

Nuclear Physics

Mark Scheme 5

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Particle & Nuclear Physics
Sub Topic	Nuclear Physics
Paper Type	Theory
Booklet	Mark Scheme 5

Time Allowed: 78 minutes

Score: /65

Percentage: /100

A*	A	B	C	D	E	U
>85%	77.5%	70%	62.5%	57.5%	45%	<45%

1 (a) (constant) probability of decay M1
per unit time A1 [2]
(reference to decay of isotope / mass / sample / nuclide, allow max 1 mark)

(b) either when time = $t_{1/2}$, $N = \frac{1}{2}N_0$
or $\frac{1}{2}N_0 = N \exp(-\lambda t_{1/2})$ M1
either $2 = \exp(\lambda t_{1/2})$ M1
or $\frac{1}{2} = \exp(-\lambda t_{1/2})$ M1
(taking logs), $\ln 2 = 0.693 = \lambda t_{1/2}$ A1 [3]

(c) $A = \lambda N$
 $1.8 \times 10^5 = N \times (0.693 / \{1.66 \times 10^8\})$ C1
 $N = 4.3 \times 10^{13}$
mass = $60 \times (N/N_A)$ or $60 \times N \times u$ C1
= $(60 \times 4.3 \times 10^{11}) / (6.02 \times 10^{23})$
= 4.3×10^{-9} g A1 [3]

[Total: 8]

2 (a) (i) $\Delta N / \Delta t$ (ignore any sign) B1 [1]
(ii) $\Delta N / N$ (ignore any sign) B1 [1]

(b) source must decay by 8% C1
 $A = A_0 \exp(-\ln 2 t / T_{1/2})$ or $A/A_0 = 1 / (2^{t/T})$ C
 $0.92 = \exp(-\ln 2 \times t / 5.27)$ or $0.92 = 1 / (2^{t/5.27})$ C
 $t = 0.634$ years A1 [4]
= 230 days
(allow 2 marks for $A/A_0 = 0.08$, answer 7010 days
allow 1 mark for $A/A_0 = 0.12$, answer 5880 days)

3	(a) change/loss in kinetic energy = change/gain in electric potential energy $2 \times \frac{1}{2}mv^2 = q^2 / 4\pi\epsilon_0 r$ $2 \times \frac{1}{2} \times 2 \times 1.67 \times 10^{-27} \times v^2$ $= (1.6 \times 10^{-19})^2 / (4\pi \times 8.85 \times 10^{-12} \times 1.1 \times 10^{-14})$ $v = 2.5 \times 10^6 \text{ m s}^{-1}$	B1 C1 M1 A0 [3]
	(b) $pV = \frac{1}{2}Nm< c^2 >$ and $pV = NkT$	C1
	$\frac{1}{2} m< c^2 > = \frac{3}{2} kT$ (award 1 mark of first two if $< c^2 >$ not used)	C1
	$\frac{1}{2} \times 2 \times 1.67 \times 10^{-27} \times (2.5 \times 10^6)^2 = \frac{3}{2} \times 1.38 \times 10^{-23} \times T$	C1
	$T = 5 \times 10^8 \text{ K}$	A1 [4]
4	(c) e.g. this is <u>very</u> high temperature temperature found in stars (any sensible comment, 1 mark) (if $T < 10^6 \text{ K}$, should comment that too low for fusion to occur)	B1 [1]
4	(a) since momentum before combining is zero momenta must be equal and opposite after <u>equal momenta</u> so photon energies equal	B1 B1 B1 [3]
	(b) $E = mc^2$ $= 9.1 \times 10^{-31} \times (3.0 \times 10^8)^2$ $= 8.19 \times 10^{-14} (\text{J})$ $= (8.19 \times 10^{-14}) / (1.6 \times 10^{-13})$ $= 0.51 \text{ MeV}$	C1 C1 A1 [3]

5 (a) energy required to (completely) separate the nucleons (in a nucleus) B1 [1]

(b) (i) U labelled near right-hand end of line B1
Ba and Kr in approximately correct positions B1 [2]

(ii) binding energy is $A \times E_B$ B1
either binding energy of U < binding energy of (Ba + Kr)
or E_B of U < E_B of (Ba + Kr) B1 [2]

(c) Krypton-92 reduced to 1/8 in 9 s M1
in 9 s, very little decay of Barium-141 M1
so, approximately 9 s A1 [3]
OR

$$\lambda_{Kr} = 0.231 \text{ or } \lambda_{Ba} = 6.42 \times 10^{-4}$$
$$8 = e^{-\lambda B \times t} / e^{-\lambda K \times t}$$
$$t = 9.0 \text{ s}$$

(M1)

(C1)

(A1)

6 (a) probability of decay
of a nucleus per unit time M1
(allow 1 mark for $A = \lambda N$, with symbols explained) A1 [2]

(b) (i) $\lambda = \ln 2 / (28 \times 365 \times 24 \times 3600)$ C1
 $= 7.85 \times 10^{-10} \text{ s}^{-1}$ A1 [2]

(ii) $A = (-)\lambda N$ C1
 $N = (6.4 \times 10^9) / (7.85 \times 10^{-10})$ C1
 $= 8.15 \times 10^{18}$ C1
mass = $(8.15 \times 10^{18} \times 90) / (6.02 \times 10^{23})$ (e.c.f. for value of N) C1
 $= 1.22 \times 10^{-3} \text{ g}$ A1 [4]

(iii) volume = $(1.22 \times 10^{-3} / 2.54 =) 4.8 \times 10^{-4} \text{ cm}^3$ A1 [1]

(c) *either* very small volume of Strontium-90 has high activity
or dust can be highly radioactive
breathing in dust presents health hazard B1 [2]

7	(a) (i)	<i>either</i> number = $6.02 \times 10^{23} \times (2.65 \times 10 / 234)$ or number = $(2.65 \times 10^0) / (234 \times 1.66 \times 10^{-2})$ = 6.82×10^{15}	C1 A1	[2]
	(ii)	$A = 2N$ $604 = A \times 6.82 \times 10^{15}$ $A = 8.86 \times 10^{-14} \text{ s}^{-1}$	C1 A1	[2]
	(iii)	$T_{1/2} = \ln 2 / \lambda$ = $7.82 \times 10^{12} \text{ s}$ = $2.48 \times 10^5 \text{ years}$	C1 A1	[2]
	(b)	half-life is (very) long (compared with time of counting)	B1	[1]
	(c)	there would be appreciable decay of source during the taking of measurements	B1	[1]

8	(a)(i)	energy required to separate the nucleons in a nucleus nucleons separated to infinity / completely	M1 A1	[2]
	(ii)	S shown at peak	B1	[1]
	(b)(i)	4	A1	[1]
	(ii) 1.	idea of energy as product of A and energy per nucleon energy = $(8.37 \times 142 + 8.72 \times 90) - 235 \times 7.59$ = 1189 + 785 - 178 = 190 MeV (-1 for each a.e.)	C1 A2	[3]
	2.	energy = mc^2 1 MeV = $1.6 \times 10^{-13} \text{ J}$ energy = $(190 \times 1.6 \times 10^{-13}) / (3.0 \times 10^8)^2$ = $3.4 \times 10^{-28} \text{ kg}$	C1 C1 A1	[3]