Write your **student number** in the boxes above. **Letter**

Chemistry ½

Question and Answer Book - SOLUTIONS

VCE Examination (Term 1 Mock) - April 2025

- Reading time is **15 minutes**
- Writing time is **2 hours**

Materials Supplied

- Question and Answer Book of 27 pages.
- Multiple-Choice Answer Sheet.

Instructions

- Follow the instructions on your Multiple-Choice Answer Sheet.
- At the end of the examination, place your Multiple-Choice Answer Sheet inside the front cover of this book.

Students are **not** permitted to bring mobile phones and/or any unauthorised electronic devices into the examination room.

Contents

Student's Full Name: _____

Student's Email: _____

Tutor's Name: _____

Marks (Tutor Only): _____

Section A

Instructions

- Answer **all** questions in pencil on the Multiple-Choice Answer Sheet.
- Choose the response that is **correct** or that **best answers** the question.
- A correct answer scores 1; an incorrect answer scores 0.
- Marks will **not** be deducted for incorrect answers.
- No marks will be given if more than one answer is completed for any question.
- Unless otherwise indicated, the diagrams in this book are not drawn to scale.

Learning Objective [2.2.3] Calculate the relative atomic mass of a compound from its relative isotopic abundance.

Question 1 D1

Which of the following values has exactly 4 significant figures?

A. 43,553

B. 0.2390

C. 4.32×10^4

D. 0.0004

Learning Objective [1.1.1] Describe the composition of an atom, & write the isotopic symbol of an element/ion & use it to identify an element's/ion's atomic & mass number.

Question 2 D1

For the atom of ^{12}C, which of the following statements is false?

A. There are a total of 12 protons and neutrons in this atom.

B. The number of electrons would be less than the number of protons as the atom is charged.

C. The concept of moles is based on this atom.

D. The number of electrons in this atom is equal to the atomic number.

Learning Objective [1.1.3] Explain Schrodinger's model of the atom & identify differences between his model & Bohr's model.

Question 3 D1

Which of the following does the Schrödinger model most accurately present?

A. Electrons are found in fixed positions within shells.

B. Atoms are mostly made up of empty space.

C. Electron position is not fixed but found in regions called orbitals.

D. Atoms have a nucleus which consists of neutrons but no protons.

Learning Objective [1.1.2] Describe Bohr's model of the atom & draw shell model diagrams & apply emission spectra to Bohr's model of the atom.

Question 4 D1

Which of the following trends in the periodic table is true?

A. Moving across a period, electronegativity decreases.

B. Moving down a group, first ionisation energy increases.

C. Moving up a group, the metallic nature of an atom decreases.

D. The atomic radius of atoms decreases going from right to left across a period.

Question 5

Learning Objective [2.2.1] Calculate the percentage composition by mass of an element in a compound/molecule.

D1

What is the percentage composition of P in H_3PO_4?

A. 65.31%

B. 3.06%

C. 31.63%

D. 33.54%

Question 6

Learning Objective [2.3.2] Apply stoichiometry to find the amount of another substance used/produced.

D1

Consider the reaction that creates ammonia gas.

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

Find the mass of ammonia that is formed from $3.42 \times 10^2\ g$ of hydrogen gas. Assume that nitrogen gas is in excess.

A. $1.938 \times 10^4\ g$

B. $1.938 \times 10^2\ g$

C. $1.938 \times 10^1\ g$

D. $1.938 \times 10^3\ g$

Question 7

Learning Objective [2.3.4] Apply limiting reagent to calculate the mass of product(s) formed, and to calculate the amount of excess reagent leftover.

D1

Consider the reaction between aluminium chloride and lithium hydroxide.

$$AlCl_3 + 3LiOH \rightarrow Al(OH)_3 + 3LiCl$$

If there is $2.45\ mol$ of $AlCl_3$ and 4.50 moles of LiOH, what is the excess reagent and how much is it in excess by?

A. $AlCl_3$ is in excess by $2.05\ mol$.

B. $AlCl_3$ is in excess by $0.95\ mol$.

C. LiOH is in excess by $2.05\ mol$.

D. LiOH is in excess by $0.95\ mol$.

Question 8

Learning Objective [1.1.4] Write electron configurations of elements & ions, in both ground & excited states, using both Bohr & Schrodinger models (including Cu & Cr exceptions & condensed notation).

D1

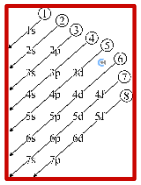
What's the electron configuration for selenium written using Schrödinger's subshell notation?

A. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 4p^6\ 3d^8$

B. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 4p^6\ 3d^9$

C. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^8\ 4p^5$

D. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^4$



Subshells are filled in the following order (from lowest energy to highest energy):

s subshells hold 2 e⁻, p subshells hold 6 e⁻, d subshells hold 10 e⁻ and f subshells hold 14 e⁻.

So selenium's electron configuration is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 4p^6\ 3d^8$ following these rules.

Question 9

Learning Objective [1.5.3] Explain the properties of ionic compounds (hardness, high MP/BP, brittleness, electrical conductivity in various states), with reference to their structure and bonding.

D1

Which of the following statements about ionic compounds is correct?

A. Ionic compounds are ductile.

B. Ionic solids are good electrical conductors in

C. All salts are ionic compounds.

Salts are formally defined as chemical compounds consisting of an assembly of cations and anions. All ionic compounds fit this description.

D. Ionic compounds have lower boiling points than covalent ones.

Question 10

Learning Objective [2.3.4] Apply limiting reagent to calculate the mass of product(s) formed, and to calculate the amount of excess reagent leftover.

