HOLY CROSS COLLEGE
Life to the Full

W-16

11 PHYSICS ATAR
TEST 6: NUCLEAR PHYSICS

NAME: SOLUTIONS MARK: $\frac{\quad}{33}$

1. Copy and complete these reaction equations.

(a) $^{141}_{57}La \longrightarrow {}^{141}_{58}Ce + {}^{0}_{-1}e$ (1)

(b) $^{226}_{88}Ra \longrightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$ (1)

(c) $^{1}_{0}n + {}^{239}_{94}Pu \longrightarrow {}^{130}_{54}Xe + {}^{106}_{40}Zr + 4{}^{1}_{0}n$ (1) (3)

2. Consider three beams of α, β and γ radiations of ***equal energy***. When passing through matter, they have differing ***ionising power*** and ***penetrating ability***.

(a) Arrange them in decreasing order (i.e. highest mentioned first) of:

(i) ionising power.

α, β, γ (1)

(ii) penetrating ability.

γ, β, α (1)

(2)

(b) Look at the α particle rankings in part (a) above. Explain why you have rated this radiation as you have.

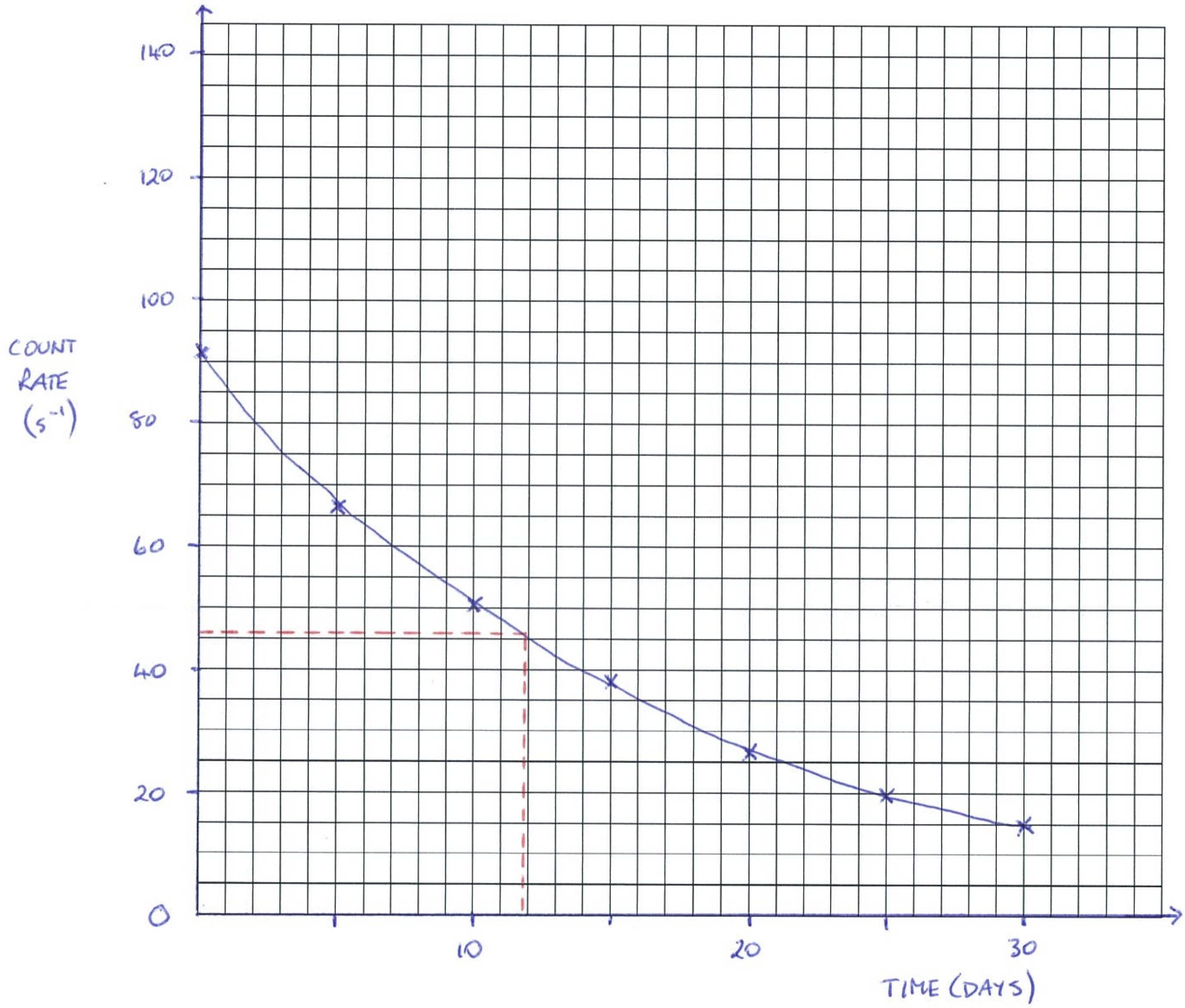
- Very large nucleus and slow - able to remove electrons from atoms easily. (1)
- Unable to penetrate well due to large size. (1)

(2)

3. A sample of Ra-233 is delivered to a research laboratory and found to give an a particle count rate of 92 per second. However, over the next month, the count rate diminishes as follows.

TIME (days)	0	5	10	15	20	25	30
COUNT RATE (s^{-1})	92	67	51	38	27	20	15

Plot the data on the graph paper below and determine the half-life.



