Page 1 Test yourself on prior knowledge

1 Any of the following three similarities: Same number of protons; same number of electrons; same atomic number; all electrically neutral.

Different number of neutrons.

2 +2

3 35 and 37 (If you did not know of these isotopes, you can look them up.)

Then 0.75 x 35 + 0.25 x 37 = 35.5

chlorine-35, p = 17, n = 18;

chlorine-37, p = 17, n = 20

4 **a)** 118

b) 176

c) 118

d) Since the number of protons and electrons is the same, the ratio of their masses is the same as that of a single proton to a single electron i.e. 1:1800

Page 5 Test yourself

1 Specific charge = charge per unit mass

2 Nuclides with the same number of protons but different numbers of neutrons; i.e. nuclides with the same proton number, Z, but different nucleon number, A.

3 134×10^{-12} m / 27×10^{-15} m = 4 963
For gold, atomic radius: nuclear radius ≈ 5 000:1

4 The electrons are fired at the nucleus with considerably higher energy (about 200 MeV or higher) than the alpha particles (about 7 MeV), so can get closer to the nucleus. As well as this, electrons do not experience the strong force that exists between protons and neutrons within nuclei.

5 **a)** p = 14; n = 14; e = 14

b) **i)** $Q = +2e = 2 \times (+)1.6 \times 10^{-19}\ \text{C} = +3.2 \times 10^{-19}\ \text{C}$

ii) $A = 28$

iii) $m = (14 \times m_p) + (14 \times m_n)$

$= (14 \times 1.673 \times 10^{-27}\ \text{kg}) + (14 \times 1.675 \times 10^{-27}\ \text{kg})$

$= 4.687 \times 10^{-26}\ \text{kg}$

Specific charge $= Q/m$

$= 3.2 \times 10^{-19}\ \text{C} / 4.687 \times 10^{-26}\ \text{kg}$

$= 6.8 \times 10^{6}\ \text{C kg}^{-1}$

6 **a)** Ge-74 = $^{74}_{32}Ge \Rightarrow$ Z = 32 $\Rightarrow$ Q = 32 × (+)1.6 × 10^{-19} C

= 5.12 × 10^{-18} C

b) $n = \frac{Q}{e} = \frac{+4.80\times10^{-19}\,\text{C}}{-1.60\times10^{-19}\,\text{C}} = -3$

There are therefore 32 – 3 = 29 electrons in this ion.

7 **a)** Charge on deuteron = (1 × +1.60 × 10^{-19} C)

= +1.60 × 10^{-19} C

Mass of deuteron = (1.673 × 10^{-27} kg) + (1.675 × 10^{-27} kg)

= 3.348 × 10^{-27} kg

Specific charge = (+1.60 × 10^{-19} C) / (3.348 × 10^{-27} kg)

= 4.78 × 10^{7} Ckg^{-1}

b) Charge on carbon-12 nucleus (6 protons) = (6 × +1.60 × 10^{-19} C)

= +9.60 × 10^{-19} C.

Mass of carbon-12 nucleus (6 protons + 6 neutrons)

= (6 × 1.673 × 10^{-27} kg) + (6 × 1.675 × 10^{-27} kg)

= 2.009 × 10^{-26} kg

Specific charge = (+9.60 × 10^{-19} C) / (2.009 × 10^{-26} kg)

= 4.78 × 10^{7} Ckg^{-1}

(this is the same answer numerically as the specific mass of the deuteron)

c) Charge on (oxygen-16)$^{2-}$ ion (2 ‘extra’ electrons) = (2 × -1.60 × 10^{-19} C)

= -3.20 × 10^{-19} C.

Mass of (oxygen-16)$^{2-}$ ion (8 protons + 8 neutrons + 10 electrons)

= (8 × 1.673 × 10^{-27} kg) + (8 × 1.675 × 10^{-27} kg) + (10 × 9.11 × 10^{-31} C)

= 2.679 × 10^{-26} kg

Specific charge = (-3.20 × 10^{-19} C) / (2.679 × 10^{-26}kg)

= –1.19 × 10^{7} C kg^{-1}

8 **a)** p = 86

b) n = (222 – 86) = 136

c) $^{222}_{86}Rn$

9 **a)** $^{63}_{29}Cu$ and $^{65}_{29}Cu$

b) n_{63} = (63 – 29) = 34

n_{65} = (65 – 29) = 36

c) $\left(63 \times \frac{69}{100}\right) + \left(65 \times \frac{31}{100}\right) = 43.47 + 20.15 = 63.62 \approx 63.5$

The atomic mass is related to the nucleon number. Because copper has two main isotopes, in chemistry, the atomic mass is always written as the average value of each, and this is why the atomic mass of copper is always 63.5 on a Periodic Table.