D1

3.15 g of zinc powder was reacted with 10.2 g of O_2. How many g of O_2 remain unreacted?

A. 0.00

B. 8.66 g

C. 9.43 g

D. 9.80 g

$2Zn_{(s)} + O_{2(g)} \rightarrow 2ZnO_{(s)}$

$n(Zn) = \frac{3.15\ g}{65.4\ g\ mol^{-1}} = 0.048165\ldots\ mol$

$n(O_2) = \frac{10.2\ g}{32.0\ g\ mol^{-1}} = 0.31875\ mol$

Divide each n(reactant) by their coefficients in the balanced equation to identify limiting reagent (reactant with the smallest number after dividing).

Zn: 0.048165… mol / 2 = 0.02408… mol (limiting)

O_2: 0.31875 mol / 1 = 0.31875 mol

$n(O_2)$ reacted = 0.5 × n(Zn) = 0.02408… mol

$m(O_2)$ reacted = 32.0 g mol^{-1} × 0.02408… mol = 0.77064… g

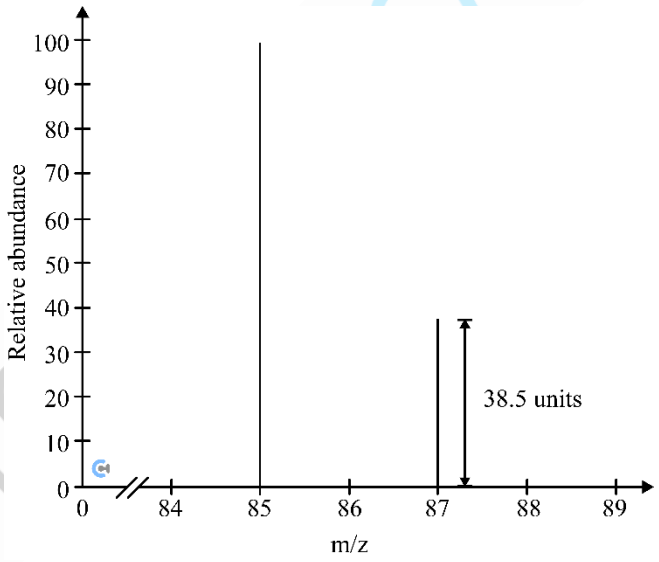
$m(O_2)$ unreacted = 10.2 g - 0.77064… g ≈ 9.43 g

Question 11

Learning Objective [2.2.5] Apply mass spectrum readings to RAM & relative isotopic abundance calculations.

D1

Given the following mass spectrum of rubidium nuclei, what's the % abundance of the radioisotope rubidium-87?



A. 27.8%

B. 38.5%

C. 40.0%

D. 61.5%

Question 12

D1

How many niobium atoms are in 15 g of Nb_2O_5?

A. 3.4×10^{22}

B. 6.8×10^{22}

C. 1.7×10^{23}

D. 9.03×10^{24}

$M_r(Nb_2O_5) = (2 \times 92.9\ g\ mol^{-1} + 5 \times 16.0\ g\ mol^{-1}) = 265.8\ g/mol$

$n(Nb_2O_5) = \frac{15\ g}{265.8\ g\ mol^{-1}} = 0.0564\ldots\ mol$

$n(Nb) = 2 \times n(Nb_2O_5)$

number of Nb atoms $= 2 \times n(Nb_2O_5) \times 6.02 \times 10^{23} = 6.8 \times 10^{23}$

Learning Objective [2.2.1] Calculate the percentage composition by mass of an element in a compound/molecule.

Question 13

D1

Which of the following statements is true about the allotropes of carbon?

A. Carbon forms 4 bonds with itself when forming graphite.

B. Diamonds are electrically conductive.

C. Graphite exists in layers held together by weak dispersion forces.

D. Diamond has a weak covalent network lattice.

Learning Objective [1.3.3] Explain the covalent lattice structures & bonding of diamond and graphite, and apply these to their properties.

Question 14

D1

When a solution of barium chloride is mixed with a solution of sodium sulphate, what is the precipitate formed?

A. $NaBr$

B. $BaSO_4$

C. $NaCl$

D. Br_2SO_4

Learning Objective [1.9.3] Identify which compounds will or will not dissolve in water, with reference to SNAPE and/or solubility tables.

Question 15

D1

Which of the following is the correct formula for ammonium carbonate?

A. NH_4CO_3

B. NH_3CO_3

C. $(NH_4)_2CO_3$

D. $NH_4(CO_3)_2$

Learning Objective [1.5.1] Write the formula of simple & complex (containing polyatomic and transition metal ions) ionic compounds and be able to name them.

Question 16

D1

Which of the following molecules have a tetrahedral parent geometry?

A. CCl_4

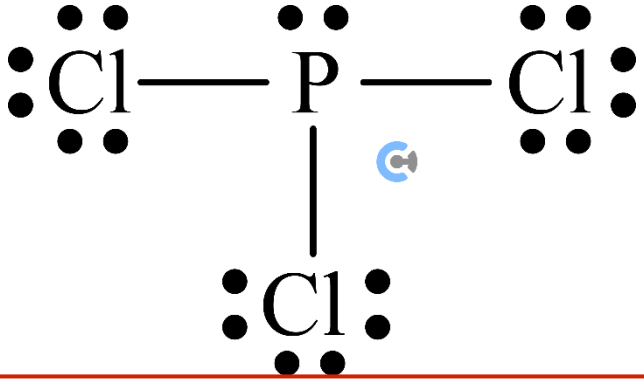
B. H_2O

C. NH_3

D. All of the above.

Learning Objective [1.6.2] Identify the geometries (parent & molecular) of molecules, with reference to VSEPR theory.

