated at a different frequency / *OWTTE*; ***[3]***

(f) $\Delta T = \dfrac{\Delta V}{\gamma V}$; *(award mark if correct substitution seen)*

$\dfrac{\Delta V}{V} = \dfrac{6.4\times10^{-2}\times\text{area}}{4.0\times10^{2}\times\text{area}} = 1.6\times10^{-4}$;

$\Delta T = \left(\dfrac{1.6\times10^{-4}}{5.1\times10^{-5}} =\right) 3.1\,\text{K}$; ***[3]***