1. A sample of bromine was analysed in a time of flight (TOF) mass spectrometer and found to contain two isotopes, ^{79}Br and ^{81}Br

After electron impact ionisation, all of the ions were accelerated to the same kinetic energy (KE) and then travelled through a flight tube that was 0.950 m long.

(a) The $^{79}Br^+$ ions took 6.69×10^{-4} s to travel through the flight tube.

Calculate the mass, in kg, of one ion of $^{79}Br^+$
Calculate the time taken for the $^{81}Br^+$ ions to travel through the same flight tube.

The Avogadro constant, $L = 6.022 \times 10^{23}$ mol^{-1}

$KE = \frac{1}{2}mv^2$ where m = mass (kg) and v = speed (m s^{-1})

$v = \frac{d}{t}$ where d = distance (m) and t = time (s)

Mass of one ion of $^{79}Br^+$ ____________________ kg

Time taken by $^{81}Br^+$ ions ____________________ s

(5)

(b) Explain how ions are detected and relative abundance is measured in a TOF mass spectrometer.

___

___

___

___

___

___

(2)

(Total 7 marks)

2. This question is about s-block metals.

(a) Give the full electron configuration for the calcium ion, Ca^{2+}

____

(1)

(b) Explain why the second ionisation energy of calcium is lower than the second ionisation energy of potassium.

____

____

____

____

____

(2)

(c) Identify the s-block metal that has the highest first ionisation energy.

____

(1)

(d) Give the formula of the hydroxide of the element in Group 2, from Mg to Ba, that is least soluble in water.

____

(1)

(e) A student added 6 cm^3 of 0.25 mol dm^{-3} barium chloride solution to 8 cm^3 of 0.15 mol dm^{-3} sodium sulfate solution.
The student filtered off the precipitate and collected the filtrate.

Give an ionic equation for the formation of the precipitate.
Show by calculation which reagent is in excess.
Calculate the total volume of the other reagent which should be used by the student so that the filtrate contains only one solute.

Ionic equation ____

Reagent in excess ____

Total volume of other reagent ____

____

____

____

____

(3)

(f) A sample of strontium has a relative atomic mass of 87.7 and consists of three isotopes, ^{86}Sr, ^{88}Sr and ^{88}Sr

In this sample, the ratio of abundances of the isotopes ^{86}Sr :^{88}Sr is 1:1

State why the isotopes of strontium have identical chemical properties.

Calculate the percentage abundance of the ^{88}Sr isotope in this sample.

Why isotopes of strontium have identical chemical properties

____

____

____

Percentage abundance of ^{88}Sr ____________________ %

(4)

(g) A time of flight (TOF) mass spectrum was obtained for a sample of barium that contains the isotopes ^{136}Ba, ^{137}Ba and ^{138}Ba

The sample of barium was ionised by electron impact.

Identify the ion with the longest time of flight.

____

(1)

(h) A $^{137}Ba^+$ ion travels through the flight tube of a TOF mass spectrometer with a kinetic energy of 3.65×10^{-16} J
This ion takes 2.71×10^{-5} s to reach the detector.

$KE = \frac{1}{2}mv^2$ where m = mass (kg) and v = speed (m s^{-1})

The Avogadro constant, $L = 6.022 \times 10^{23}$ mol^{-1}

Calculate the length of the flight tube in metres.

Give your answer to the appropriate number of significant figures.

Length of flight tube ____________________ m

(5)

(Total 18 marks)

3. Magnesium exists as three isotopes: ^{24}Mg, ^{25}Mg and ^{26}Mg

(a) In terms of sub-atomic particles, state the difference between the three isotopes of magnesium.

___

___

___

(1)

(b) State how, if at all, the chemical properties of these isotopes differ.

Give a reason for your answer.

Chemical properties ____

____

Reason ____

____

____

(2)

(c) ^{25}Mg atoms make up 10.0% by mass in a sample of magnesium.

Magnesium has A_r = 24.3

Use this information to deduce the percentages of the other two magnesium isotopes present in the sample.

^{24}Mg percentage = ________ % ^{26}Mg percentage = ________ %

(4)

(d) In a TOF mass spectrometer, ions are accelerated to the same kinetic energy (KE).

$KE = \frac{1}{2}mv^2$ where m = mass (kg) and v = velocity (m s^{-1})

$v = \frac{d}{t}$ where d = distance (m) and t = time (s)

In a TOF mass spectrometer, each $^{25}Mg^+$ ion is accelerated to a kinetic energy of 4.52×10^{-16} J and the time of flight is 1.44×10^{-5} s.
Calculate the distance travelled, in metres, in the TOF drift region.
(The Avogadro constant L = 6.022×10^{23} mol^{-1})

Distance = ___________________ m

(4)

(Total 11 marks)

Mark schemes

1. (a) $= 79 / (1000 \times 6.022 \times 10^{23}) = 1.31 \times 10^{-25}$ kg

1

Then either follow **method 1** (or **method 2** below)

Do not mix and match methods

Method 1

$V_{79} = \frac{d}{t} = 0.950 / 6.69 \times 10^{-4}$

$= 1420$ ms^{-1}

In method 1, M2 can be awarded in M3

1

KE = ½ mv^2

$= ½ \times 1.312 \times 10^{-25} \times (1420)^2$

$= 1.32 \times 10^{-19}$ J

Mark consequential to their velocity and mass. Allow mass of 79 etc.

1

$V_{81} = \sqrt{\left(\frac{2KE}{m}\right)}$

$= \sqrt{1.963 \times 10^6}$

$= 1.40 \times 10^3$ ms^{-1}

(allow 1.398×10^3 - 1.402×10^3)

Mark consequential to their velocity and mass. Allow mass of 81 etc.