The following molecule relates to both Question 17 and Question 18



Learning Objective [1.7.1] Identify polar & non-polar bonds within a covalent molecule, with reference to electronegativity.

Question 17 D1

Which of the following best describes the **bonds** within this molecule?

A. The bonds are ionic.

B. The bonds are polar covalent.

C. The bonds are non-polar covalent.

D. None of the above.

Learning Objective [1.8.2] Explain how dipole-dipole attractive forces form & identify molecules that can exhibit them.

Question 18 D1

Which of the following is **true** about the entire molecule?

A. It is non-polar as its geometry is tetrahedral.

B. There is no net dipole.

C. It can form dipole-dipole bonds.

D. It can form hydrogen bonds.

Question 19 Learning Objective [1.8.4] Apply intermolecular bonding to compare molecules' melting & boiling points.

Which of the following best describes why water is a liquid at room temperature? D1

A. It has strong electrostatic attraction between molecules.

B. It has strong dispersion forces.

C. It can exhibit hydrogen bonding.

D. It has strong covalent bonds.

Learning Objective [1.10.1] Identify which substances would dissolve one another based on miscibility and polarity.

Question 20 D1

Which of the following compounds would best mix with water?

A. CCl_4

B. HCl

C. HF

D. C_6H_{14}

Learning Objective [2.2.3] Calculate the relative atomic mass of a compound from its relative isotopic abundance.

Question 21

Chlorine exists in 2 forms in nature: Cl-35 and Cl-37, with abundances of 25% and 75% respectively. Its relative atomic mass is:

D1

A. 36.0

B. 36.5

C. 35.5

D. 50

Question 22

Learning Objective [2.3.1] Write balanced chemical equations.

D1

Which of the following is a correctly balanced equation?

A. $C_2H_5OH + O_2 \rightarrow CO_2 + H_2O$

B. $2C_2H_6O + 7O_2 \rightarrow 4CO_2 + 6H_2O$

C. $C_2H_5OH + 6O_2 \rightarrow 2CO_2 + 3H_2O$

D. $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$

Question 23

Learning Objective [1.4.1] Write balanced equations for the reactions between a metal & oxygen & between a metal & water, & explain any relevant implications of these reactions.

What is/are the product(s) of a reaction between oxygen gas and magnesium metal?

D1

A. MgO

B. Mg_2O

C. $Mg(OH)_2$

D. $Mg(OH)_2$ and H_2

Question 24

Learning Objective [1.9.1] Explain the process by which ionic compounds dissolve in water with reference to ion-dipole bonding.

Which of the following best explains how NaCl dissolves in water?

D1

A. It forms ionic bonds with water molecules.

B. It dissociates and the sodium ions form ion-dipole bonds with the hydrogen atoms in water molecules.

C. It ionises and the chloride ions form ion-dipole bonds with the oxygen atoms in water molecules.

D. The ionic bonds within the lattice are disrupted, and then ion-dipole bonds are formed between the ions and water molecules.

Question 25

Learning Objective [1.11.1] Apply R_f values to qualitative analysis for TLC.

Qualitative analysis in TLC is best described as:

D1

A. Matching the R_f value of a substance with that of a known compound under identical conditions.

B. Matching the R_t of a substance with that of a known compound under identical conditions.

C. Determining concentrations of chemicals by constructing a calibration curve.

D. Identifying the most polar substance based on adsorption and desorption.

Learning Objective [1.4.3] Explain how metals are obtained & recycled, & their associated advantages & disadvantages.

Question 26

D1

Which of the following is **not** true regarding metal extraction and recycling?

A. Not all metals are recycled.

B. Metal recycling promotes a circular economy.

C. Most metals exist in their pure form in nature.

D. Metals are smelted to remove impurities.

Question 27

Learning Objective [2.2.2] Find the empirical formula & molecular formula of a compound.

D1

Which of the following is true regarding empirical and molecular formulae?

A. The empirical formula lists the actual number of atoms in a compound.

B. The molecular formula lists the ratio of atoms in a compound.

C. Two or more compounds can have the same empirical formula.

D. A substance's empirical formula cannot be the same as its molecular formula.

Question 28

Learning Objective [1.3.1] Explain the metallic bonding model.

D1

The metallic bonding model is best described as:

A. Cations and anions held together by electrostatic attraction.

B. Cations and a sea of delocalised electrons, both of which are moving freely.

C. Cations arranged in a lattice, surrounded by a sea of delocalised electrons.

D. Metals bonding to one another via dispersion forces.

Learning Objective [1.2.1] Explain why the periodic table is arranged the way it is, with respect to blocks, periods & groups.

Question 29

D1

Why is fluorine found in the p-block of the periodic table?

A. It has 6 valence electrons.

B. It has a partially filled P subshell as it's outmost shell.

C. Because it is in period 2.

D. Because it is in group 17.

Question 30

Learning Objective [1.3.2] Identify properties of metals (high MP/BP, electrical & thermal conductivity, malleability & ductility, lustre).

D1

Copper is often used in electrical wiring. This can be best attributed to the fact that it is:

A. Ductile

B. Malleable

C. Brittle

D. A thermal conductor

Section B

Instructions

- Answer all questions in the spaces provided.
- Write your responses in English.
- Give simplified answers to all numerical questions, with an appropriate number of significant figures; unsimplified answers will not be given full marks.
- Show all working in your answers to numerical questions; no marks will be given for an incorrect answer unless it is accompanied by details of the working.
- Ensure chemical equations are balanced and that the formulas for individual substances include an indication of state, for example, $H_2(g), NaCl(s)$.
- Unless otherwise indicated, the diagrams in this book are not drawn to scale.

