Answers to examination-style questions

Answers	Marks	Examiner's tips
1 (a) antiproton; antiparticle; **–1 (or –e)** neutrino; **particle**; **0** neutron; **particle**; **0** positron; **antiparticle**; **+1(or +e)**	3	There are six spaces to fill; the answers are shown here in bold type. All 6 correct: 3 marks 4 or 5 correct: 2 marks 2 or 3 correct: 1 mark
(b) (i) they carry opposite charges (+e and –e)	1	The magnetic field therefore forces them in opposite directions.
(ii) they lose kinetic energy gradually as they travel along their paths	1	'The slower it went, the more it would bend' (passage). Slower charged particles are deflected more easily by a magnetic field.
(iii) *Relevant points include*: • the speed is greater where the track is less curved • the straighter track must therefore be before the particle met the plate • the direction of the curve shows that the charge is positive • the track must therefore be due to a positron	3	'… he discovered a beta particle that slowed down but bent in the opposite direction to all the other beta trails …' (passage).
2 (a) 90 protons 139 neutrons and 90 electrons	1 1	Proton number $Z = 90$ Number of neutrons = 229 – 90 Number of electrons = Z
(b) X = 90	1	This is still thorium, and here X is used to represent the proton number.
Y = any value between 212 and 252	1	In a **different** isotope, the nucleon number cannot be 229.
Z = 90	1	The number of electrons is unchanged.
3 (a) 18 protons 19 neutrons	1 1	Proton number $Z = 18$ Number of neutrons = 37 – 18
(b) charge = +2 or +2*e* $Q = 2 \times 1.6 \times 10^{-19} = 3.2 \times 10^{-19}$ C	1	2 electrons have been removed, so the ion's charge is positive.
(c) (i) neutron	1	$Q = 0$ for a neutron, so (Q/m) is also zero.
(ii) electron	1	The electron's small mass gives it the largest (Q/m).
(d) $(\%) = \dfrac{16 \times 9.11 \times 10^{-31}}{37 \times 1.67 \times 10^{-27}} \times 100$	2	Marks are for correct nuclear mass, and for correct substitution of values in rest of the equation.
$= 2.4 \times 10^{-2}$ %	1	Remember to multiply by 100 to get a percentage.

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4 (a) number of protons = number of electrons (e.g. 13)	**1**	Neutral atoms have an equal number of protons and electrons.
number of neutrons = (28 – number of protons) (e.g. 15)	**1**	There could have been 14 protons and 14 neutrons!
(b) (i) nuclei have same number of protons	**1**	This answer follows directly from the definition of isotopes.
(ii) but a different number of neutrons, or nucleons	**1**	
(iii) $\frac{Q}{m} = \frac{92 \times 1.60 \times 10^{-19}}{236 \times 1.67 \times 10^{-27}}$ $= 3.7 \times 10^{7}\ \text{C kg}^{-1}$	**1**	The mark is for correct substitution of charge and mass values and a correct calculation.
(iv) 95	**1**	The number of protons and neutrons (given by the mass numbers for the nuclei) on each side is the same.
5 (a) X = 225	**1**	Nucleon numbers must balance in the decay, and α is a helium nucleus with $A = 4$.
Y = 88	**1**	Proton numbers must also balance, and $Z = 2$ for the α particle.
(b) ratio $\left(= \frac{225}{4}\right) = 56$	**1**	The answer is a ratio of two masses and has **no unit**.
6 (a) (i) a helium nucleus (or a doubly-ionised helium atom)	**1**	**(i)** tests your factual knowledge. An α particle consists of 2 protons and 2 neutrons, giving these charge and mass values.
Properties: • charge +2e • mass ≈ 4 units	**2**	
(ii) $^{215}_{85}\text{At} \rightarrow {}^{211}_{83}\text{Bi} + \alpha$	**2**	1 mark for writing $^{211}_{83}\text{Bi}$ as the product nucleus and the second mark for the completed reaction equation.
(b) (i) *Relevant points include*: • a neutron changes into a proton • the proton remains in the nucleus • a high energy electron (β^- particle) is emitted from the nucleus • an antineutrino is also emitted • the nucleus becomes more stable	**3**	Electrons do not reside in the nucleus; the β^- particle is formed at the instant of decay. The antineutrino is necessary to explain the range of energies of the β^- particles that are emitted.
(ii) $^{99}_{42}\text{Mo} \rightarrow {}^{99}_{43}\text{Tc} + \beta^- + \bar{\nu}$	**2**	1 mark for inserting the missing values of 99 and 43, and 1 mark for including the antineutrino. In β^- decay A stays the same but Z increases by 1 (since a neutron changes into a proton).

