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CHEMISTRY

Physical Chemistry

Level & Board	AQA (A-LEVEL)
TOPIC:	ATOMIC STRUCTURE
PAPER TYPE:	QUESTION PAPER 3
TOTAL QUESTIONS	10
TOTAL MARKS	47

Atomic structure

1. The Rutherford model of the atom is an early atomic model that describes the atom as a small, dense, positively charged nucleus surrounded by negatively charged electrons orbiting in circular paths. However, as scientific knowledge has advanced, more accurate atomic models incorporating additional features have been developed.

(a) Please state two distinct characteristics of the current atomic model that differ from the Rutherford model.

(2)

(b) In a time-of-flight mass spectrometer, a Krypton (Kr) sample was analyzed by ionizing it using electron impact to create 1+ ions. The resulting spectrum displayed four peaks with m/z values and percentage abundance.
The following table shows the details of each peak:

m/z	Percentage Abundance
78	0.4%
80	2.3%
82	11.6%
83	11.5%
84	57%
85	To be determined

Your task is to determine the symbol and mass number of the ion that reaches the detector first. Please calculate the relative atomic mass of Kr in this sample and provide your answer to 1 decimal place.

(4)

2. Time-of-flight mass spectrometer: What is the equation for the ionization of molecule M through electrospray ionization?

A. $M(l) + e^- \rightarrow M^+(g) + 2e^-$
B. $M(g) + e^- \rightarrow M^+(g) + 2e^-$
C. $M(l) + H^+ \rightarrow MH^+(g)$
D. $M(g) + H^+ \rightarrow MH^+(g)$

(1)

3. Please select the correct electron configuration of Cu^{2+} in its ground state from the following options:

A. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3$
B. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^9$
C. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3\ 4s^2$
D. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^2$

(1)

4. Which electron configuration shows an atom of a transition metal?

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A. [Ar] $4s^2 3d^0$
B. [Ar] $4s^2 3d^8$
C. [Ar] $4s^2 3d^{10}$

D. [Ar] $4s^2 3d^{10} 4p^1$

(1)

5. Time of flight (TOF) mass spectrometry is a crucial analytical technique used to determine the mass-to-charge ratio (m/z) of ions in a sample.
This method examines a mixture containing three compounds using a TOF mass spectrometer after ionization through electrospray ionization. The three compounds are known to have specific molecular formulas.
C_3H_7OH
C_5H_9OH
$C_3H_7O_2NS$

(a) Can you explain how electrospray ionization works in ionizing molecules?

(3)

(b) What is the ion formula that reaches the detector first in a TOF mass spectrometer?

(1)

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(c) A TOF mass spectrometer analyzes a germanium sample with electron impact ionization.
Write an equation for the germanium atom ionization process, including state symbols.

(1)

(d) In the time-of-flight mass spectrometer, a Arsenic ion with a kinetic energy of 4.138×10^{-12} J reaches the detector in 2.542×10^{-5} s, after traveling a distance of 88.00 cm in the flight tube.

The equation gives the kinetic energy of an ion

$$K.E = \frac{1}{2}mv^2$$

Where

m = mass/kg

v = speed / m s^{-1}

The Avogadro constant L = 6.022×10^{23} mol^{-1}.

Use this information to calculate the mass, in g, of one mole of these Arsenic ions.