Question 1 (8 marks)

Betty is creating a model of the atom for her school project and wishes to produce a representation of Bohr's Model. To do this, she picks ^{14}N as her reference atom.

D3

a. Explain what the Bohr's Model is in reference to ^{14}N. Ensure to explain the electron distribution and key aspects of the model. 2 marks

Learning Objective [1.1.2] Describe Bohr's model of the atom & draw shell model diagrams & apply emission spectra to Bohr's model of the atom.

The Bohr model of the atom states that atoms exist with a positively-charged nucleus, with protons and neutrons ($7p$ and $7n$ for nitrogen) in the centre of the atom surrounded by empty space (1). Electrons reside in shells, a fixed distance away, surrounding the nucleus (2), and these shells have fixed energy levels.

b. Betty wonders how Bohr's model was discovered. Explain how the production of an emission spectrum from a flame test links to key aspects of the model. 2 marks

D2

Learning Objective [1.1.2] Describe Bohr's model of the atom & draw shell model diagrams & apply emission spectra to Bohr's model of the atom.

The emission spectrum is based on electrons becoming excited to a higher energy level, and then dropping down to ground state, giving off light energy in the process (1). It reveals that electrons exist in discrete energy levels - and can move between them - called shells (2).

c. Betty's competitor, Linda, presents a model instead using the Schrödinger's Model.

Provide the subshell configuration for the following atoms:

i. Na

Learning Objective [1.1.4] Write electron configurations of elements & ions, in both ground & excited states, using both Bohr & Schrodinger models (including Cu & Cr exceptions & condensed notation).

$1s^2\ 2s^2\ 2p^6\ 3s^1$ D1

ii. Cl

Learning Objective [1.1.4] Write electron configurations of elements & ions, in both ground & excited states, using both Bohr & Schrodinger models (including Cu & Cr exceptions & condensed notation).

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$ D1

iii. Cr

Learning Objective [1.1.4] Write electron configurations of elements & ions, in both ground & excited states, using both Bohr & Schrodinger models (including Cu & Cr exceptions & condensed notation).

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6 3d^5 4s^1$ or $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6 4s^1 3d^5$ D1

d. State the condensed Schrödinger notation of potassium. 1 mark

$[Ar]4s^1$ D1

Learning Objective [1.1.4] Write electron configurations of elements & ions, in both ground & excited states, using both Bohr & Schrodinger models (including Cu & Cr exceptions & condensed notation).

Question 2 (5 marks)

Nash is investigating moles and masses of two different compounds.

a. He first investigated sulfuric acid (H_2SO_4).

i. Find the molar mass of sulphuric acid. 1 mark

Learning Objective [2.1.2] Apply molar mass to mole calculations using $n = m/M$

D1

$2 + 32.1 + 64 = 98.1\ g/mol$

ii. Find the mass of $6.16\ mol$ of sulphuric acid. 1 mark

Learning Objective [2.1.2] Apply molar mass to mole calculations using $n = m/M$

D1

b) $m(H_2SO_4) = 6.16 \times (2+32.1+64)$
$= 604.3\ g$

$= 604\ g$

b. He then investigates oxygen gas (O_2).

i. Find the amount, in mol, of oxygen atoms in $15.00\ g$ of oxygen gas. 2 marks

Learning Objective [2.1.2] Apply molar mass to mole calculations using $n = m/M$

D2

$n(O_2) = \frac{m}{Mr} = \frac{15}{32} = 0.469\ mol$

$n(O) = 2 \times n(O_2) = 0.938\ mol$

ii. State the number of oxygen atoms in $15.00\ g$ of oxygen gas. 1 mark

Learning Objective [2.1.1] Apply Avogadro's number to mole calculations using $n = N/Na$

D1

$N(O) = n \times N_A = 0.938 \times 6.02 \times 10^{23} = 5.64 \times 10^{23}$ atoms

Question 3 (8 marks)

The periodic table, aside from presenting all elements, is arranged to observe certain trends to predict the properties of elements.

a. Between $Na(s)$ and $Cs(s)$, explain which of these metals is more likely to react. Make references to relevant trends in your answer. 3 marks

Learning Objective [1.4.2] Apply trends in the periodic table to metal reactivity

D3

$Cs(s)$ is more likely to react. This is because $Cs(s)$ is lower in the group meaning it has more electron shells/larger atomic radius (1). Thus, the valence electrons are less attracted to the nucleus and thus are more likely to be donated/greater metallic character (2). This allows $Cs(s)$ to be more likely to react (3).

b. Identify and explain one key property of group 18 compounds. 2 marks

Learning Objective [1.2.1] Explain why the periodic table is arranged the way it is, with respect to blocks, periods & groups.

D2

Inert (1) This is because the noble gases already have a full outer shell with 8 electrons according to the octet rule (2). This means that they do not accept or gain anymore electrons and thus do not react.

c. What occurs to the electronegativity of atoms moving from left to right across a period? Explain your answer with reference to at least two other trends. 3 marks

Learning Objective [1.2.2] Explain what the terms 'electronegativity, 'atomic radius', 'first ionisation energy', 'metallic character' & 'non-metallic character' mean, & explain how they vary across a period & down a group.