Page 8 Test yourself

10 a) i) C and D

ii) B

iii) A and C

b) There are many short thick tracks from alpha particles and one (possibly two) longer and thinner track(s) from beta particles.

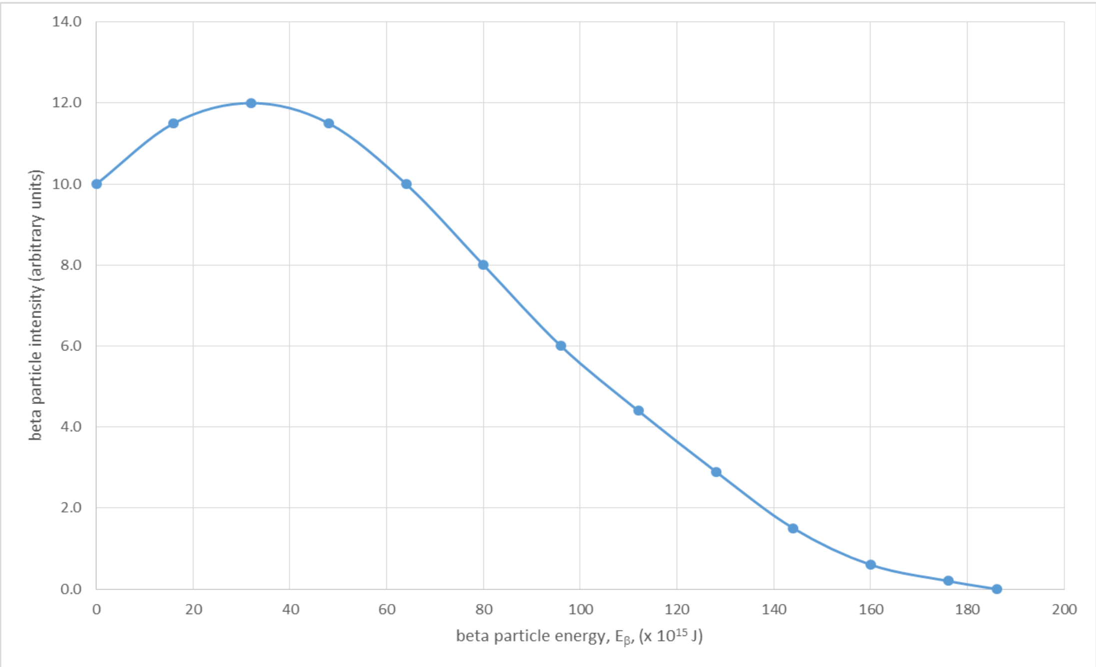
11 Alpha particles are highly ionising and easily ionise the air between the grid and the electrode, but beta particles and gamma rays are much less ionising and are less likely to ionise any air between the grid and the electrode.

12 Some alpha particles have a range of about 3.6 cm in air; these come from radium-226. Others have a longer range of about 4.7 cm and come from radium-223. The alpha particles with the longest range must have higher energy and so come from radium-223.

Page 9 Activity

The beta particle emission spectrum of bismuth-210

1



2 10×10^{-15} J and 55×10^{-15} J

3 $(186 \times 10^{-15}\ \text{J} - 10 \times 10^{-15}\ \text{J}) = 176 \times 10^{-15}$ J

and

$(186 \times 10^{-15}\ \text{J} - 55 \times 10^{-15}\ \text{J}) = 131 \times 10^{-15}$ J

Page 10 Test yourself

13 ${}^{238}_{92}\text{U} + {}^{2}_{1}\text{H} \rightarrow {}^{238}_{93}\text{Np} + 2{}^{1}_{0}\text{n}$

${}^{238}_{93}\text{Np} \longrightarrow {}^{0}_{-1}\text{e} + {}^{238}_{94}\text{Pu}$

14 ${}^{241}_{95}\text{Am} \rightarrow {}^{237}_{93}\text{Np} + {}^{4}_{2}\text{He}$

15 ${}^{90}_{38}\text{Sr} \rightarrow {}^{90}_{39}\text{Y} + {}^{0}_{-1}\text{e} + {}^{0}_{0}\bar{\nu}$

