InkPhysics

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

NAVY SCREEN EDITION

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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 $n \rightarrow p + e^- +$ anti-ν_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 + anti-p → π^+ + π^-; (ii) p → e^+ + γ; (iii) ν_e + n → 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 → 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]