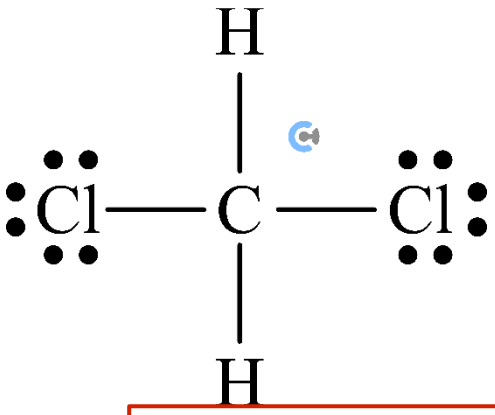
Learning Objective [1.2.3] Find the effective nuclear/core charge of an element, explain how it varies across a period & down a group, & apply it to other trends observed in the periodic table.

D3

Increased (1). Moving left to right, the core charge of atoms increase (2) whilst the radius of the atom decreases (3). This means that electrons are more strongly attracted to the nucleus, and thus electronegativity is higher.

Question 4 (7 marks)

A molecule of CH_2Cl_2 is shown below:



Learning Objective [1.6.2] Identify the geometries (parent & molecular) of molecules, with reference to VSEPR theory.

a. Complete the table below regarding the molecule shown. 2 marks

D1

Parent Geometry	Molecular Geometry
Tetrahedral	Tetrahedral

b. Explain whether the molecule above is polar or non-polar. Refer to its geometry and bonds. 3 marks

Learning Objective [1.7.1] Identify polar & non-polar bonds within a covalent molecule, with reference to electronegativity.

Learning Objective [1.7.2] Draw partial charges & corresponding polarity arrows on covalent molecules.

D3

Although CH_2Cl_2 is tetrahedral, the tetrahedral shape is $3D$. Therefore, although there are two Cls, they do not oppose each other directly. Hence, the polar C-Cl bonds (1) don't act in the opposite direction (2), which results in a net dipole being formed in the molecule. As such, CH_2Cl_2 is polar (3).

c. State the types of intermolecular bonds this molecule can undergo, and justify why. 2 marks

Learning Objective [1.8.1] Explain how dispersion forces form & identify molecules that can exhibit them.

Learning Objective [1.8.2] Explain how dipole-dipole attractive forces form & identify molecules that can exhibit them.

D2

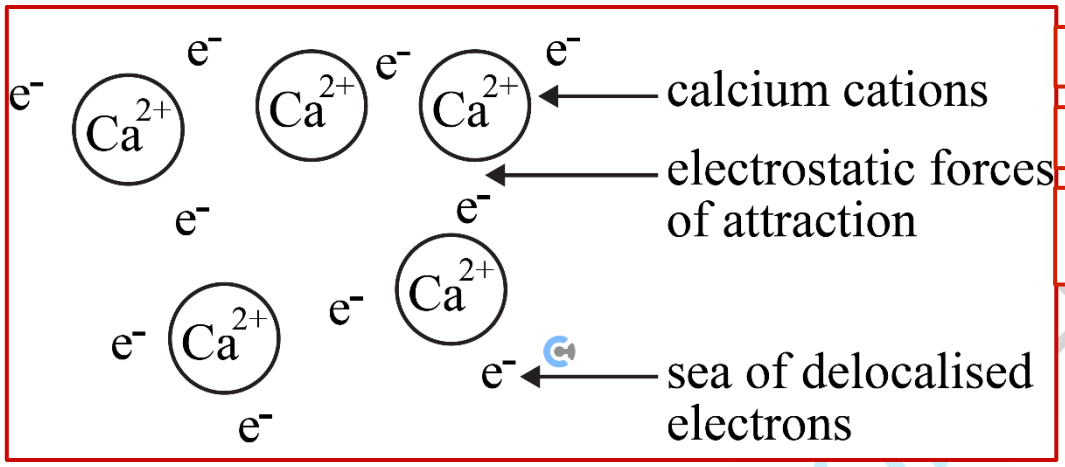
Dispersion forces, as all molecules can undergo them (1).
Dipole-dipole forces as the molecule is polar (2).

Question 5 (6 marks)

Learning Objective [1.3.1] Explain the metallic bonding model.

a. Draw the metallic lattice structure of calcium metal below, ensuring that the diagram has exactly 10 electrons. Ensure to draw and label any relevant forces of attraction. 3 marks

D2



1m for labelling

1m for five Ca^{2+}

1m for exactly $10e^-$

b. With reference to its structure, explain why metals such as calcium are malleable. 3 marks

Learning Objective [1.3.2] Identify properties of metals (high MP/BP, electrical & thermal conductivity, malleability & ductility, lustre).

D3

Metals exist as cations surrounded by a sea of delocalised electrons (1).
When a metal is struck, the structure is not broken, but stays intact (2) due to the strong electrostatic attraction between cations and electrons (3), allowing it to be shaped.

Question 6 (8 marks)

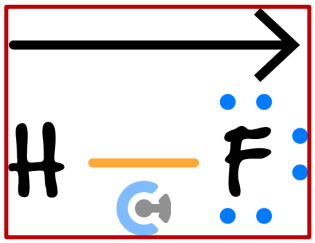
Hydrofluoric acid, also known as HF, is an acidic substance. We usually dilute it in several ways to make it safer for human handling.

a. The structure of HF is to be investigated.

D2

Learning Objective [1.6.1] Draw Lewis structures of atoms & covalent molecules.

i. Draw the Lewis Structure of HF. 1 mark



D2

ii. Draw the polarity arrow on HF above. 1 mark

Learning Objective [1.7.2] Draw partial charges & corresponding polarity arrows on covalent molecules.

b. Explain whether HF is polar or non-polar. 2 marks

D3

Learning Objective [1.7.3] Identify polar & non-polar molecules with reference to polar & non-polar bonds, as well as molecular geometry.

