

IB PHYSICS: Atomic and Nuclear Markscheme (topic 7)

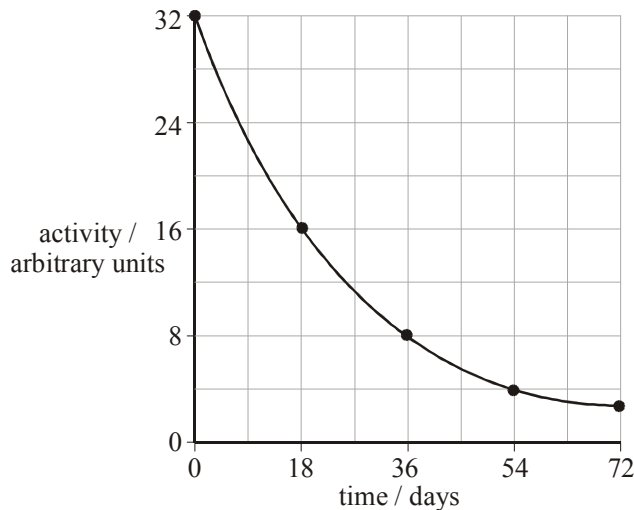
1. (a) *[1]* for any valid and relevant point e.g.
 Geiger-Marsden experiment involved bombardment of gold foil by alpha particles;
 most passed straight through / were deviated through small angles but,
 some deflected through large angles;
 these alpha particles were heading towards central nucleus; 3 max
- (b) *[1]* for any valid and relevant point e.g.
 protons in nucleus repel each other (seen or implied);
 but are held together by the strong nuclear force / or neutrons are
 involved keeping it bound together / *OWTTE*; 2 max
- (c) (i) attempted use of $F = \frac{q_1 q_2}{4\pi\epsilon_0 r^2}$;
 with $q_1 = q_2 = 10^{29} e = 1.6 \times 10^{-10} \text{ C}$;
 and $r = 100 \text{ m}$;
 to get $F = 2.3 \times 10^{26} \text{ N} \approx 10^{26} \text{ N}$; 4 max
- (ii) people are overall electrically neutral;
 equal numbers of positive charges mean that overall the electrical
 force is zero / *OWTTE*; 2 max

[11]

2. D

[1]

3. (a) (i) isotope: nuclei of elements with different number of neutrons;
Accept same Z different A / OWTTE. 1
- (ii) time for the activity to halve in value / time for the number of nuclei
 to transmute to nuclei of another element / *OWTTE*; 1
- (b) (i) ${}^{227}_{86}\text{Ac} \rightarrow {}^{227}_{90}\text{Th} + \beta^- \text{ (e)}$; 1
- (ii)



correct data points;
 sensible attempt at line of best fit;

2

- (iii) 5.0 (± 1); 1
- (iv) Geiger tube plus counter; 2
 count for given time and divide count by time to get activity;
Or if candidates use Geiger tube plus ratemeter, [1] then some other detail is needed such as source must be placed close to the GM tube [1].
- (c) mass defect = $227.0278 - (223.0186 + 4.0026) = 0.0066 \text{ u}$;
 $= 6.148 \text{ MeV } c^{-2}$;
 therefore energy of $\gamma = 6.148 - 5.481 = 0.667 \text{ MeV}$; 3
- [11]**

4. C **[1]**

5. (a) (i) *fission*:
 nucleus splits;
 into two parts of similar mass;
radioactive decay:
 nucleus emits;
 a particle of small mass and/or a photon; 4
- (ii) ${}_{92}^{235}\text{U} + {}_0^1\text{n}$;
 $\rightarrow {}_{38}^{90}\text{Sr} + {}_{54}^{142}\text{Xe} + 4 {}_0^1\text{n}$; 2
Allow ecf for RHS if LHS is incorrect.
- (iii) mass number unchanged;
 atomic number increases by +1; 2
- (b) (i) use of $E_k = \frac{p^2}{2m}$ / equivalent;
 correct conversion of MeV to joule ($1.63 \times 10^{-11} \text{ J}$);
 correct conversion of mass to kilogram ($1.50 \times 10^{-25} \text{ kg}$);
 momentum = $2.2 \times 10^{-18} \text{ N s}$; 4
- (ii) total momentum after fission must be zero;
 must consider momentum of neutrons (and photons); 2
- (iv) xenon not opposite to strontium but deviation $< 30^\circ$;
 arrow shorter / longer; 2
- (c) (i) energy = $0.25 \times 198 \times 1.6 \times 10^{-13}$;
 $= 7.9 \times 10^{-12} \text{ J}$; 2
- (ii) use of $\Delta Q = mc\Delta Q$;
 energy = $0.25 \times 4200 \times 80$;
 $= 8.4 \times 10^4 \text{ J}$; 3

(iii) number of fissions = $\frac{(8.4 \times 10^4)}{(7.9 \times 10^{-12})}$;
 mass = $1.1 \times 10^{16} \times 3.9 \times 10^{-25}$;
 = 4.1×10^{-9} kg;

4

[25]

6. B

[1]

7. B

[1]

8. C

[1]

9. C

[1]

10. B

[1]

11. (a) ${}_{25}^{54}\text{Mn} \rightarrow {}_{24}^{54}\text{Ar} + \beta^+ + \nu$
 A = 54;
 Z = 24;
 ν (name or symbol);

3 max

Award [1] for each correct answer up to [3 max].

