# 11. Particle Physics

## 11.1 Atoms, nuclei and radiation

## Paper 2

Marking Scheme

## Q1.

| | | |
|---|---|---|
| (a) | $^{66}_{29}Cu$ | **B1** |
| (b)(i) | the energy of the decay is fixed / constant | **B1** |
| | the energies of the beta particles have a (continuous) range of values / varies / not constant | **B1** |
| | another particle / an (anti)neutrino must possess the extra / remaining energy (difference between energy of the decay and the β kinetic energy) | **B1** |
| (b)(ii) | (electron) antineutrino | **B1** |
| (b)(iii) | $^{66}_{29}Cu \rightarrow {}^{66}_{30}Zn + {}^{0}_{-1}\beta + {}^{0}_{0}\overline{\upsilon}_{e}$<br><br>values for Cu and Zn correct with no other extra particles on either side of the equation | **B1** |
| | second term correct ( $^{0}_{-1}\beta$ ) | **B1** |
| | third term correct ( $^{0}_{0}\overline{\upsilon}_{e}$ ) | **B1** |

## Q2.

| | | |
|---|---|---|
| (a)(i) | $P = 40$ **and** $R = 0$ | **A1** |
| | $Q = 20$ **and** $S = -1$ | **A1** |
| (a)(ii) | (electron) antineutrino | **B1** |

## Q3.

| | | |
|---|---|---|
| (a) | mass of α (particle) is <u>much</u> greater (than $\beta^+$ particle) | **B1** |
| | both particles are positively charged | **B1** |
| | (magnitude of) charge on α (particle) is twice the charge (on $\beta^+$ particle) | **B1** |
| (b)(i) | cross labelled Q at (82, 212) | **B1** |
| (b)(ii) | particles emitted are:<br>• beta-minus (particle) / electron<br>• (electron) antineutrino<br><br>either particle named | **B1** |
| | both particles named and no incorrect particles named | **B1** |

## Q4.

| | | |
|---|---|---|
| (a)(i) | Y and Z have equal numbers of protons and (so) they have the same charge | **B1** |
| (a)(ii) | Y has (two) fewer protons (than X) | **M1** |
| | (so) Y has less charge (than X) | **A1** |

## Q5.

| | | |
|---|---|---|
| (a)(i) | number of protons: equal/same | **B1** |
| | number of neutrons: unequal/different | **B1** |
| (a)(iii) | (electron) antineutrino | **B1** |

## Q6.

| | | |
|---|---|---|
| (a) | a (very) small proportion of (alpha) particles are deflected (back) through large angles / angles greater than 90° | **B1** |
| | a large proportion of (alpha) particles pass straight through / deflected by small angles | **B1** |
| (b) | electromagnetic wave / electromagnetic radiation | **A1** |
| (d)(i) | 1.32 u | **A1** |

**Q7.**

| | | |
|---|---|---|
| (b) | number of $\alpha$-particles = 6 | **B1** |
| | number of $\beta^-$ particles = 4 | **B1** |

**Q8.**

| | | |
|---|---|---|
| (a)(i) | change in $A$ = 0 | **A1** |
| | change in $Z$ = (+)1 | **A1** |
| (a)(ii) | (electron) antineutrino | **B1** |

**Q9.**

| | | |
|---|---|---|
| (a)(i) | P = 0 **and** Q = 137 | **A1** |
| | R = –1 **and** S = 56 | **A1** |

**Q10.**

| | | |
|---|---|---|
| (a) | 92 protons and 146 neutrons (in nucleus) | **B1** |
| | 92 (orbital) electrons | **B1** |
| (b) | charge = $2e$<br>$(= 2 \times 1.60 \times 10^{-19}$ C) | **C1** |
| | mass = 4u<br>$(= 4 \times 1.66 \times 10^{-27}$ kg) | **C1** |
| | ratio $= (2 \times 1.60 \times 10^{-19}) / (4 \times 1.66 \times 10^{-27})$<br>$= 4.8 \times 10^{7}$ C kg$^{-1}$ | **A1** |

