

1

A radioactive nucleus emits a β^- particle then an α particle and finally another β^- particle. The final nuclide is

A an isotope of the original element

☐

B the same element with a different proton number

☐

C a new element of higher proton number

☐

D a new element of lower nucleon number

☐

(Total 1 mark)

2

A nucleus of a particular element decays, emitting a series of α and β^- particles.

Which of the following series of emissions would result in an isotope of the original element?

A 1 α and 1 β^-

☐

B 1 α and 2 β^-

☐

C 2 α and 1 β^-

☐

D 2 α and 2 β^-

☐

(Total 1 mark)

3

The element uranium has an isotope $^{237}_{92}\text{U}$.

(a) Explain what is meant by an isotope.

(2)

- (b) Determine the charge in coulomb of the $^{237}_{92}\text{U}$ nucleus.

charge = _____ C

(2)

- (c) A positive ion of $^{237}_{92}\text{U}$ has a charge of $+4.80 \times 10^{-19}$ C.

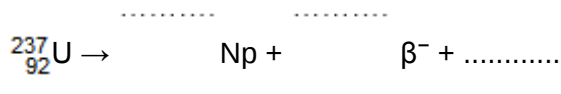
Determine the number of electrons in the ion.

number of electrons = _____

(2)

- (d) $^{237}_{92}\text{U}$ decays by β^- emission to form an isotope of neptunium (Np).

Complete the equation for this decay.



(3)

(Total 9 marks)

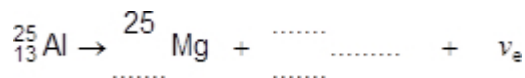
4

- (a) Name the only stable baryon.

(1)

- (b) (i) When aluminium-25 ($^{25}_{13}\text{Al}$) decays to magnesium-25 (Mg-25) an electron neutrino (ν_e) and another particle are also emitted.

Complete the equation to show the changes that occur.



(2)

(ii) Name the exchange particle responsible for the decay.

(1)

(Total 4 marks)

5

(a) The table below contains data for four different nuclei, P, Q, R and S.

Nuclei	Number of neutrons	Nucleon number
P	5	11
Q	6	11
R	8	14
S	9	17

(i) Which nucleus contains the fewest protons?

nucleus _____

(1)

(ii) Which **two** nuclei are isotopes of the same element?

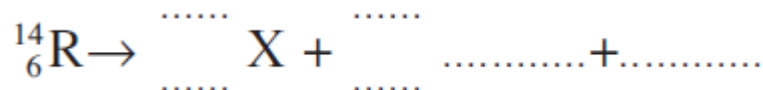
nuclei _____ and _____

(1)

(iii) State and explain which nucleus has the smallest specific charge.

(2)

- (iv) Complete the following equation to represent β^- decay of nucleus R to form nucleus X.



(3)

- (b) (i) The strong nuclear force is responsible for keeping the protons and neutrons bound in a nucleus.
Describe how the strong nuclear force between two nucleons varies with the separation of the nucleons, quoting suitable values for separation.

(3)

- (ii) Another significant interaction acts between the protons in the nucleus of an atom.
Name the interaction and name the exchange particle responsible for the interaction.

Interaction _____

Exchange particle _____

(2)

(Total 12 marks)

6

- (a) Describe how the strong nuclear force between two nucleons varies with the separation of the nucleons quoting suitable values for separation.

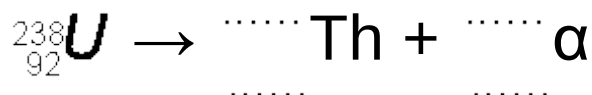
(3)

(b) An unstable nucleus can decay by the emission of an *alpha particle*.

(i) State the nature of an alpha particle.

(1)

(ii) Complete the equation below to represent the emission of an α particle by a ${}^{238}_{92}\text{U}$ nucleus.



(2)

(c) ${}^{238}_{92}\text{U}$ decays in stages by emitting α particles and β^- particles, eventually forming ${}^{206}_{82}\text{Pb}$, a stable *isotope* of lead.

(i) State what is meant by isotopes.