HF is polar due to the difference in electronegativity between the F and the H (1), resulting in an uneven distribution of electrons and thus, a net dipole (2).

c. State what sort of intermolecular bonds HF molecules can make. 1 mark

Learning Objective [1.8.3] Explain how hydrogen bonds form & identify molecules that can exhibit them.

Dispersion, Hydrogen bonding (may also mention dipole-dipole forces but not necessary.).

D1

d. Would we expect HF to have a higher boiling point than HBr? Justify your answer. 3 marks

Learning Objective [1.8.4] Apply intermolecular bonding to compare molecules' melting & boiling points.

D3

HF would have a higher boiling point (1). While both are polar and can form dipole-dipole attractions and have a similar dispersion force strength, Br is less electronegative than F and so would not leave the H exposed, and as such, HBr cannot form hydrogen bonds whereas HF can (2). Thus, this gives HF an overall stronger intermolecular bond strength, and more thermal energy would be required to break its IMB (3).

Do not write in this area.

Question 7 (12 marks)

Salts refer to ionic compounds, which are made up of a metal cation and a non-metal anion. One classic example of salt is NaCl, which is widely used and known as table salt, used in cooking and preservation.

a. Explain the structure of a salt crystal, with reference to the ionic bonding model. Ensure to identify any relevant intramolecular forces. 2 marks

Note: You may refer to the specific bonding within NaCl to aid your explanation.

D2

Learning Objective [1.5.2] Explain the structure of ionic compounds and be able to draw electron transfer diagrams.

NaCl has a lattice structure (1), in which the Na(s) atom donates an electron to the Cl atom, thus that the metal becomes a positively charged cation and the chlorine becomes a negatively charged anion. These then interact via strong electrostatic forces holding them together in the lattice (2).

b. Would solid NaCl be electrically conductive? Why or why not? 2 marks

D2

Learning Objective [1.5.3] Explain the properties of ionic compounds (hardness, high MP/BP, brittleness, electrical conductivity in various states), with reference to their structure and bonding.

No (1). This is because there are no free moving charged particles, since the cations and anions are fixed in place and held together by the very strong electrostatic forces (2).

c. Despite being hard, when salt crystals are subject to pressure, they crumble and break away, instead of bending and stretching. Identify this property, and explain why it is the case with reference to the ionic bonding model. 2 marks

D2

Learning Objective [1.5.3] Explain the properties of ionic compounds (hardness, high MP/BP, brittleness, electrical conductivity in various states), with reference to their structure and bonding.

Brittle (1). When force is applied the lattice shifts and like-charged particles align which leads to electrostatic forces of repulsion (2) and thus the lattice breaks.

d. Another salt, magnesium nitrate is also commonly used in society.

i. Write the formula of magnesium nitrate. 1 mark

Learning Objective [1.5.1] Write the formula of simple & complex (containing polyatomic and transition metal ions) ionic compounds and be able to name them.

D1

$Mg(NO_3)_2$

ii. Provide the fully balanced dissociation reaction for this salt, when it is mixed with water. 1 mark

Learning Objective [1.9.2] Write balanced equations for ionic compounds dissociating/ionising in water.

D1

$Mg(NO_3)_2(s) \xrightarrow{H_2O} Mg^{2+}(aq) + 2NO_3^-(aq)$

e. An aqueous solution of this salt is then combined with $KOH\ (aq)$.

i. Write the balanced full equation

Learning Objective [1.9.3] Identify which compounds will or will not dissolve in water, with reference to SNAPE and/or solubility tables.

Learning Objective [1.9.4] Write full & ionic equations for precipitation reactions.

D1

$Mg(NO_3)_2(aq) + 2KOH(aq) \rightarrow Mg(OH)_2(s) + 2KNO_3(aq)$

ii. State the identity of any spectator ions. 1 mark

Learning Objective [1.9.4] Write full & ionic equations for precipitation reactions.

D1

NO_3^-, K^+

iii. Write the balanced net ionic equation. 1 mark

Learning Objective [1.9.4] Write full & ionic equations for precipitation reactions.

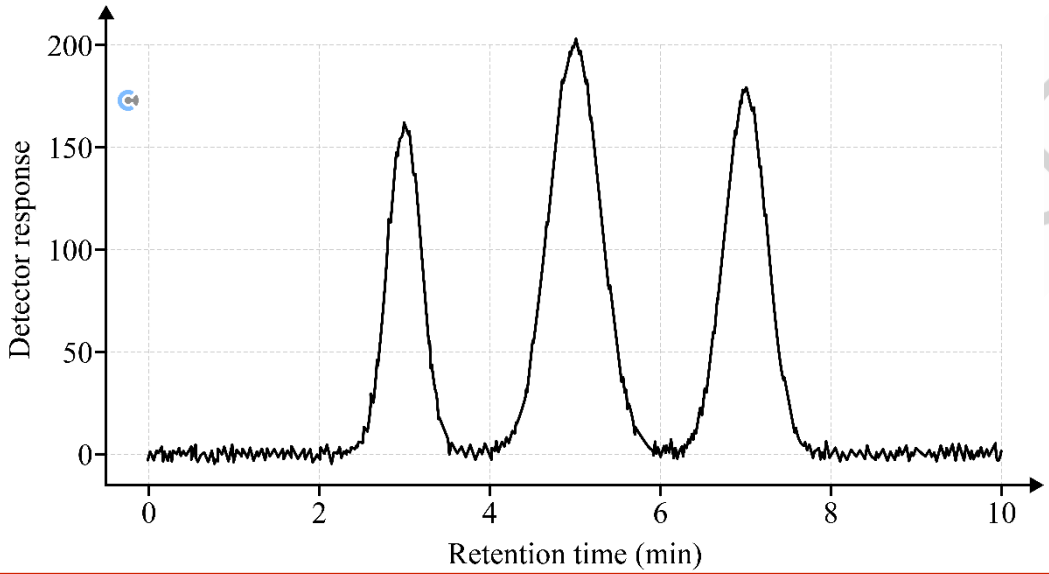
D1

$Mg^{2+}(aq) + 2OH^-(aq) \rightarrow Mg(OH)_2(s)$

Question 8 (5 marks)

