ICSE CLASS 10 · PHYSICS

Chapter 12 : RADIOACTIVITY

STEP-BY-STEP SOLUTIONS & MARKING SCHEME (40 MARKS)

Maximum Marks: 40 · Section A (20) compulsory · Section B: any two of three questions (2 × 10 = 20) · $A = Z + N$ · $E = (\Delta m)c^2$ · 1 a.m.u. = 931 MeV · 1 kWh = 3.6×10^6 J

Marks for each step are shown in square brackets on the right. Parts added in the solution diagrams are drawn in red.

SECTION A (20 Marks)

Question 1 — Multiple choice [8 marks, 1 mark each]

No.	Answer	Reason
(i)	**(b)** 12	Number of neutrons = A − Z = 23 − 11 = 12.
(ii)	**(c)** gamma radiations	γ-radiations can pass through hundreds of metres of air and need thick lead or concrete to stop them.
(iii)	**(c)** atomic number	Isotopes have the same number of protons (same Z) but different mass numbers.
(iv)	**(d)** the nucleus of the atom	In the nucleus a neutron changes into a proton and an electron; the electron is ejected from the nucleus.
(v)	**(c)** Both (A) and (R) are true, and (R) is the correct explanation for (A).	Both are true: deflection is smaller for the heavier particle, so (R) explains (A).
(vi)	**(a)** −2 and −4	α-emission ($^4_2$He) reduces Z by 2 and A by 4.
(vii)	**(b)** 93.1 MeV	E = 0.1 × 931 = 93.1 MeV.
(viii)	**(c)** 10^7 K	At about 10^7 K the nuclei gain enough kinetic energy to overcome their electrostatic repulsion.

Question 2 [6 marks]

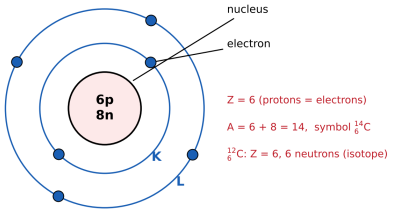
(a) (i) **Atomic number** is the number of protons in the nucleus of an atom (equal to the number of electrons in a neutral atom). [1] **[2]**

(ii) **Mass number** is the total number of nucleons (protons + neutrons) in the nucleus of an atom. [1]

(b) (i) Atomic number Z = number of protons = **6**. [1] **[3]**

(ii) Mass number A = 6 + 8 = **14**; the symbol is $^{14}_{6}\mathbf{C}$. [1]

(iii) Both have Z = 6 but different mass numbers (14 and 12), so they are **isotopes** of carbon. [1]



Solution to Q2(b)

(c) Any one: causes burns, damages living cells and tissues, causes cancer or leukaemia, causes genetic damage (mutation). [1] **[1]**

Question 3 [6 marks]

(a) Change in mass number = 235 − 207 = 28. **[3]**

(i) Each α-particle reduces A by 4 (β does not change A), so number of α-particles = 28 ÷ 4 = **7**. [1]

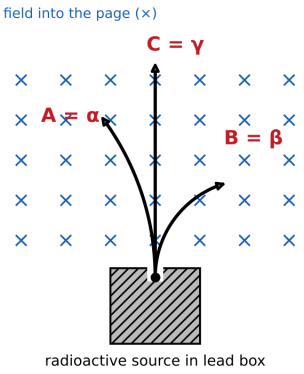
(ii) Seven α-particles reduce Z by 14: 92 − 14 = 78, but the final Z is 82, so Z increases by 4. Each β increases Z by 1, so number of β-particles = **4**. [1]

(iii) For $^{207}_{82}$Pb: neutrons = A − Z = 207 − 82 = **125**. [1]

(b) (i) A deflects to the left (positive): **α-particles**; B deflects to the right (negative): **β-particles**; C is undeflected: **γ-radiations**. [1] **[3]**

(ii) A β-particle is much lighter than an α-particle (the force on it produces a much larger deflection), so B is deflected more than A. [1]

(iii) **Fleming's left hand rule**. [1]



Solution to Q3(b)

SECTION B (20 Marks) — any two questions

Question 4 [10 marks]

(a) Any three (1 mark each): **[3]**

• Nature: α-particles are helium nuclei (2 protons + 2 neutrons); β-particles are fast-moving electrons.

• Charge: α is positive (+2e); β is negative (−e). Mass: α is about 4 times the mass of a proton; β has the mass of an electron.

• Ionising power: α is very high (about 100 times that of β); β is much less.

• Penetrating power: α is small (stopped by thin paper); β is larger (stopped by about 5 mm of aluminium).

• Deflection in fields: α is deflected less; β is deflected more and in the opposite direction.

