Mass and Energy Interchange – Mark Scheme

1. B – 2 marks

2. D – 2 marks

3. (a) energy needed to separate **(1)**
nucleus into constituent nucleons **(1)** — 2

(b) (i) mass defect = 26 × 1.00728 + 30 × 1.00867 **(1)**
+ 26 × 0.00055 **(1)** – 55.93493 = 0.529(u) **(1)**
binding energy = 0.529 × 931 = 492 (MeV) **(1)**
binding energy per nucleon $\frac{492}{56}$ = 8.8 (MeV) **(1)**

(ii) mass defect = $0.529 \times 1.66 \times 10^{-27} = 8.8 \times 10^{-28}$ (kg) **(1)** — 6

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4. (a) (i) energy (required to break nucleus up into / released when nucleus is formed from) separate nucleons **(1)**
(E_p of nucleons decreases when they come together / work is done on nucleons by the strong force) **(1)**
energy associated with the strong force **(1)**

(ii) mass of nucleus < total mass of constituent nucleons **(1)**
Δm is difference between mass of nucleus and total mass of nucleons **(1)**
[$\Delta m = Zm_p + (A - Z)m_n - m_{nucleus}$ **(1)** **(1)**]

$E_b = (\Delta m)c^2$ **(1)**
[or E_b is energy equivalent of mass defect using $E = mc^2$] — max 4
QWC 1

(b) mass of nucleus = 63.92915 – (30 × 0.00055) = 63.91265 (u) **(1)**
Δm = (30 × 1.00728) + (34 × 1.00867) – 63.91265 **(1)**
= 0.60053 (u) **(1)**
E_b = 0.60053 × 931.3 = 559.3 (MeV) **(1)**
E_b/nucleon = $\frac{559.3}{64}$ = 8.74 (MeV/nucleon) **(1)**
(allow C.E. for Δm and E_b) — 5

(c) nucleus has high value of E_b/nucleon
[or is near maximum of E_b/nucleon vs A curve] **(1)** — 1

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5. (a) (i) proton number 82 and nucleon number 214 **(1)**

(ii) Pb **(1)** — 2

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(b) (i) kinetic energy [or electrostatic potential energy] **(1)**

(ii) $\Delta m = \dfrac{E}{c^2}$ **(1)**

$= \dfrac{8.6 \times 10^{-13}}{(3 \times 10^8)^2}$ = 9.6 × 10^{-30} kg **(1)** 3

[5]

6. (a) (i) ${}^{238}_{92}\text{U} \rightarrow {}^{4}_{2}\alpha$ **(1)** + ${}^{234}_{90}\text{Th}$ **(1)**

(ii) Δm = 238.05076 – 4.00260 – 234.04357 = 0.00459(u) **(1)**
Q = 931 × 0.00459 (MeV) **(1)**
= 4.3MeV **(1)** 5

(b) (i) overall change in proton number (= 92 – 82) = 10
change in proton number due to α particles (= 8 × 2) = 16 **(1)**
therefore ΔZ = –6 for the β^- particles corresponding to the six β^- particles **(1)**

(ii) proton changes to a neutron plus a positron [or p → n + β^+(+ ν_e + Q)] **(1)**
Pb-206 has a lower neutron to proton ratio than U-238 **(1)**
α alpha emission raises the neutron to proton ratio slightly **(1)**
β^- emission lowers the ratio (more) **(1)**
β^+ emission increases neutron to proton ratio **(1)**
positron emission competes with α emission but is
energetically less favourable **(1)** max 6

[11]

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