Kevin was on his way to teach his Chemistry $1/2$ class and was pulled over for a random breath test. It is known that alcohol (ethanol) has a retention time of 6 minutes on a particular HPLC set-up.

Below is the chromatogram obtained from Kevin's blood sample when run under the same set-up under identical conditions:



Learning Objective [1.11.2] Apply retention time (Rt) to qualitative analysis for Column Chromatography/HPLC.

a. State whether Kevin has ethanol in his bloodstream. Justify your answer. 1 mark

D2

No, as there is no peak at $R_t = 6$ mins. Must mention retention time/R_t of 6 mins to get the mark.

b. The large peak in the middle corresponds to glucose. If Kevin wanted to determine the concentration of glucose in his blood, explain the steps he would have to perform to undertake this analysis. 4 marks

D3

Learning Objective [1.11.3] Draw calibration curves & apply them to quantitative analysis for Column Chromatography/HPLC.

Create standard solutions of known concentration of glucose (1).
Run those under the same chromatogram under identical conditions (2).
Observe their peak areas/detector response, and construct a calibration curve of peak area against concentration (3).
Compare the peak area of Kevin's blood sample to that of the calibration curve, and identify what concentration corresponds to it (4).

Question 9 (4 marks)

An experiment was conducted to experimentally determine Avogadro's number using a sample of nitric acid, HNO_3.

Learning Objective [2.1.2] Apply molar mass to mole calculations using $n = m/M$

a. Calculate the moles of nitric acid in a $7.31 \times 10^3\ mg$ sample. 2 marks

Learning Objective [2.1.3] Apply unit conversions to calculation questions

D2

Molar mass $= 1 + 14 + (16 \times 3) = 63\ g\ mol^{-1}$
$7310\ mg = 7.310\ g$
$7.310 / 63 = 0.11603$ moles

b. Hence, given that we determine that there are approximately 1.95×10^{23} atoms of oxygen in the sample, calculate the experimental value of Avogadro's Number. 2 marks

D2

Learning Objective [2.1.1] Apply Avogadro's number to mole calculations using $n = N/Na$

$$\frac{1}{3} \times \frac{1.95 \times 10^{23}}{0.11603} = 5.60 \times 10^{23}\ mol^{-1}$$

Do not write in this area.

Learning Objective [2.2.5] Apply mass spectrum readings to RAM & relative isotopic abundance calculations.

Question 10 (5 marks)

Arjun is experimenting with his new mass spectrometer in his garage, and adding different compounds into the machine to observe the spectra which are produced.

a. Explain what mass spectrometry is primarily used for. 1 mark

Mass spectrometry is used to find the molar mass of a molecule.

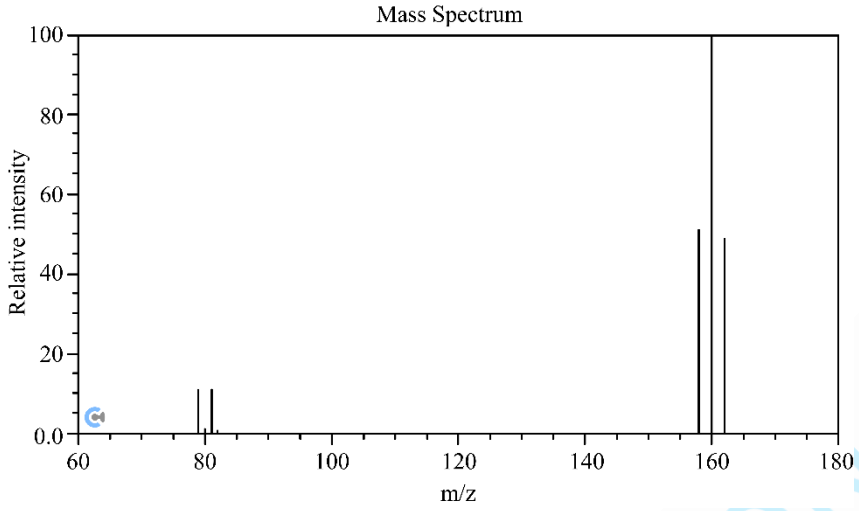
D1

b. State what is meant by the m/z ratio. State what it is used to reveal. 1 mark

Mass to charge ratio. It reveals the molar mass.

D1

c. Below is a graph of the spectra produced after placing an unknown **diatomic** molecule into the mass spectrometer.



i. What is the likely identity of the molecule? 1 mark

D1

Bromine/Br_2 - Use 160 peak.

ii. Explain the presence of the two side peaks around the major peak at 160 m/z. Justify your answer. 2 marks

D2

These form due to bromine gas created from the 79-79 isotope combination and the 81-81 isotope combination.