(2)

(ii) If there are eight alpha decays involved in the sequence of decays from

${}^{238}_{92}\text{U}$ to ${}^{206}_{82}\text{Pb}$ deduce how many β^- decays are involved.

answer = _____

(3)

(Total 11 marks)

7

A neutral atom of a radium isotope may be represented by ${}^{228}_{88}\text{Ra}$.

(a) (i) Name the constituents of this atom and state how many of each are present.

(3)

(ii) Which constituent of an atom has the largest specific charge?

(1)

(iii) This isotope of radium decays by β^- decay to form an element with symbol, Ac. Write down an equation that represents this decay.

(4)

(b) ${}^A_Z\text{Ra}$ is a neutral atom of a different isotope of radium. State a possible value for A and for Z.

A: _____

Z: _____

(2)

(Total 10 marks)

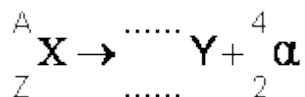
8

Alpha decay is a process by which an unstable *isotope* of an element may decay.

(i) State what is meant by isotopes.

(2)

(ii) Complete this equation for alpha decay.



(2)

- (iii) Calculate the specific charge of an alpha particle, stating an appropriate unit.

answer = _____

(4)

- (iv) Explain why the alpha particle, once outside the nucleus, is unaffected by the strong nuclear force.

(2)

(Total 10 marks)

9

- (a) (i) Determine the charge, in C, of a ${}_{92}^{239}\text{U}$ nucleus.

- (ii) A positive ion with a nucleus has a charge of $4.80 \times 10^{-19} \text{ C}$. Determine how many electrons are in this ion.

(4)

- (b) A ${}_{92}^{238}\text{U}$ nucleus may decay by emitting **two** β^- particles to form a plutonium nucleus ${}_{Y}^{X}\text{Pu}$.
State what X and Y represent and give the numerical value of each.

X _____

Y _____

(4)

(Total 8 marks)

10

- (a) Name the constituent of an atom which

- (i) has zero charge,

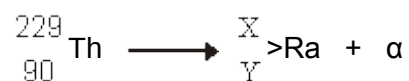
- (ii) has the largest charge to mass ratio,

- (iii) when removed leaves a different isotope of the element.

(3)

- (b) An α particle is the same as a nucleus of helium, ${}_{2}^{4}\text{He}$.

The equation



represents the decay of thorium by the emission of an α particle.

Determine

- (i) the values of X and Y, shown in the equation,

X = _____

Y = _____

(ii) the ratio $\frac{\text{mass of } {}^x_y\text{Ra nucleus}}{\text{mass of } \alpha \text{ particle}}$

(3)

(Total 6 marks)

Mark schemes

1	A	[1]
2	B	
3	(a) (isotopes have) same number of protons ✓ <i>allow atomic mass / proton number</i> different numbers of neutrons ✓ <i>allow mass number / nucleon number</i> <i>TO where mix up atomic number and mass number</i>	[1]
	2	
	(b) $92 \times 1.60 \times 10^{-19}$ ✓ <i>correct power</i> <i>penalise minus sign on answer line</i>	
	(+) 1.47×10^{-17} (C) ✓ <i>Allow 2 sf answer 1.5×10^{-17} (C)</i> <i>Pay attention to powers on answer line</i>	2
	(c) $(4.8 \times 10^{-19} \div 1.60 \times 10^{-19}) = 3$ ✓ <i>or</i> $1.47 \times 10^{-17} - 4.8 \times 10^{-19} (= Q)$ (ecf)	
	$(92 - 3 =) 89$ ✓ <i>95 on answer line 1 mark</i> $(n = \frac{Q}{e} = \frac{1.47 \times 10^{-17} - 4.8 \times 10^{-19}}{1.6 \times 10^{-19}}) = 89$ (ecf) <i>Integer value for n</i>	2
	(d) ${}_{92}^{237}\text{U} \rightarrow {}_{93}^{237}\text{Np} + {}_{-1}^0\beta + \overline{\nu}_{(e)}$ ✓ ✓ ✓ <i>one mark for:</i> • both numbers correct on Np • both numbers correct on β^- • correct symbol for (electron) antineutrino	3
		[9]
4	(a) proton	1

- (b) (i) β^+ identified even if numbers incorrect or correct numbers for β^+ **and** proton number on Mg correct

