A-Level Chemistry

Mass Number and Isotopes

Question Paper

Time available: 63 minutes
Marks available: 57 marks

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1. This question is about atomic structure.

(a) Define the mass number of an atom.

_____

_____

(1)

(b) Complete the table below to show the numbers of neutrons and electrons in the species shown.

	Number of protons	**Number of neutrons**	**Number of electrons**
^{46}Ti	22		
$^{49}Ti^{2+}$	22		

(2)

(c) A sample of titanium contains four isotopes, ^{46}Ti, ^{47}Ti, ^{48}Ti and ^{49}Ti
This sample has a relative atomic mass of 47.8
In this sample the ratio of abundance of isotopes ^{46}Ti, ^{47}Ti and ^{49}Ti is 2:2:1

Calculate the percentage abundance of ^{46}Ti in this sample.

Abundance of ^{46}Ti _____ %

(3)

(Total 6 marks)

2. This question is about time of flight (TOF) mass spectrometry.

(a) Define the term relative atomic mass.

_____

_____

_____

_____

(2)

(b) A sample of krypton is ionised using electron impact.

The mass spectrum of this sample of krypton has four peaks.

The table shows data from this spectrum.

m/z	82	83	84	86
Relative intensity	6	1	28	8

Calculate the relative atomic mass (A_r) of this sample of krypton.

Give your answer to 1 decimal place.

A_r _____

(2)

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

The kinetic energy of an ion is given by the equation $KE = \frac{1}{2}mv^2$

Where:
KE = kinetic energy / J
m = mass / kg
v = speed / m s^{-1}

In a TOF mass spectrometer, each $^{84}Kr^{+}$ ion is accelerated to a kinetic energy of 4.83×10^{-16} J and the time of flight is 1.72×10^{-5} s

Calculate the length, in metres, of the TOF flight tube.

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

Length of flight tube _____ m

(4)

(Total 8 marks)

3. This question is about the isotopes of chromium.

(a) Give the meaning of the term relative atomic mass.

_____

_____

_____

_____

(2)

(b) A sample of chromium containing the isotopes ^{50}Cr, ^{52}Cr and ^{53}Cr has a relative atomic mass of 52.1

The sample contains 86.1% of the ^{52}Cr isotope.

Calculate the percentage abundance of each of the other two isotopes.

Abundance of ^{50}Cr _____ % Abundance of ^{53}Cr _____ %

(4)

(c) State, in terms of the numbers of fundamental particles, **one** similarity and **one** difference between atoms of ^{50}Cr and ^{53}Cr

Similarity _____

_____

Difference _____

_____

_____

(2)

The sample of chromium is analysed in a time of flight (TOF) mass spectrometer.

(d) Give **two** reasons why it is necessary to ionise the isotopes of chromium before they can be analysed in a TOF mass spectrometer.

1. _____

_____

2. _____

_____

(2)

(e) A $^{53}Cr^{+}$ ion travels along a flight tube of length 1.25 m
The ion has a constant kinetic energy (*KE*) of 1.102×10^{-13} J

$$KE = \frac{mv^2}{2}$$

m = mass of the ion / kg
v = speed of ion / m s^{-1}

Calculate the time, in s, for the $^{53}Cr^{+}$ ion to travel down the flight tube to reach the detector.

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

Time _____ s

(5)

(Total 15 marks)

4. 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)

5. Time of flight (TOF) mass spectrometry is an important analytical technique.

A mixture of three compounds is analysed using a TOF mass spectrometer.
The mixture is ionised using electrospray ionisation.
The three compounds are known to have the molecular formulas:

$C_3H_5O_2N$
$C_3H_7O_3N$
$C_3H_7O_2$ NS

(a) Describe how the molecules are ionised using electrospray ionisation.

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(b) Give the formula of the ion that reaches the detector first in the TOF mass spectrometer.

_____

(1)

(c) A sample of germanium is analysed in a TOF mass spectrometer using electron impact ionisation.

Give an equation, including state symbols, for the process that occurs during the ionisation of a germanium atom.

_____

(1)

(d) In the TOF mass spectrometer, a germanium ion reaches the detector in 4.654×10^{-6} s
The kinetic energy of this ion is 2.438×10^{-15} J
The length of the flight tube is 96.00 cm

The kinetic energy of an ion is given by the equation $KE = \frac{1}{2}mv^2$

where
m = mass / kg
v = speed / m s^{-1}

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

Use this information to calculate the mass, in g, of one mole of these germanium ions.
Use your answer to state the mass number of this germanium ion.

Mass of one mole of germanium ions _____ g

Mass number of ion _____

(5)

(Total 10 marks)

6. 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)