

AS Physics 9702

Unit 11 · Particle physics

Worked answers

Try the separate worksheet first. These worked answers explain methods as well as results. Equivalent valid reasoning and sensible rounding may also be correct. Suggested marks are RevisionTown practice guidance, not Cambridge marking instructions.

Scope: Cambridge International AS Physics 9702, 2025–2027 learning outcomes. The published 2028–2030 AS scope has been checked separately and is substantively unchanged. Version: 11 October 2026.

U11-Q1 · 7 marks

(a) Predominantly forward transmission shows that the strongly scattering central region occupies a very small fraction of the atom [1]. Rare large deflections show that substantial mass and positive charge are concentrated in a small dense nucleus [2]. (b) The positive α -particle experiences strong electrostatic repulsion on close approach to the positive nucleus [1]. (c) Protons of charge $+e$ and neutral neutrons are in the nucleus [2]; electrons of charge $-e$ occupy the surrounding atomic region [1].

U11-Q2 · 7 marks

(a) $A = 26$ is the total proton-plus-neutron count; $Z = 12$ is the proton count [2]. (b) ^{24}Mg has 12 protons, 12 neutrons and 12 electrons; neutral ^{26}Mg has 12 protons, 14 neutrons and 12 electrons; $^{26}\text{Mg}^{2+}$ has 12 protons, 14 neutrons and 10 electrons [3]. (c) The 24 and 26 nuclides are isotopes because they have equal Z and different neutron counts [1]. Ionisation changes the electron number, leaving the nucleus and isotope unchanged [1].

U11-Q3 · 16 marks

(a) α : helium nucleus, $+2e$, approximately 4 u; β^- : electron, $-e$, 9.11×10^{-31} kg; β^+ : positron, $+e$, the same mass; γ : electromagnetic photon, zero charge, zero rest mass [12, one mark for each correct composition, charge and rest mass]. (b) A positron has the same mass as an electron and the opposite charge; a proton has $+e$ but a much greater mass [2]. (c) β^- accompanies an electron antineutrino, and β^+ accompanies an electron neutrino [2].

U11-Q4 · 6 marks

(a) Daughter $A = 210 - 4 = 206$, $Z = 84 - 2 = 82$, and $N = 206 - 82 = 124$ [2]. Equation: $^{210}_{84}\text{Po} \rightarrow ^{206}_{82}\text{Pb} + ^4_2\text{He}$ [1]. (b) Nucleon total: $210 = 206 + 4$; charge-number total: $84 = 82 + 2$ [2]. (c) The emitted α -particle is the helium nucleus without orbital electrons, carrying $+2e$; it is not a neutral helium atom [1].

U11-Q5 · 7 marks

(a) ${}^{32}_{15}\text{P} \rightarrow {}^{32}_{16}\text{S} + {}^0_{-1}\text{e} + \bar{\nu}_e$ [2]. (b) Proton count rises from 15 to 16; neutron count falls from 17 to 16; A remains 32 [1]. (c) $n \rightarrow p + e^- + \bar{\nu}_e$ [1]. One d becomes u: $d \rightarrow u + e^- + \bar{\nu}_e$, and udd becomes uud [2]. Charge in units of e checks as $-1/3 = +2/3 - 1 + 0$ [1].

U11-Q6 · 7 marks

(a) ${}^{11}_6\text{C} \rightarrow {}^{11}_5\text{B} + {}^0_{+1}\text{e} + \nu_e$ [2]. (b) One proton changes to a neutron, so proton count falls 6 to 5 and neutron count rises 5 to 6; there are still 11 nucleons [2]. (c) $u \rightarrow d + e^+ + \nu_e$ [1]. The charged particle is a positron, the electron's antiparticle [1]. Charge checks as $+2/3 = -1/3 + 1 + 0$ [1].

U11-Q7 · 7 marks

(a) Discrete nuclear energy states permit particular alpha transitions; a given transition has a fixed energy partition with daughter recoil, so different transitions can give separate sharp alpha energies [2]. In beta decay the electron shares energy variably with the antineutrino and daughter recoil, producing a continuous electron-energy distribution while conserving total energy [2]. (b) The electron antineutrino carries $1.10 - 0.43 = 0.67$ MeV [2]. (c) Rest mass and energy are different properties; a gamma photon has zero rest mass but carries electromagnetic energy and momentum [1].

U11-Q8 · 5 marks

(a) One u is one twelfth of the mass of a neutral carbon-12 atom at rest in its ground state [1]. (b) $22.99 \times 1.66 \times 10^{-27} = 3.81634 \times 10^{-26} \text{ kg} \approx 3.82 \times 10^{-26} \text{ kg}$ [1]. $(8.30 \times 10^{-27}) / (1.66 \times 10^{-27}) = 5.00 \text{ u}$ [1]. (c) A is an exact count, whereas u is a mass unit [1]; actual particle masses and nuclear binding mean the measured mass is not simply A times exactly 1 u [1].

U11-Q9 · 11 marks

(a) A fundamental particle has no known smaller constituents in the particle model used here [1]. An individual quark is fundamental [1]. (b) Up, charm and top each have $+2e/3$; their antiquarks each have $-2e/3$. Down, strange and bottom each have $-e/3$; their antiquarks each have $+e/3$ [4 for complete groups and antiparticle charges]. (c) u plus anti-s: $+2e/3 + e/3 = +e$, a meson. d plus anti-u: $-e/3 - 2e/3 = -e$, a meson. ucc: $+2e/3 + 2e/3 + 2e/3 = +2e$, a baryon [3]. (d) A meson must contain one quark and one antiquark [1]; u and d are both quarks [1]. No mass or stability of these combinations is implied.

U11-Q10 · 7 marks

(a) Proton udd: $(\frac{2}{3} + \frac{2}{3} - \frac{1}{3})e = +e$. Neutron udd: $(\frac{2}{3} - \frac{1}{3} - \frac{1}{3})e = 0$ [2]. (b) Proton and neutron are composite baryons, hence hadrons [1]. Electron and electron neutrino are fundamental leptons [2]. A quark-antiquark pair is a composite meson, hence a hadron [1]. (c) A neutron is neutral but contains three charged quarks, giving a counterexample to the proposed implication [1].

U11-Q11 · 5 marks

(a) After α : $A = 210$, $Z = 81$. After first β^- : $A = 210$, $Z = 82$. After second β^- : $A = 210$, $Z = 83$ [3]. (b) Emitted charge is $+2e - e - e = 0$, so the initial and final nuclear charges both equal $+83e$ [1]. (c) The two beta decays emit two electron antineutrinos [1].

U11-Q12 · 3 marks

C is correct [1]. Electrons and neutrinos are fundamental leptons [1]. A ignores the positron's electron-like mass; a proton is much heavier and composite. B confuses electric neutrality with absence of structure; a neutron is udd. D incorrectly applies a baryon's three-quark structure to an electron [1 for the three errors].

U11-Q13 · 3 marks

B is correct [1]. Its charge balance is $-1/3 = +2/3 - 1 + 0$ [1], and β^- emission requires an electron antineutrino [1]. A and C violate charge conservation as written and have incorrect beta-minus products. D is the beta-plus quark transformation, not beta-minus.

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