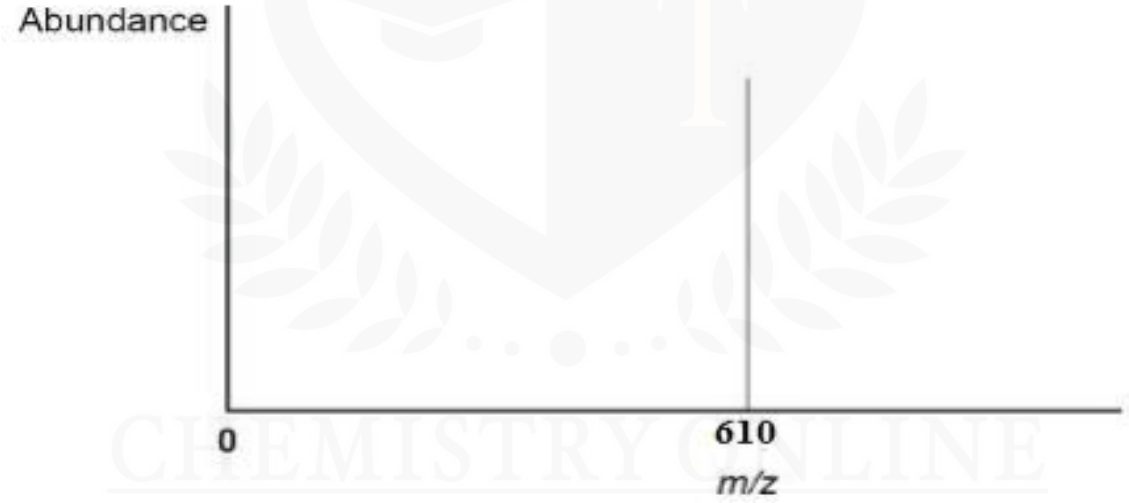
(4)

6. The first ionization energies of the elements in Period 3 change as the atomic number increases.

Explain the pattern in the first ionization energies of the elements from Sodium to Argon.

(6)

7. Time of flight (TOF) mass spectrometry can be used to analyze large molecules such as proctolin, and endocaine (QYNAD).
QYNAD is ionized by electrospray ionization and its mass spectrum is shown in the diagram



(a) Describe the process of electrospray ionization. Give an equation to represent the ionization of QYAND in this process.

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(4)

(b) What is the relative molecular mass of QYAND?

(1)

(c) A molecule Y is ionized by electron impact in a TOF mass spectrometer.

The Q+ ion has a kinetic energy of 3.06×10^{-11} J This ion takes 1.23×10^{-5} s to reach the detector.

The length of the flight tube is 1.20 m

Calculate the relative molecular mass of Y.

$$K.E = \frac{1}{2}mv^2$$

where m = mass/kg

v = speed / m s^{-1}

The Avogadro constant L = 6.022×10^{23} mol^{-1}.

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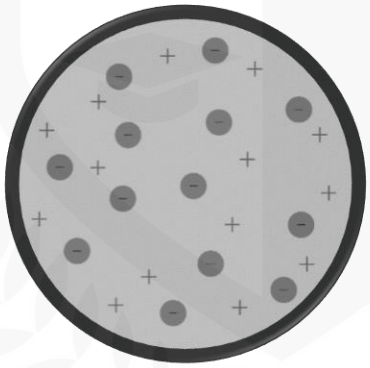
(3)

8. Please tick the atom which has the greatest first ionization energy.

A. H
B. He
C. Li
D. Ne

(1)

9. This inquiry concerns the atomic structure and a significant discovery made in the 19th century by JJ Thomson.
Thomson's groundbreaking research identified the electron and hypothesized that negatively charged electrons were distributed throughout an atom, akin to plums in a pudding of positive charge.
The accompanying diagram illustrates an atom of element Q, according to the 'plum pudding' model.



It is established that an atom of R contains thirteen electrons.

(a) State two differences between the ‘plum pudding’ model and the model of atomic structure used today.

(2)

(b) Deduce the complete electron configuration of an atom of element Q.

(1)

(c) Identify element Q and find the formula of the compound formed with a Group 7 metal in the same period.

(2)

10. This question is about atomic structure.

(a) Write the complete electron configuration for each of the following species: Br^- and Ti^{2+}

(2)

(b) Write an equation, including state symbols, to represent the process that occurs when the third ionization energy of Chromium is measured.

(1)

(c) State which elements Beryllium and Boron have the lower first ionization energy. Explain your answer:

(3)

(d) A time-of-flight (TOF) mass spectrometer was used to analyze a palladium sample. The sample underwent electron impact ionization, resulting in a spectrum with five peaks.

The table below shows the abundance of each peak, measured as a percentage of the total.

m/z	Abundance / %
102	1.02
104	11.4
105	22.33
106	27.33
108	28.46
110	11.72

What is the symbol and mass number of the ion that would reach the detector first in the sample? Also,

calculate the relative atomic mass of Palladium in the sample.

Give your answer to one decimal place.

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