(b) (i) The lead absorbs radiation in all directions except through the narrow opening, so a narrow beam is obtained and the surroundings are protected. [1] **[3]**

(ii) α-particles have very small penetrating power and cannot reach the cells deep inside the body; they cannot even pass through the skin. [1]

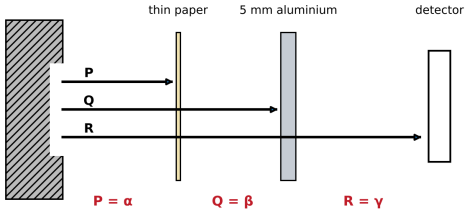
(iii) γ-rays are the most penetrating, so they can pass out of the body and be detected, and cause less damage inside the body. [1]

(c) (i) P is stopped by paper: **α-particles**; Q is stopped by aluminium: **β-particles**; R passes through both: **γ-radiations**. [1] **[4]**

(ii) **P (α-particles)** has the maximum ionising power. [1]

(iii) **R (γ-radiation)**; its wavelength is of the order of 10^{-4} nm (10^{-13} m). [1]

(iv) **γ-radiation** (for example from cobalt-60) is used to destroy cancer cells. [1]



Solution to Q4(c)

Question 5 [10 marks]

(a) Any three (1 mark each): **[3]**

• Wear lead-lined aprons and lead gloves.

• Handle the radioactive substances with long lead tongs and never touch them by hand.

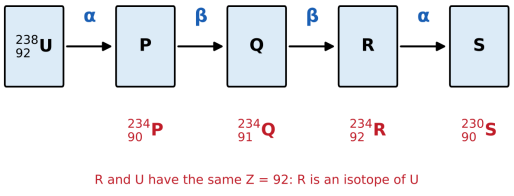
• Keep the radioactive substance in a thick lead container with a narrow opening.

• Wear film badges to monitor the amount of radiation received; stay within the safety limit and work for short periods.

(b) (i) α-emission: Z decreases by 2 and A by 4: P is $^{234}_{90}$**P** (Z = 90, A = 234). [1] **[3]**

(ii) β-emission raises Z by 1 without changing A: Q is $^{234}_{91}$**Q** and R is $^{234}_{92}$**R**. R has the same atomic number (92) as U but a different mass number, so R and U are **isotopes**. [1]

(iii) α-emission from R: S is $^{230}_{90}$**S** (Z = 92 − 2 = 90, A = 234 − 4 = 230). [1]



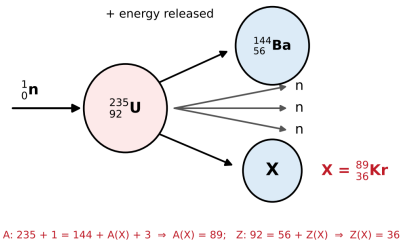
Solution to Q5(b)

(c) (i) Conservation of mass number: 235 + 1 = 144 + A + 3, so A = 89; conservation of charge: 92 = 56 + Z, so Z = 36. X is $^{89}_{36}$**Kr** (krypton-89). [1] **[4]**

(ii) A **slow neutron** is used for the fission of $^{235}_{92}$U. [1]

(iii) E = Δm × 931 = 0.2 × 931 = **186.2 MeV**. [1]

(iv) By using moderators (graphite or heavy water) and control rods to absorb some of the neutrons, so that the chain reaction proceeds at a steady rate. [1]



Solution to Q5(c)

Question 6 [10 marks]

(a) (i) **$E = (\Delta m)c^2$**, where E is the energy released (J), Δm is the loss of mass (kg) and c is the speed of light (3×10^8 m s^{-1}). [1] **[3]**

(ii) $\Delta m = 2$ g $= 2 \times 10^{-3}$ kg; $E = 2 \times 10^{-3} \times (3 \times 10^8)^2 =$ **1.8×10^{14} J**. [1]

(iii) $E = 1.8 \times 10^{14} \div 3.6 \times 10^6 =$ **5×10^7 kWh**. [1]

(b) Any three (1 mark each): **[3]**

• In fission a heavy nucleus splits into two nearly equal parts; in fusion two light nuclei combine into a heavier nucleus.

• Fission occurs at ordinary temperature when neutrons are bombarded; fusion needs a very high temperature (about 10^7 K) and pressure.

• Fission can be controlled (nuclear reactor); fusion cannot be controlled so far.

• Fission products are radioactive and their waste is a problem; fusion products are not radioactive.

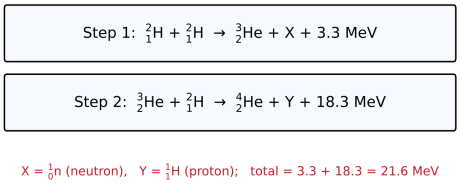
• For the same mass, energy released in fusion is much more than in fission.

(c) (i) The process is **nuclear fusion**. Nuclei are positively charged and repel each other; at about 10^7 K they gain enough kinetic energy to overcome the repulsion and fuse. [1] **[4]**

(ii) Step 1: mass number 2 + 2 = 3 + A, so A = 1, and charge 1 + 1 = 2 + Z, so Z = 0: X is a **neutron** ($^1_0$n). Step 2: 3 + 2 = 4 + A gives A = 1 and 2 + 1 = 2 + Z gives Z = 1: Y is a **proton** ($^1_1$H). [1]

(iii) Total energy = 3.3 + 18.3 = **21.6 MeV**. [1]

(iv) Any one: for the same mass much more energy is obtained; the fuel (deuterium from sea water) is abundant; the products are not radioactive, so no serious waste disposal problem. [1]



Solution to Q6(c)

Marks summary	
Section A: Q1 (8) + Q2 (2 + 3 + 1 = 6) + Q3 (3 + 3 = 6)	**20**
Section B: any two of Q4 – Q6 (10 marks each)	**20**
Total	**40**