Nuclear Physics

Mark Scheme 2

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Particle & Nuclear Physics
Sub Topic	Nuclear Physics
Paper Type	Theory
Booklet	Mark Scheme 2

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** nucleus/nuclei emits — M1
spontaneously/randomly — A1
α-particles, β-particles, γ-ray photons — A1 [3]

(b) $N - \Delta N$ — A1 [1]

(ii) $\Delta N / \Delta t$ — **A1**

(iii) $\Delta N / N$ — **A1**

(iv) $\Delta N / N \Delta t$ — A1 [1]

(c) graph: smooth curve in correct direction starting at (0,0) — M1
n at $2t_{½}$ is 1.5 times that at $t_{½}$ ($\pm$ 2 mm) [2]

2 **(a)** **(i)** energy : $5.75 \times 1.6 \times 10^{-13}$
: 9.2×10^{-13} J — A1 [1]

(ii) number = $1900 / (9.2 \times 10^{-13} \times 0.24)$ — C1
: 8.6×10^{15} S^{-1} — A1 [2]

(b) **(i)** decay constant= $0.693/(2.8 \times 365 \times 24 \times 3600)$ — C1
$= 7.85 \times 10^{-9}$ s^{-1} *(allow 7.8 or 7.9 to 2 s.f.)* — A1 [2]

(ii) ***A=?..N***
$8.6 \times 10^{15} = 7.85 \times 10^{-9} \times N$ — C1
$N = 1.096 \times 10^{24}$ — C1

mass= $(1.096 \times 10^{24} \times 236)/(6.02 \times 10^{23})$ — M1
= 430g — A1 [4]

(c) $0.84 = 1.9 \exp(-7.85 \times 10^{-9} t)$ — C1
t= 1.04×10^{8} s
= 3.3 years — A1 [2]

3 **(a** 'light' nuclei combine to form 'heavier' nuclei B1 [1]

(b) *either* energy = $c^2\Delta m$
or energy = $(3.00 \times 10^8)^2 \times 1.66 \times 10^{-27}$ C1
energy = 1.494×10^{-10} J C1
= $(1.494 \times 10^{-10}) / (1.60 \times 10^{-13})$
= 934 MeV (*3 s.f.*) A1 [3]

(ii) Δm = (2.01356 + 3.01551) – (4.00151 + 1.00867)
= 5.02907 – 5.01018
= 0.01889 u C1

energy = 0.01889 × 934
= 17.6 MeV (*allow 2 s.f.*) A1 [2]

(iii) high temperature means high speeds / kinetic energy of nuclei B1
D and T nuclei collide despite repelling one another B1 [2]

4 **(a** activity = $(1.7 \times 10^{14}) / (2.5 \times 10^6)$
= 6.8×10^7 Bq kg^{-1} A1 [1]

(b) (energy released per second in 1.0 kg of steel
= $6.8 \times 10^7 \times 0.067 \times 1.6 \times 10^{-13}$
= 7.3×10^{-7} J B [1]

(ii) this is a very small quantity of energy so steel will not be warm B1 [1]

(iii) $A = A_0 e^{-\lambda t}$ and $\lambda t_{½} = \ln 2$ C
$400 = (6.8 \times 10^7) \exp(-[\ln 2 \times t] / 92)$
t = 1600 years

or

$A = A_0 / 2^n$ (C1)
n = 17.4 (C1)
t = 17.4 × 92 = 1600 years [3]

5 **(a)** energy required to separate the nucleons (in a nucleus) M1
to infinity A1 [2]
(*allow reverse statement*)

(b) **(i)** $\Delta m = (2 \times 1.00867) + 1.00728 - 3.01551$ C1
$= 9.11 \times 10^{-3}$ u C1
binding energy = $9.11 \times 10^{-3} \times 930$
= 8.47 MeV A1 [3]
(*allow 930 to 934 MeV so answer could be in range 8.47 to 8.51 MeV)*
(*allow 2 s.f.*)

(ii) $\Delta m = 211.70394 - 209.93722$
$= 1.76672$ u C1
binding energy per nucleon = $(1.76672 \times 930)/210$ C1
= 7.82 MeV A1 [3]
(*allow 930 to 934 MeV so answer could be in range 7.82 to 7.86 MeV*)
(*allow 2 s.f.*)

(c) <u>total</u> binding energy of barium and krypton M1
is greater than binding energy of uranium A1 [2]

6 **(a** time for number of atoms / nuclei / activity (of the isotope) M1
to be reduced to one half (of its initial value) A1 [2]

(b) **(i)** $A = \lambda N$ C1
$460 = N \times \ln 2 / (8.1 \times 24 \times 60 \times 60)$ C1
$N = 4.6 \times 10^{8}$ A1 [3]

(ii) number of water molecules in 1.0 kg $= (6.02 \times 10^{23}) / (18 \times 10^{-3})$ C
$= 3.3 \times 10^{25}$
ratio $= (3.3 \times 10^{25}) / (4.6 \times 10^{8})$
$= 7.2\ (7.3) \times 10^{16}$ A1 [2]

(c) $A = A_0\, e^{-\lambda t}$ <u>and</u> $\lambda t_{½} = \ln 2$ C1
$170 = 460 \exp(-\{\ln 2\, t\}/8.1)$
$t = 11.6$ days (*allow 2 s.f.*) A [3]

7 **(a** energy to separate nucleons (in a nucleus) M1
separate to infinity A1 [2]

(b) (i) fission [1]

(ii) U: near right-hand end of line B1 [1]

2. Mo: to right of peak, less than 1/3 distance from peak to U B1 [1]

3. La: 0.4 → 0.6 of distance from peak to U B1 [1]

(iii) right-hand side, mass = 235.922 u C1
mass change = 0.210 u A1 [2]

2. energy = mc^2 C1
$= 0.210 \times 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$
$= 3.1374 \times 10^{-11}$ J C1
= 196 MeV (*need 3 s.f.*) A1 [3]
(*use of 1 u = 934 MeV, allow 3/3; use of 1 u = 930 MeV or 932 MeV, allow 2/3*)
(*use of 1.67×10^{-27} not 1.66×10^{-27} scores max. 2/3*)