



QUESTION WORKBOOK

Conservation laws

Particles · Year 12

AQA 3.2.1.7 · CIE 11.1.9, 11.2.5 · OCR A 6.4.2(h), 6.4.2(i), 6.4.2(j)

18 questions · 52 marks

PRINT EDITION

SECTION A · Warm-up

A1 State four quantities that are always conserved in particle interactions. [2]

A2 Describe the change in a quark that occurs in beta-minus decay and state the other particles emitted. [2]

A3 Describe the change in a quark that occurs in beta-plus decay and state the other particles emitted. [2]

A4 State the electron lepton number of the positron, of the electron neutrino and of the proton. [2]

A5 State what it means for a quantity to be conserved in a particle interaction. [1]

SECTION B · Standard

- B1** Show that the interaction $p + p \rightarrow p + n + \pi^+$ conserves both charge and baryon number (π^+ is a meson of charge +1). [3]

- B2** Explain what conservation of strangeness tells you about whether an interaction proceeds by the strong or the weak interaction. [3]

- B3** Show that the decay $n \rightarrow p + e^- + \text{anti-}\nu_e$ conserves charge, baryon number and lepton number. [3]

- B4** A student suggests the decay $p \rightarrow n + e^+$ could occur on its own. Explain why this cannot be a complete interaction. [3]

- B5** Explain why the decay $\mu^- \rightarrow e^- + \gamma$ is never observed, even though it conserves charge. [3]

- B6** A kaon decays by $K^+ \rightarrow \pi^+ + \pi^0$. The K^+ has strangeness +1; pions have strangeness 0. Deduce which interaction is responsible for this decay. [3]

- B7** A free proton never decays, even though the proposed decay $p \rightarrow n + e^+ + \nu_e$ conserves charge, baryon number and lepton number. Rest energies: proton 938.3 MeV, neutron 939.6 MeV, positron 0.511 MeV; the neutrino's rest energy is negligible. Explain, with a calculation, why this decay cannot occur for a free proton, and why protons bound in some nuclei can nevertheless decay this way. [4]

- B8** A lambda particle (quark content uds) decays into a proton (uud) and a π^- . State the quark flavour change in this decay and name the interaction responsible. [2]

SECTION C · Stretch

- C1** In the interaction $p + p \rightarrow p + n + X$, the particle X is a meson. Using conservation of charge and baryon number, determine the charge and baryon number of X . [4]

- C2** A strong interaction produces two strange particles: $\pi^- + p \rightarrow K^0 + X$, where K^0 has strangeness $+1$. State the strangeness of X and explain your reasoning. [4]

- C3** Describe how conservation laws are used to decide whether a proposed particle interaction can occur. [3]

- C4** Three interactions are proposed: (i) $p + \text{anti-}p \rightarrow \pi^+ + \pi^-$; (ii) $p \rightarrow e^+ + \gamma$; (iii) $\nu_e + n \rightarrow p + e^-$. Deduce which of the proposed interactions are allowed, justifying each answer with the relevant conservation laws. [4]

- C5** In the strong interaction $K^- + p \rightarrow n + X$, the K^- has strangeness -1 and baryon number 0. Determine the charge, baryon number and strangeness of X, and hence identify X from the following candidates, all of charge 0: K^0 ($B = 0, S = +1$), anti- K^0 ($B = 0, S = -1$), π^0 ($B = 0, S = 0$), Λ^0 ($B = +1, S = -1$). [4]