

Option B — Quantum Physics and Nuclear Physics

- B1.** (a) appropriate reference to the energy of electrons within the atom *e.g.* the electrons of an atom have energy;
not all energy values are possible (within an atom) / energy can only take discrete values; [2]
- (b) electrons accelerated through p.d.;
travel through a vacuum;
strike surface of tungsten (and emit X-rays); [3]
Look for the above marking points in the form of a diagram or description.
- (c) characteristic peaks identified as evidence for quantization;
these correspond to photon energy due to transitions between allowed levels / *OWTTE*; [2]
- (d) $f\left(=\frac{c}{\lambda}\right) = 7.32 \times 10^{14} \text{ Hz};$
 $E = hf = 4.85 \times 10^{-19} \text{ J};$
this corresponds to the energy difference between the two energy levels that give rise to photons of this wavelength/frequency; [3]
- B2.** (a) ${}^{13}_6\text{C}$ *or* carbon nucleus $A = 13, Z = 6;$
 ${}^0_1\beta^+$ *or* ${}^0_1e^+$ *or* β^+ $A = 0, Z = 1$ *or* positron $A = 0, Z = 1;$
 ${}^0_0\nu$ *or* neutrino $A = 0, Z = 0;$ (*do not accept antineutrino*) [3]
- (b) carbon nucleus; [1]
- (c) substitution into $\lambda = \frac{\ln(2)}{T_{\frac{1}{2}}};$
to give $\lambda = 6.9 \times 10^{-2} \text{ min}^{-1}$ *or* $1.1 \times 10^{-3} \text{ s}^{-1};$ [2]
- (d) (i) initial number of nuclei
 $= \frac{0.13 \text{ mg}}{13 \text{ g}} = 6 \times 10^{18};$
initial rate of decay $(= 6 \times 10^{18} \times 6.9 \times 10^{-2} \text{ min}^{-1}) = 4.1 \times 10^{17} \text{ min}^{-1}$ *or* $6.9 \times 10^{15} \text{ s}^{-1};$ [2]
- (ii) amount $= 0.13e^{-6.9 \times 10^{-2} \times 15};$
 $= 0.050 \text{ mg};$ [2]
- or*
- 15 minutes = 1.5 half lives;
therefore remaining mass $= \frac{0.13}{2^{1.5}} = 0.050 \text{ mg};$

(b) white light;
with red and blue fringe/border; [2]

H2. (a) the ratio of the speed of light in a vacuum to the speed of light in a substance; [1]
Accept ratio of $\sin(i)$ to $\sin(r)$ provided that the angles i and r are unambiguously defined.

(b) (i) line (R) bent away from normal and line (L) obeying law of reflection; [1]
Judge by eye.

(ii) $\sin(\text{critical angle}) = 0.67$ / critical angle = 42° ;
the refracted ray eventually disappears;
when the critical angle has been passed for angles greater than the critical angle;
the light undergoes total internal reflection / all the light is internally/totally reflected; [4]

- H4.** (a) (i) realization that missing fringes are related to the diffraction pattern of individual slits;
 at the expected angle for constructive interference from the double slit, the individual slits have a minimum / *OWTTE*; [2]
- (ii) missing fringe corresponds to fourth fringe so path difference corresponds to 4λ (at $\theta = 0.01857$ rad);
 first slit minimum at $\theta = \frac{\lambda}{b} \therefore b = \frac{\lambda}{\theta} = \frac{650 \text{ nm}}{0.01857} = 3.5 \times 10^{-5} \text{ m}$; [2]
Accept substitution which avoids calculating angle e.g.
 $\theta = \frac{4\lambda}{d} = \frac{\lambda}{b} \therefore b = \frac{d}{4} = 3.5 \times 10^{-5} \text{ m}.$
- (b) fringes will be brighter;
 more slits therefore more light getting through;
 sharper;
 slightly away from constructive interference, each subsequent slit further out of phase, so net result will be zero amplitude / *OWTTE*;
 not have missing fringes; [3 max]
To award [3] answers must include two changes and one corresponding explanation.
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