**Q11.**

| | | |
|---|---|---|
| (a)(i) | (electron) neutrino | **B1** |
| (a)(iii) | $\beta^+$ (particle) | **B1** |

**Q12.**

| | | |
|---|---|---|
| (a) | the nucleus is charged | **B1** |
| | the majority of the mass (of atom) is in the nucleus | **B1** |

**Q13.**

| | | |
|---|---|---|
| (a) | $\alpha$-particle mass given as 4u | **B1** |
| | $\alpha$-particle charge given as (+)2*e* | **B1** |
| | both $\beta$-particles mass given as 0.0005 u | **B1** |
| | $\beta^+$ charge given as (+)*e* and $\beta^-$ charge given as –*e*<br>(Completed table:<br>mass / u: $\alpha$ = 4; $\beta^+$ = 0.0005; $\beta^-$ = 0.0005<br>charge / *e*: $\alpha$ = (+)2; $\beta^+$ = (+)1; $\beta^-$ = –1<br>) | **B1** |
| (b)(iii) | (electron) antineutrino(s) emitted | **B1** |
| | energy (released in decay)/momentum shared between antineutrino and $\beta^-$ particle | **B1** |

**Q14.**

| | | |
|---|---|---|
| (d)(i) | **1.** R plotted at (95,147) | **B1** |
| | **2.** S plotted at (96,146) | **B1** |
| (d)(ii) | (electron) antineutrino | **B1** |

**Q15.**

| | | |
|---|---|---|
| (b)(i) | number of protons = 92 | **A1** |
| | number of neutrons = 146 | **A1** |
| | number of electrons = 90 | **A1** |
| (b)(iii) | number of $\alpha$-particles = 2 | **A1** |
| | number of $\beta^-$ particles = 2 | **A1** |

**Q16.**

| | | |
|---|---|---|
| (a)(i) | P = 0 **and** Q = 39 | **A1** |
| | R = (+)1 **and** S = 20 | **A1** |

**Q17.**

| | | |
|---|---|---|
| (b)(i) | number of protons = 13 **and** number of neutrons = 12 | **A1** |
| (b)(ii) | (charge =) $13 \times 1.60 \times 10^{-19}$ (C) = $2.1 \times 10^{-18}$ (C) | **A1** |

**Q18.**

| | | |
|---|---|---|
| (a)(i) | proton number = 17<br>**and**<br>nucleon number = 35 | **A1** |
| (a)(ii) | (electron) neutrino | **B1** |

**Q19.**

| | | |
|---|---|---|
| (a) | number of protons = 92 | **A1** |
| | number of neutrons = 142 | **A1** |

**Q20.**

| | | |
|---|---|---|
| (c) | $\beta^-$ particles have range of/different/various speeds/velocities/momenta/energies | **M1** |
| | so they follow different paths | **A1** |

**Q21.**

| | | |
|---|---|---|
| (b) | (electron) antineutrino | **B1** |
| (c) | kinetic (energy) | **B1** |
| (d) | Y has one more proton (and one less neutron)/X has one less proton (and one more neutron)<br>**or**<br>Y has more protons (and fewer neutrons)/X has fewer protons (and more neutrons)<br>**or**<br>a neutron changes to a proton<br>**or**<br>the number of protons increases | **M1** |
| | (so) not isotopes | **A1** |

**Q22.**

| | | |
|---|---|---|
| (c)(i) | protons = 96 | **A1** |
| | neutrons = 148 | **A1** |

**Q23.**

| | | |
|---|---|---|
| (b)(i) | nucleon number = 27 | **A1** |
| | proton number = 13 | **A1** |
| (b)(iii) | an (electron) antineutrino / $\bar{\nu}_{(e)}$ is produced (and this has energy) | **B1** |
| | X has kinetic energy | **B1** |