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7 **(a)** **(i)** 9.11×10^{-31} kg	**1**	The β^+ particle is a positron, with the same rest mass as an electron.
(ii) $f\left(=\frac{c}{\lambda}\right)=\frac{3.00\times10^{8}}{8.30\times10^{-13}}$ $(= 3.61 \times 10^{20}$ Hz)	**1**	All 3 marks would be available for direct use of $E = (hc/\lambda)$, but you must show your working whatever method you choose.
$E\ (= hf) = 6.63 \times 10^{-34} \times 3.61 \times 10^{20}$	**1**	
$= 2.4 \times 10^{-13}$ J	**1**	
(iii) $E=\frac{2.39\times10^{-13}}{1.60\times10^{-13}}$	**1**	Since 1 eV = 1.60×10^{-19} J, it follows that 1 MeV is 10^6 times larger.
= 1.5 MeV	**1**	
(b) weak interaction	**1**	Always involved in β decay
(c) A = neutron	**1**	$p \rightarrow n + \beta^+ + \nu_e$
B = W^+	**1**	Proton must lose + charge
C = (electron) neutrino or $\nu_{(e)}$	**1**	**Not** antineutrino
8 **(a)** **(i)** electron	**1**	A positron is a 'positive electron', having the same mass and equal but opposite charge.
(ii) they annihilate, or destroy each other	**1**	2 photons are always needed when annihilation takes place.
forming two gamma rays (or photons)	**1**	'Forming **energy**' would not be enough for the second mark.
(b) energy released = 2 × 0.51 = 1.02 MeV	**1**	The antiparticle must have the same rest mass as the particle.
$= 1.02 \times 1.60 \times 10^{-13} = 1.6 \times 10^{-13}$ J	**1**	The energy released is the total of the rest energies. The energy released could be greater than this if the particles were to meet with a significant amount of kinetic energy, so the value calculated is the minimum energy released.
9 **(a)** **(i)** they annihilate, or destroy each other, or form two photons	**1**	This is straightforward annihilation of a particle and its antiparticle.
(ii) the energy associated with the rest masses must be added	**1**	**Total** energy includes both the kinetic energy and the rest mass energy of the two colliding particles. Photons have no rest mass.
(b) There are 3 possibilities: the particles produced could • be more numerous • be more massive • have greater kinetic energy	**any 2**	Annihilation can produce particles other than photons (e.g. muons) when the colliding particles have a total energy greater than the rest masses of the particles that are produced.

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10 (a) weak interaction	**1**	The diagram in **(b)** showing W^- is a big hint!
(b) arrow from e^- arrow, pointing top left and labelled ν_e	**1**	You must show p becoming n, and e^- becoming ν_e.
arrow from p arrow, pointing top right and labelled n	**1**	
11 (a) γ photon/electromagnetic force	**2**	1 mark for naming the exchange particle and the second mark for the corresponding interaction.
(b) Possible roles are: • transfers energy • transfers momentum • transfers force • (sometimes) transfers charge	**any 2**	One mark for each named role.
12 A high energy γ photon is required	**1**	Energy must be sufficient to create at least the total rest masses of the particles produced.
It is converted into a particle and its antiparticle	**1**	This occurs in the vicinity of another particle, such as a nucleus or an electron.
Suitable example named, such as: • proton + antiproton • electron + positron	**1**	Only one example is needed.