16 ${}^{32}_{15}\text{P} \rightarrow {}^{32}_{16}\text{S} + {}^{0}_{-1}\text{e} + {}^{0}_{0}\bar{\nu}$

17 ${}^{238}_{94}\text{Pu} \rightarrow {}^{234}_{92}\text{U} + {}^{4}_{2}\text{He}$

18 ${}^{3}_{1}\text{H} \rightarrow {}^{3}_{2}\text{He} + {}^{0}_{-1}\text{e} + {}^{0}_{0}\bar{\nu}$

Page 11 Test yourself

19 a) $E = hf$

$\Rightarrow f = \frac{E}{h}$

$= \frac{3.6\times10^{-19}\ J}{6.63\times10^{-34}\ Js}$

$= 5.4 \times 10^{14}$ Hz (2 significant figures)

b) Power = energy per photon × number of photons per second

$= 3.6 \times 10^{-19}\ \text{J} \times 0.9 \times 10^{17}$

= 0.032 W (2 significant figures)

20 a) $\text{E} = \text{hf}$

$\Rightarrow \text{E} = \frac{\text{hc}}{\lambda}$

$= \frac{6.63\times10^{-34}\ \text{J s}\times3.0\times10^{8}\text{ms}^{-1}}{420\times10^{-9}\ \text{m}}$

$= 4.7 \times 10^{-19}\ \text{J} \approx 5 \times 10^{-19}\text{J}$

b) Blue photons have higher energy than red photons because they have a higher frequency. This means that they will require a higher potential difference to create them.

Page 13 Test yourself

21 $f = \frac{E}{h} = \frac{1.5\times10^{-10} J}{6.63\times10^{-34}\text{Js}} = 2.3 \times 10^{23}\text{Hz}$

$\lambda = \frac{c}{f} = \frac{3\times10^{8}\text{ms}^{-1}}{2.3\times10^{23}\text{Hz}} = 1.3 \times 10^{-15} m$

The calculation on page 12 shows that photons from electron–positron have λ = 2.4 pm

$\frac{2.4\times10^{-12}\text{ m}}{1.3\times10^{-15}\text{ m}} = 1846$

So the wavelength of photons produced in electron–positron annihilation is almost 2000 times greater than that of those produced in proton–antiproton annihilation.

22 a) Here are some examples of correct answers:

Proton – antiproton

Electron – positron

Neutron – antineutron

b) They have the same mass-energy.

c) Their charge is different.

23 a) Pair creation

b) $2 \times 1.5 \times 10^{-10}$ J = 3×10^{-10} J – the rest energy of the proton-antiproton pair

c) The excess energy is transferred into kinetic energy of the proton and antiproton.

d) The energy of the photon would not be high enough: electrons and positrons are less massive than protons and antiprotons and so can be produced by photons with lower energy.

e) It will annihilate a proton, forming a photon pair.

f) The conservation of charge would be violated.

Pages 14-17 Practice questions

1 D

2 B

3 B

4 C

5 B

6 A

7 C

8 D

9 B

10 C

11 a) i) Neutron [1]

ii) Electron [1]

iii) Neutron [1]

b) i) Anti-electron neutrino [1]

ii) A = 99 [1]

Z = 44 [1]

12 a) An atom / nucleus with the same atomic number / number of protons [1]

different mass / nucleon number / different number of neutrons [1]

b) ${}^{A}_{Z}\mathrm{X} \rightarrow {}^{A-4}_{Z-2}\mathrm{Y} + {}^{4}_{2}\mathrm{He}$ [2]

c) Strong nuclear force is very short range [1]

so once outside the nucleus the alpha particle no longer experiences the force [1]

13 a) p = 20; n = 28; e = 18 [1]

b) Charge = +2e = 2 × 1.6 × 10^{-19} C = 3.2 × 10^{-19} C [1]

c) $specific\ charge\ of\ ion = \frac{charge\ of\ ion}{mass\ of\ ion}$

Mass of ion = mass of protons + mass of neutrons + mass of electrons

= (20 × 1.673 × 10^{-27} kg) + (28 × 1.675 × 10^{-27} kg) + (18 × 9.11 × 10^{-31} kg)

= 8.04 × 10^{-26} kg [1]

$specific\ charge\ of\ ion = \frac{+3.2\times10^{-19}}{8.04\times10^{-26}} = 3.98 \times 10^{6}\ kg$ [1]

14 a) Repulsive then attractive [1]

Short range [1]

