



QUESTION WORKBOOK

Quarks and antiquarks

Particles · Year 12

AQA 3.2.1.6 · CIE 11.2.1, 11.2.2, 11.2.3, 11.2.4
OCR A 6.4.2(e), 6.4.2(f), 6.4.2(g), 6.4.2(i), 6.4.2(k), 6.4.2(l)

19 questions · 52 marks

PRINT EDITION

SECTION A · Warm-up

A1 State the electric charge of the up quark and of the down quark, as fractions of the elementary charge e . [2]

A2 State the quark composition of a proton and of a neutron. [2]

A3 State the baryon number of a quark and of an antiquark. [2]

A4 State the strangeness of the strange quark and of the anti-strange quark. [2]

A5 The π^- is the antiparticle of the π^+ (up, anti-down). State the quark composition of the π^- and show that its charge is $-1e$. [2]

A6 State two properties of a quark that take the opposite sign for its antiquark. [2]

SECTION B · Standard

B1 Show, using the quark charges, that a proton (uud) has a charge of $+1e$. [2]

B2 Show, using the quark charges, that a neutron (udd) has a charge of 0. [2]

B3 A positive pion is made of an up quark and an anti-down quark. Calculate its charge and its baryon number, showing your working. [4]

B4 State the quark composition of an antiproton and show that its charge is $-1e$. [3]

- B5** The Δ^{++} baryon has charge $+2e$, baryon number $+1$ and strangeness 0 . Deduce its quark composition, showing your reasoning. Quark charges: up $+2/3 e$, down $-1/3 e$. [3]

- B6** In beta-minus decay a down quark changes into an up quark, emitting a W^- boson. Show that charge is conserved at this vertex. [2]

- B7** Explain, in terms of quark content, why kaons have strangeness $+1$ or -1 but pions always have strangeness 0 . [3]

SECTION C · Stretch

- C1** Describe the beta-minus decay of a neutron in terms of its quarks, naming what the changed quark becomes and the particles emitted. [4]

- C2** A positive kaon is made of an up quark and an anti-strange quark. The anti-strange quark has charge $+1/3 e$ and strangeness $+1$. Determine the charge and the strangeness of the K^+ , showing your working. [3]

- C3** Explain why the quark model assigns the neutron the composition udd rather than uud . [3]

- C4** A baryon has charge 0 and strangeness -1 . Deduce its quark composition, using only up, down and strange quarks. Quark charges: up $+2/3 e$, down $-1/3 e$, strange $-1/3 e$; the strange quark has strangeness -1 . [4]

- C5** A student claims to have detected a baryon with charge $+1$ and strangeness $+1$. Deduce whether such a particle can be built from up, down and strange quarks and their antiquarks. The strange quark has strangeness -1 and baryon number $+1/3$; an antiquark has baryon number $-1/3$. [4]

- C6** State the maximum possible charge of a baryon built from up, down and strange quarks, and explain your reasoning. Quark charges: up $+2/3$ e, down $-1/3$ e, strange $-1/3$ e. [3]