β or β^+ identified and all numbers correct

i.e Second mark not awarded if numbers are correct but there is a minus on the β particle

Allow 1 for consistent equation for β^- decay

2

- (ii) W^+ (condone W but not W^-)

1

[4]

5

- (a) (i) Q / boron / B ✓

1

- (ii) P and R / R and P ✓

1

- (iii) R ✓

6 / 14 is smallest fraction / 0.43 smallest ratio / 4.13×10^7 C / kg ✓

Cannot get second mark if not awarded first mark

2

- (iv) ${}^{14}_6R \rightarrow {}^{14}_7X + {}^0_{-1}e + \overline{\nu}_{(e)}$ ✓✓✓

One mark for each correct symbol on rhs

Ignore -ve sign on e.

Can have neutrino with 0,0 on answer lines

Ignore any subscript on neutrino

3

- (b) (i) repulsive below / at 0.5 fm (accept any value less or equal to 1 fm) ✓
attractive up to / at 3 fm (accept any value between 0.5 and 10 fm) ✓
 short range OR becomes zero OR no effect ✓

Can get marks from labelled graph

Don't accept negligible for 3rd mark

3

- (ii) interaction: electromagnetic / em ✓

(virtual) photon/ γ ✓

2

[12]

6

- (a) repulsive then attractive **(1)**

short range (if distance quoted must be of order fm) **(1)**

correct distance for cross over (accept range 0.1 – 1.0 fm) **(1)**

3

- (b) (i) a helium nucleus (accept 2p and 2n) **(1)** 1
- (ii) $(\downarrow 92 \uparrow 238) U \rightarrow (\downarrow 90 \uparrow 234) Th + (\downarrow 2 \uparrow 4) \alpha$ **(1)** 2
- (c) (i) same atomic number/proton number **(1)**
- different number of neutrons/nucleons **(1)** 2
- (ii) evidence of subtraction of mass number or atomic number **(1)**
- (thus atomic number decreases to) **76 (1)**
- (atomic number of lead is 82 therefore) **6 (82 – 76) beta decays (1)** 3
- [11]**

7

- (a) (i) 88 protons **(1)**
- 140 neutrons **(1)**
- 88 electrons **(1)** 3
- (ii) electron **(1)** 1
- (iii) ${}_{88}^{228} Ra \rightarrow {}_{89}^{228} Ac + {}_{-1}^0 e + \bar{\nu}_e$ **(1)(1)(1)(1)** 4
- (b) 228 ± 10 **(1)**
- 88 **(1)** 2
- [10]**

8

- (i) same atomic number/number of protons ✓
- different mass/nucleon number/different number of neutrons ✓ 2
- (ii) ${}_Z^A X \rightarrow {}_Z^{A-4} Y + {}_2^4 \alpha$ ✓✓ 2
- (iii) $\frac{q}{m} = \frac{2 \times 1.6 \times 10^{-19}}{4 \times 1.67 \times 10^{-27}}$ ✓✓
- $\frac{q}{m} = 4.8 \times 10^7 \text{ Ckg}^{-1}$ ✓✓ 4

(iv) strong nuclear force is short range ✓

no effect at distances larger 3 fm

(except any distance less than 10 fm) ✓

2

[10]

9

(a) (i) (charge) = $92 \times 1.60 \times 10^{-19}$
= 1.47×10^{-17} (C) **(1)**

(ii) (magnitude of ion charge) = $3(e)$ **(1)**
number of electrons (= $92 - 3$) = 89 **(1)**

4

(b) X: number of nucleons [or number of neutrons plus protons or mass number] **(1)**

239 **(1)**

Y: number of protons [or atomic number] **(1)**

94 **(1)**

4

[8]

10

(a) (i) neutron **(1)**

(ii) electron **(1)**

(iii) neutron **(1)**

3

(b) (i) (X =) 225 **(1)**
(Y =) 88 **(1)**

(ii) $\left(\frac{\text{mass of } {}^{225}_{88}\text{Ra}}{\text{mass of } \alpha \text{ particle}} = \frac{225}{4} \right) = 56(.3)$ **(1)**
(allow C.E. for value of X from (i))

3

[6]