Correct distance for crossover (a range of 0.1 – 1.0 fm) [1]

b) A helium nucleus (or 2p + 2n) [1]

c) ${}^{238}_{92}\mathrm{U} \rightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\alpha$ [2]

15 a) The charge per unit mass of a particle. [1]

	Number of protons	Number of neutrons	Specific charge of nucleus … **b)** Ckg^{-1} [1]
First isotope	92	143	**d)** $Q = 92 \times 1.6 \times 10^{-19} = 1.47 \times 10^{-17}$ C [1] $m = (92 \times 1.673 \times 10^{-27}) + (143 \times 1.675 \times 10^{-27}) = 3.93 \times 10^{-25}$ kg [1] $\frac{Q}{m} = \frac{1.47 \times 10^{-17}}{3.93 \times 10^{-25}} = 3.75 \times 10^{7}\,\mathrm{Ckg}^{-1}$ [1]
Second isotope	**c)** 92 [1]	**e)** $\frac{Q}{m} = 3.7 \times 10^{7} = \frac{1.47 \times 10^{-17}}{A \times 1.67 \times 10^{-27}}$ [1] $A \times 1.67 \times 10^{-27} = \frac{1.47 \times 10^{-17}}{3.7 \times 10^{7}}$ [1] $A = \frac{3.97 \times 10^{-25}}{1.67 \times 10^{-27}} = 238$ [1] Number of neutrons = 238 – 92 = 146 [1]	3.7×10^{7}

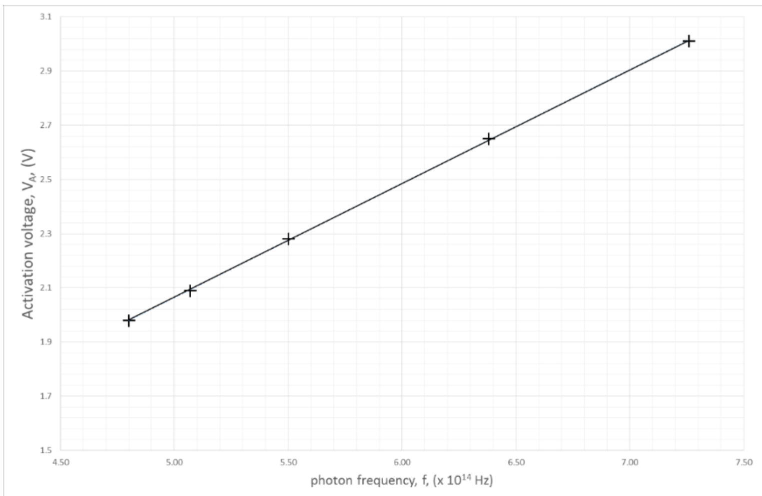
16 a)

1. Select LED.
2. Observe LED by eye through blackened tube.
3. Increase potential difference across LED until photons observed.
4. Record activation voltage.
5. Repeat for other LEDs.

b)

LED number	Wavelength of emitted photons, λ/nm	Frequency of emitted photons, *f*/Hz	Activation voltage, V_A/V
1 violet	413	**7.26×10^{14}**	3.01
2 blue	470	**6.38×10^{14}**	2.65
3 green	545	**5.50×10^{14}**	2.28
4 yellow	592	**5.07×10^{14}**	2.09
5 red	625	**4.80×10^{14}**	1.98

c)



d) Gradient = 4.1×10^{-15} VHz^{-1}

e) Gradient = $\frac{h}{e}$

$\Rightarrow$ h = gradient $\times$ e = 4.199×10^{-15} VHz^{-1} $\times$ 1.6×10^{-19} C = 6.72×10^{-34} Js

17 a) $Z \rightarrow Z - 2;\ A \rightarrow A - 4$

b) $Z \rightarrow Z + 1;\ A \rightarrow A$

c) $Z \rightarrow Z + 1;\ A \rightarrow A + 2$

18 a) Electron (β-); anti-electron neutrino

b) p = 20 ; n = 22 ; e = 20

19 Conservation of energy requires:

$$2m_\mu c^2 = 2hf$$

$$\Rightarrow photon\ energy, hf = m_\mu c^2$$

m_μ = 1.88×10^{-28} kg

$$\Rightarrow photon\ energy = (1.88 \times 10^{-28}\ \text{kg}) \times (3.0 \times 10^{8}\ \text{m s}^{-1})^2$$

$$= 1.69 \times 10^{-11}\ \text{J}$$