(b) charged vector boson

1 max

(c) (i) strong nuclear force (interaction)
Also accept just "strong".

1 max

(ii) meson

1 max

[6]

12. (a) (i) fission

1 max

(ii) kinetic energy

1 max

(b) the two neutrons can cause fission in two more uranium nuclei producing four neutrons so producing eight *etc.*; *OWTTE*;

1 max

- (c) (i) the fuel rods contain a lot more U-238 than U-235;
neutron capture is more likely in U-238 than U-235 with
high energy neutrons;
but if the neutrons are slowed they are more likely to produce
fission in U-235 than neutron capture in U-238; 3 max
*The argument is a little tricky so be generous. The candidate
needs to know about there being two isotopes present in the fuel
and something about the dependence of the fission and capture
in the two isotopes on neutron energy.*
- (ii) control the rate at which the reactions take place;
by absorbing neutrons; 2 max
- (d) *Look for **four** of the following main points and award [1] each.*
energy lost by the slowing of the neutrons and fission elements heats the pile;
this heat extracted by the molten sodium / pressurised water / other
suitable substance;
which is pumped to a heat exchanger;
water is pumped through the heat exchanger and turned to steam;
the steam drives a turbine;
which is used to rotate coils (or magnets) placed in a magnetic field
(or close to coils) which produces electrical energy; 4 max
*Alternatively, award 4 for a good answer, [2] for a fair answer
and [1] for a weak answer.*

[12]

13. (a) *Deduct [1] for each error or omission, stop at zero* 2 max

<i>Property</i>	<i>Effect on rate of decay</i>		
	<i>increase</i>	<i>decrease</i>	<i>stays the same</i>
<i>temperature of sample</i>			✓
<i>pressure on sample</i>			✓
<i>amount of sample</i>	✓		

- (b) (i) the probability of decay (of a nucleus);
is 4.3×10^{-4} (1 in 2326) in each year; 2
- (ii) mass defect = $5.2 \times 10^{-3} u$;
energy = mc^2
= $5.2 \times 10^{-3} \times 1.661 \times 10^{-27} \times 9.00 \times 10^{16} / 1 u = 930 \text{ MeV}$;
= $7.77 \times 10^{-13} \text{ J} / 4.86 \text{ MeV}$; 3 max
- (c) (i) (linear) momentum must be conserved;
momentum before reaction is zero;
so equal and opposite after (to maintain zero total); 3
- (ii) $0 = m_{\alpha}v_{\alpha} + m_{\text{Rn}}v_{\text{Rn}}$;
 $\frac{v_{\alpha}}{v_{\text{Rn}}} = -\left(\frac{m_{\text{Rn}}}{m_{\alpha}}\right)$
= $-\frac{222}{4} = -55.5$; 3
Ignore absence of minus sign.
- (d) (i) $N_0 = \frac{(15.0 \times 10^{-6} \times 6.02 \times 10^{23})}{226}$;

$$= 4.0 \times 10^{16} (3.996 \times 10^{16});$$

$$(ii) \quad N = 3.996 \times 10^{16} \exp(-4.30 \times 10^{-4} \times 30);$$

$$= 3.95 \times 10^{16} (3.945 \times 10^{16});$$

$$(iii) \quad \text{mean activity} = \frac{(N_0 - N)}{t}$$

$$= \frac{(3.996 \times 10^{16} - 3.945 \times 10^{16})}{(30 \times 365 \times 24 \times 3600)};$$

$$= 5.4 \times 10^5 \text{ Bq};$$

6 max

Allow activity in yr⁻¹.

(e) neutrons and protons are composed of quarks;

proton is up, up, down;

neutron is up, down, down;

3

(f) (i) two (light) nuclei;

combine to form a more massive nucleus;

with the release of energy / with greater total binding energy;

3

(ii) high temperature means high kinetic energy for nuclei;

so can overcome (electrostatic) repulsion (between nuclei);

to come close together / collide;

high pressure so that there are many nuclei (per unit volume);

so that chance of two nuclei coming close together is greater;

5

[30]