InkPhysics

ANSWER BOOK

Classification of particles

Particles · Year 12

AQA 3.2.1.5 · CIE 11.2.6 · OCR A 6.4.2(c), 6.4.2(d)

20 questions · 55 marks

NAVY EDITION

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SECTION A · Warm-up

A1 Hadrons and leptons (1). Hadrons feel the strong interaction; leptons do not (1). Hadrons are further split into baryons and mesons. [2]

A2 A baryon is a hadron made of three quarks, baryon number +1, such as the proton or neutron (1). A meson is a hadron made of a quark and an antiquark, baryon number 0, such as a pion or kaon (1). [2]

A3 Any two of the following, one mark each (2): the electron; the muon; the electron neutrino; the muon neutrino; or any of their antiparticles. [2]

A4 A baryon is made of three quarks; a meson is a quark and an antiquark (1). [1]

A5 The pion (1). It is a meson (1). [2]

A6 A kaon decays into pions (also accept muons and neutrinos) (1). The decay proceeds by the weak interaction (1). [2]

SECTION B · Standard

B1 Baryon +1, antibaryon -1 (1), meson 0 (1). Baryon number is a conserved quantity: in any allowed interaction the total baryon number before equals the total afterwards (1). [3]

B2 Electron: $L_e = +1$ (1). Positron: $L_e = -1$ (1). Electron antineutrino: $L_e = -1$ (1). [3]

B3 Baryon number before: 1 (1)
Baryon number after: 1 + 0 + 0 = 1, so it is conserved (1)
Lepton number before: 0 (1)
Lepton number after: 0 + (+1) + (−1) = 0, the electron having $L_e = +1$ and the antineutrino $L_e = -1$ (1) [4]

B4 Strange particles are produced in pairs through the strong interaction (1), but decay through the weak interaction (1). Strangeness is conserved in strong interactions but can change by 0 or ±1 in weak interactions (1). [3]

B5 Muon lepton number: $1 \rightarrow 0 + 0 + 1 = 1$ ✓ (1). Electron lepton number: $0 \rightarrow (+1) + (-1) + 0 = 0$ ✓ (1). Each family balances separately, as required, so the decay is allowed (1). [3]

B6 Particles are classified by the interactions they experience, not by their mass (1). The muon does not feel the strong interaction (1) and it is fundamental, not made of quarks, so it belongs with the leptons (1). [3]

B7 Baryon number is conserved in every interaction (1), so any decaying baryon must leave a baryon among its products (1). The proton is the lightest baryon, so there is nothing lighter for it to decay into, while every other free baryon eventually decays, in steps, to a proton (1). A neutron bound in a stable nucleus is the exception that the word free excludes. [3]

B8 A kaon has strangeness +1 or −1, whereas a pion has strangeness 0 (1). Kaons decay into pions (they are longer-lived, decaying only by the weak interaction), whereas the pion is the exchange particle of the strong force between nucleons (1). [2]

SECTION C · Stretch

C1 Charge: (+1) + (−1) = 0 → 0 + 0 = 0, conserved (1)
Baryon number: 1 + 0 = 1 → 1 + 0 = 1, conserved (1)
Lepton number: 0 + (+1) = +1 → 0 + (+1) = +1, conserved (1)
All three are conserved, so the interaction is allowed (1) [4]

C2 Proton: baryon. Pion: meson (1). Muon: lepton (1). Neutron: baryon. Electron neutrino: lepton (1). [3]

C3 Leptons are fundamental (not made of quarks) (1) and do not feel the strong interaction (1); hadrons are made of quarks and do feel the strong interaction (1). [3]

C4 Creation in pairs by the strong interaction is the behaviour of strange particles (1): the strong interaction conserves strangeness, so it can only make strangeness +1 and −1 together (1). The comparatively slow decay shows the decay is by the weak interaction, the only interaction that can change strangeness (1). So X is a strange particle (for example a kaon) and it decays by the weak interaction (1). [4]

C5 Lepton number must be conserved separately for each family (1). Muon lepton number: 1 → 0, so it is not conserved (1). Electron lepton number: 0 → +1, also not conserved; either failure on its own forbids the interaction (1). [3]

C6 It feels the strong interaction, so it is a hadron (1). Its baryon number is 0, so it must be a meson (1). A meson with charge −1 and zero strangeness is the π^- (1). [3]