

# Nuclear Physics

## Mark Scheme 6

<b>Level</b>	International A Level
<b>Subject</b>	Physics
<b>Exam Board</b>	CIE
<b>Topic</b>	Particle & Nuclear Physics
<b>Sub Topic</b>	Nuclear Physics
<b>Paper Type</b>	Theory
<b>Booklet</b>	Mark Scheme 6

**Time Allowed:** 87 minutes

**Score:** /72

**Percentage:** /100

CHEMISTRY ONLINE

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

- 1 (a) curve levelling out (at 1.4  $\mu\text{g}$ ) **M1**  
 correct shape judged by masses at  $nT_{1/2}$  **A1** [2]  
 [for second mark, values must be marked on y-axis]
- (b) (i)  $N_0 = (1.4 \times 10^{-6} \times 6.02 \times 10^{23})/56$  **C1**  
 $= 1.5 \times 10^{16}$  **A1** [2]
- (ii)  $A = \lambda N$  **C1**  
 $\lambda = \ln 2 / (2.6 \times 3600) (= 7.4 \times 10^{-5} \text{ s}^{-1})$  **C1**  
 $A = 1.11 \times 10^{12} \text{ Bq}$  **A1** [3]
- (c) 1/10 of original mass of Manganese remains **C1**  
 $0.10 = \exp(-\ln 2 \times t/2.6)$   
 $t = 8.63 \text{ hours}$  **A1** [2]  
 [use of 1/9, giving answer 8.24 hrs scores 1 mark]

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 — TUITION —

2	(a)	(i)	<i>either</i> probability of decay <i>or</i> $dN/dt = (-)2N$ OR $A = (-)2N$ per unit time with symbols explained	1 1	[2]
		(ii)	greater energy of $\alpha$ particle means (parent) nucleus less stable nucleus more likely to decay hence Radium-224	0 1 1 1	[3]
	(b)	(i)	<i>either</i> $2 = \ln 2/3.6$ or $2 = \ln 2/3.6 \times 24 \times 3\ 600$ $= 0.193$ $= 2.23 \times 10^6$  unit day <sup>-1</sup> s <sup>-1</sup>  (one sig.fig., -1, allow 2 in hr <sup>-1</sup> )	1  1	[2]
		(ii)	$N = \{(2.24 \times 10^3)/224\} \times 6.02 \times 10^{23}$ $= 6.02 \times 10^{18}$ activity = 2N $= 2.23 \times 10^{-6} \times 6.02 \times 10^{18}$ $= 1.3 \times 10^{13}$ Bq	1 1 1 1	[4]
	(c)		$A = A_0 e^{-\ln 2 n T}$ $0.1 = \exp(-\ln 2 \cdot n)$ $n = 3.32$ ( $n = 3$ without working scores 1 mark)	1 1	[2]
3	(a)		S shown at the peak	B1	[1]
	(b)	(i)	Kr and U on right of peak in correct relative positions	B1	[1]
		(ii)1	binding energy of U-235 = $2.8649 \times 10^{-10}$ J binding energy of Ba-144 = $1.9211 \times 10^{-10}$ J binding energy of Kr-90 = $1.2478 \times 10^{-10}$ J energy release = $3.04 \times 10^{-11}$ J (-1 if 1 or 2 s.f.)	C2 A1	[3]
		2	$E = mc^2$ $m = (3.04 \times 10^{-11})/3.0 \times 10^8)^2 = 3.38 \times 10^{-28}$ kg (ignore s.f.)	C1 A1	[2]
		(iii)	e.g. neutrons are single particles, neutrons have no binding energy per nucleon	B1	[1]
			<b>Total</b>		

- 4 (a) greater binding energy gives rise to release of energy ..... M1  
 so must be yttrium ..... A1 [2]
- (b) probability of decay ..... M1  
 of a nucleus per unit time ..... A1 [2]
- (c) (i)1  $A = \lambda N$  ..... C1  
 $3.7 \times 10^6 \times 365 \times 24 \times 3600 = 0.025N$  ..... C1  
 $N = 4.67 \times 10^{15}$  ..... A1 [3]
- (i) mass =  $0.09 \times (4.67 \times 10^{15}) / (6.02 \times 10^{23})$  ..... C1  
 $= 6.98 \times 10^{-10}$  kg ..... A1 [2]
- (ii)  $A = A_0 e^{-\lambda t}$   
 $A/A_0 = e^{-0.025t}$  ..... C1  
 $= 0.88$  ..... A1 [2]