1

$t = \frac{d}{v} = \frac{0.950}{v_{81}}$

$= 6.80 \times 10^{-4}$ s

Mark consequential to their M4

Accept 6.77 – 6.80 × 10^{-4} s

1

Method 2

$m_1(d/t_1)^2 = m_2 (d/t_1)^2$

or

$m_1 / t_1^2 = m_2 / t_2^2$

1

$t_2^2 = t_1^2\ (m_2/m_1)$
Or
$t_2^2 = (6.69 \times 10^{-4})2 \times (81/79)$

1

$t_2^2 = 4.59 \times 10^{-7}$

Mark consequential to their M3

1

t = 6.77×10^{-4} s

Mark consequential to their M4

Accept 6.77 – 6.80 × 10^{-4} s

1

(b) ion hits the detector / negative plate <u>and</u> gains an electron

1

Not positive plate

(relative) abundance is proportional to (the size of) the current

1

[7]

2. (a) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ (4s^0)$

1

(b) **M1** In $Ca^{(+)}$ (outer) electron(s) is further from nucleus

Or $Ca^{(+)}$ loses electron from a higher (energy) orbital

Or $Ca^{(+)}$ loses electron from a 4(s) orbital or 4th energy level or 4th energy shell <u>and</u> $K^{(+)}$ loses electron from a 3(p) orbital or 3rd energy level or 3rd energy shell

Must be comparative

Allow converse arguments

1

M2 More shielding (in Ca^+)

1

(c) Be /Beryllium

1

(d) $Mg(OH)_2$

1

(e) $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$

Ignore state symbols

1

n $BaCl_2$ (6/1000 × 0.25) = 1.5×10^{-3} and n Na_2SO_4 = (8/1000 × 0.15) = 1.2×10^{-3} and $BaCl_2$ /barium chloride in excess

Working required or 3×10^{-4} of $BaCl_2$

1

10 cm^3 (of 0.15 mol dm^{-3} sodium sulfate)

or 0.01dm^3

1

(f) **M1** Same electronic configuration / same number of electrons (in outer shell) / all have 37 electrons (1)

Ignore protons and neutrons unless incorrect numbers

Not just electrons determine chemical properties

1

M2 $\frac{86x + 87x + 88(100-2x)}{100} = 87.7$ = 87.7

Alternative M2:

$\frac{86 + 87 + 88y}{1 + 1 + y} = 87.7$

1

M3 x = 10% (or × = 0.1)

M3 y = 8

1

M4 (% abundance of 88 isotope is 100 – 2x10) = 80(.0)%

M4 % of 88 isotope is 100 – 10y = 80(.0) %

Allow other alternative methods

1

(g) $^{138}Ba^{+}$

1

(h) **M1** mass = $\frac{137 \times 10^{-3}}{6.022 \times 10^{23}}$ = 2.275×10^{-25} (kg)

Calculation of m in kg

If not converted to kg, max 4

If not divided by L lose M1 and M5, max 3

1

M2 $v^2 = \frac{2KE}{m} = \frac{2 \times 3.65 \times 10^{-16}}{2.275 \times 10^{-25}} = 3.2088 \times 10^9$

For re-arrangement

1

M3 $v = \sqrt{2KE/m}$ ($v = 5.6646 \times 10^4$)

For expression with square root

1

M4 v = d/t or d = vt or with numbers

1

M5 $d = (5.6646 \times 10^4 \times 2.71 \times 10^{-5}) = 1.53 - 1.54$ (m)

M5 must be to 3sf

If not converted to kg, answer = 0.0485-0.0486 (3sf). This scores 4 marks

1

Alternative method

M1 $m = \frac{137 \times 10^{-3}}{6.022 \times 10^{23}} = 2.275 \times 10^{-25}$

M1 Calculation of m in kg

1

M2 v = d/t

M2, M3 and M4 are for algebraic expressions or correct expressions with numbers

1

M3 $d^2 = \frac{KE \times 2 t^2}{m}$

1

M4 $d = \sqrt{\frac{KE \times 2t^2}{m}}$ ($= \sqrt{(3.65 \times 10^{-16} \times 2 \times (2.71 \times 10^{-5})^2 / 2.275 \times 10^{-25})}$)

1

M5 d = 1.53 – 1.54 (m)

M5 must be to 3sf

1

[18]

3. (a) ^{24}Mg has 12n; ^{25}Mg has 13n; ^{26}Mg has 14n

OR They have different numbers of neutrons

1

(b) No difference in chemical properties

1

Because all have the same electronic structure (configuration)

OR they have the same number of outer electrons

1

(c) If fraction with mass 24 = x

Fraction with mass 26 = 0.900 − x

Fraction with mass 25 = 0.100

1

$A_r = 24x + (25 \times 0.100) + 26(0.900 - x)$

1

24.3 = 24x + 2.50 + 23.4 −26x

2x = 1.60

x = 0.800 i.e. percentage ^{24}Mg = 80.0(%) (80.0% 3sf)

1

^{26}Mg = 0.900 − 0.800 = 0.100 ie percentage ^{26}Mg = 10.0(%)

1

(d) $m = {}^{25/1000}/_{6.022 \times 10^{23}}$

1

$v^2 = 2ke/m$ or $v^2 = \dfrac{2 \times (4.52 \times 10^{-16}) \times (6.022 \times 10^{23})}{25/1000}$

1

$V = \sqrt{2.18 \times 10^{10}} = 1.48 \times 10^{5}$ (ms^{-1})

1

$D = vt = 1.48 \times 10^{5} \times 1.44 \times 10^{-5}$

D = 2.13 (m)

1

[11]