Half-life: 11·9 ± 0·2 days (1) (5)

Scales + labels - 2 marks
Plotting - 1 mark
Line of best fit - 1 mark

4. Iodine-131, used in destroying malignant tumours of the thyroid, has a half-life of 8.07 days. If the initial activity (count rate) is 3.20×10^6 Bq at the time of injection, what would be the activity after 3.50 days?

$$n = \frac{3.50}{8.07} \quad (1)$$
$$= 0.4337 \quad (1)$$

$$N = N_0 \frac{1}{2^n}$$
$$= (3.20 \times 10^6)\left(\frac{1}{2^{0.4337}}\right) \quad (1)$$
$$= \underline{2.37 \times 10^6 \text{ Bq}} \quad (1)$$

(4)

5. (a) Determine the binding energy per nucleon of a $^{218}_{84}\text{Po}$ atom. Show all of your working clearly. (Po-218 = 218.10215u)

84 protons = $84 \times 1.00727u = 84.61068u$

134 neutrons = $134 \times 1.00867u = 135.16178u$

84 electrons = $84 \times 0.000549u = 0.046116u$

$219.818576u$ (2)

Mass defect = $219.818576u - 218.10215u$
$= 1.716426u$
$= 1.599 \times 10^3$ MeV (1)

∴ Binding energy $= \frac{1.599 \times 10^3}{218}$
$= \underline{7.33 \text{ MeV/nucleon}}$ (1) (1.17×10^{-12} J/nucleon)

(4)

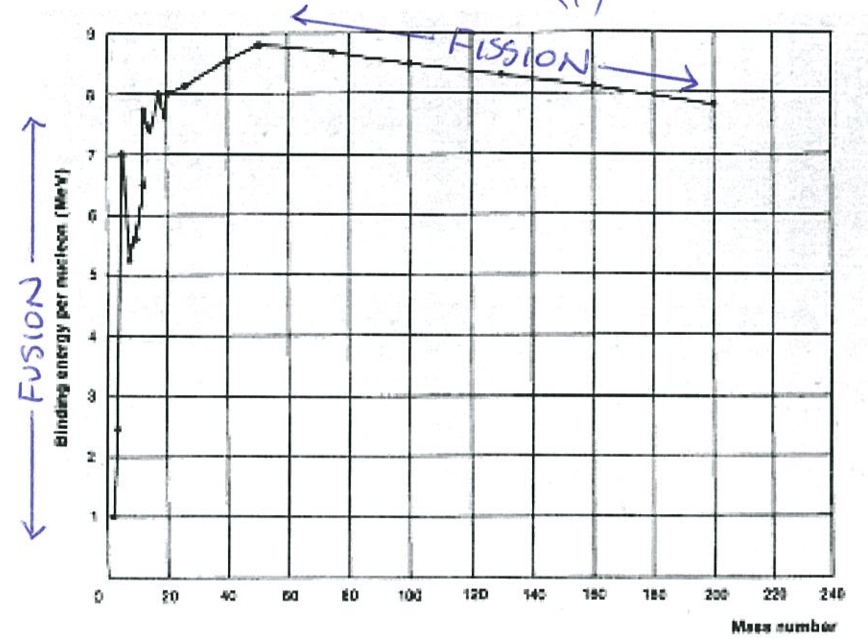
(b) Which element has the highest binding energy per nucleon?

$^{56}_{26}\text{Fe}$ (1)

(1)

(c) On the diagram below, indicate which elements along the curve undergo ***fission***, and explain why they do.

(1)



- Large nuclei are unstable and can split to form smaller nuclei. (1)
- These smaller nuclei have higher binding energies and are more stable. (1)

(3)

7. (a) When irradiating a food sample, a scientist uses an absorbed dose of 11.0 kGy of gamma radiation. How much energy would a 245 g sample absorb?

$$A.D. = \frac{E}{m}$$

$$\Rightarrow E = A.D. \times m$$

$$= (11.0\times10^3)(0.245) \quad (1)$$

$$= \underline{2.70\times10^3 \text{ J}} \quad (1)$$

(2)

(b) What dose equivalent would this be if alpha particles were used instead of gamma rays?

$$D.E. = A.D. \times Q.F.$$
$$= (11.0 \times 10^3)(20) \quad (1)$$
$$= \underline{2.20 \times 10^5 \text{ Sv.}} \quad (1)$$

(2)

8. Two deuterium nuclei (^2_1H) fuse to make helium (^3_2He) and a neutron.

(a) Write a nuclear equation for this fusion reaction.

$$^2_1H + {}^2_1H \rightarrow {}^3_2He + {}^1_0n \quad (1)$$

(1)

(b) Determine the amount of energy liberated by one such fusion reaction. (Mass ^2_1H = 3.34354 x 10^{-27} kg, mass ^3_2He = 5.00742 x 10^{-27} kg)

Mass of reactants $= 2 \times 3{\cdot}34354 \times 10^{-27}$
$= 6{\cdot}68708 \times 10^{-27}$ kg (1)

Mass of products $= 5{\cdot}00742 \times 10^{-27} + 1{\cdot}67493 \times 10^{-27}$
$= 6{\cdot}68235 \times 10^{-27}$ kg. (1)

Mass defect $= 0{\cdot}00473 \times 10^{-27}$ kg

$$E = mc^2$$
$$= (0{\cdot}00473 \times 10^{-27})(3{\cdot}00 \times 10^8)^2 \quad (1)$$
$$= \underline{4{\cdot}26 \times 10^{-13} \text{ J}} \quad (1)$$

(4)