- 5 (a) probability of decay of a nucleus ..... M1  
 per unit time ..... A1 [2]
- (b)  $A = \lambda N$  ... (ignore sign) ..... B1 [1]
- (c) (i)  $1 \text{ m}^3$  contains  $I / 0.024 = 41.7 \text{ mol}$  ..... C1  
 $1 \text{ m}^3$  contains  $41.7 \times N_A = 2.5 \times 10^{25}$  molecules ..... A1  
 (ii) number =  $(2.5 \times 10^{25}) / (1.5 \times 10^{21}) = 1.67 \times 10^4$  ..... A1  
 (iii)  $AT_{1/2} = 0.693$   
 $I = 0.693 I_0 = 0.0124 \text{ s}^{-1}$  ..... C1  
 activity =  $0.0124 \times 1.67 \times 10^4$   
 $= 210 \text{ Bq}$  ..... A1 [5]

- 6 (a) (i) *either* helium nucleus  
or contains 2 protons and 2 neutrons ..... B1 [1]
- (ii) e.g. range is a few cm in air/sheet of thin paper  
speed up to 0.1 c  
causes dense ionisation in air  
positively charged or deflected in magnetic or electric fields  
(any two, 1 each to max 2) ..... B2 [2]
- (b) (i)  ${}^4_2\alpha$  ..... B1  
*either*  ${}^1_1\text{p}$  or  ${}^1_1\text{H}$ ..... B1 [2]
- (ii) initially,  $\alpha$ -particle must have some kinetic energy ..... B1 [1]
- (ii) 2  $1.1 \text{ MeV} = 1.1 \times 1.6 \times 10^{-13} = 1.76 \times 10^{-13} \text{ J}$  ..... C1  
 $E_K = \frac{1}{2}mv^2$  ..... C1  
 $1.76 \times 10^{-13} = \frac{1}{2} \dots \dots \dots \times v^2$  ..... C1  
 $v = 7.3 \times 10^6 \text{ m s}^{-1}$  ..... A1 [4]  
use of  $1.67 \times 10^{-27} \text{ kg}$  for mass is a maximum of 3/4
- 7 (a) atoms / molecules / particles behave as elastic (identical) spheres (1)  
volume of atoms / molecules negligible compared to volume of containing vessel (1)  
time of collision negligible to time between collisions (1)  
no forces of attraction or repulsion between atoms / molecules (1)  
atoms / molecules / particles are in (continuous) random motion (1)  
(any four, 1 each) B [4]
- (b)  $pV = \frac{1}{3} Nm\langle c^2 \rangle$  and  $pV = nRT$  or  $pV = NkT$  ..... B1  
 $\frac{1}{3} Nm\langle c^2 \rangle = nRT$  or  $= NkT$  and  $\langle E_K \rangle = \frac{1}{2}m\langle c^2 \rangle$  ..... B1  
 $n = N/N_A$  or  $k = R/N_A$  ..... B1  
 $\langle E_K \rangle = \frac{3}{2} \times R/N_A \times T$  ..... A0 [3]
- (c) (i) reaction represents *either* build-up of nucleus from light nuclei  
or build-up of heavy nucleus from nuclei ..... M1  
so fusion reaction ..... A1 [2]
- (ii) proton and deuterium nucleus will have equal kinetic energies ..... B1  
 $1.2 \times 10^{-14} = \frac{3}{2} \times 8.31 / (6.02 \times 10^{23}) \times T$  ..... C1  
 $T = 5.8 \times 10^8 \text{ K}$  ..... A [3]  
(use of  $E = 2.4 \times 10^{-14}$  giving  $1.16 \times 10^9 \text{ K}$  scores 1 mark)
- (iii) *either* inter-molecular / atomic / nuclear forces exist  
or proton and deuterium nucleus are positively charged / repel ..... B1 [1]