Question 11 (8 marks)

Consider a compound that is comprised of 13.0% hydrogen, 52.2% carbon and the remainder being oxygen.

a. Determine the empirical formula of this substance. 3 marks

Learning Objective [2.2.2] Find the empirical formula & molecular formula of a compound. D2

Assume 100 g of substance (1)
$13 / 1 = 13 / 2.175 = 6$ approx.
$52.2 / 12 = 4.35 / 2.175 = 2$
$34.8 / 16 = 2.175 / 2.175 = 1$ (1)
C_2H_6O (1)

Learning Objective [2.2.2] Find the empirical formula & molecular formula of a compound.

b. Given that the molar mass of the molecule is $46\ g\ mol^{-1}$, state the molecular formula. 1 mark

D1

C_2H_6O

c. Given the equation below: 4 marks

D2

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$

If 3.56 g of the substance reacts in excess oxygen, calculate the total mass of products produced by the reaction.

Learning Objective [2.3.2] Apply stoichiometry to find the amount of another substance used/produced.

$3.56 / 46 = 0.07739$ moles

$0.07739 \times 2 = 0.15478$ moles of CO_2 $\rightarrow \times 44 = 6.81032$ g of CO_2

$0.07739 \times 3 = 0.23217$ moles of H_2O $\rightarrow \times 18 = 4.17906$ g of water

Total mass $= 10.99$ g of products

11.0 g (3sf)

Question 12 (7 marks)

Marble chips, typically comprised of $CaCO_3$, can react with hydrochloric acid to create calcium chloride.

a. What is the percentage composition of carbon in $CaCO_3$? 1 mark

Learning Objective [2.2.1] Calculate the percentage composition by mass of an element in a compound/molecule.

D1

Molar mass = 100.1

$12 / 100.1 = 12.0\%$ (3sf)

b. Consider a 5.33 g sample of $CaCO_3$ and 1.53 g of HCl reacting according to this reaction.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(s) + CO_2(g) + H_2O(l)$$

i. Determine the limiting and excess reagent of this reaction. 2 marks

Learning Objective [2.3.3] Identify the limiting reagent when reactants' amounts are known.

D2

$n(CaCO_3) = \frac{5.33}{100.1} = 0.0532$

$n(HCl) = \frac{1.53}{36.5} = 0.0419 \div 2$

$= 0.02$

$CaCO_3$ is excess & HCl is limiting

ii. Hence, calculate the amount of $CaCl_2$ produced, in g. 2 marks

Learning Objective [2.3.4] Apply limiting reagent to calculate the mass of product(s) formed, and to calculate the amount of excess reagent leftover.

D2

$n(HCl) = 0.0419$

$n(CaCl_2) = \frac{1}{2} \times n(HCl) = 0.020958$

$m(CaCl_2) = 0.020958 \times (40.1 + 71)$

$= 2.33g$

iii. State the amount, in grams, of excess reagent left over after the reaction. 2 marks

Learning Objective [2.3.4] Apply limiting reagent to calculate the mass of product(s) formed, and to calculate the amount of excess reagent leftover.

D2

$n(CaCO_3 \text{ used}) = \frac{1}{2} n(HCl) = 0.02096$

$n(CaCO_3 \text{ left}) = 0.0532 - 0.02096$

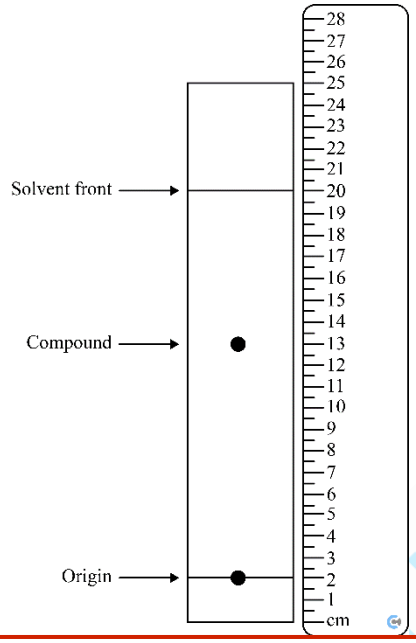
$= 0.03224$

$m(CaCO_3) = 0.03224 \times 100.1$

$= 3.23g$

Question 13 (7 marks)

The following chromatogram was obtained for a certain compound.



Learning Objective [1.10.4] Calculate Retardation factor (R_f) values for components on a TLC plate.

a. Calculate the R_f value for the compound. 1 mark

$13 - 2 \,/\, 20 - 2 \;=\; 0.61$

D1

b. If the solvent used in this setup was H_2O, then what can you conclude about the relative polarity of the compound? Justify your answer with reference to miscibility and intermolecular bonding. 3 marks

D3

Learning Objective [1.10.1] Identify which substances would dissolve one another based on miscibility and polarity.

Learning Objective [1.10.2] Apply the concepts of adsorption and desorption to stationary and mobile phases.

As the compound is relatively close to the solvent front and the solvent used with H_2O, we can conclude that the compound was relatively polar (1) as it travelled a good distance meaning it desorbs strongly into the mobile phase (2) of water, and hence, would be polar. They are miscible as they can both form dipole-dipole bonds with one another (3).

c. Consider that subsequent compounds were analysed under the same conditions.

Learning Objective [1.10.4] Calculate Retardation factor (R_f) values for components on a TLC plate.

Mark on the chromatogram above where these components should be located.

i. Compound A, which has an R_f value of 0.35. 1 mark

Located at the $8.3\ cm$ mark of the ruler. D2

ii. Compound B has an R_f value of 0.89. 1 mark

Located at the $18\ cm$ mark of the ruler. D2

d. State a major difference between TLC and paper chromatography. 1 mark

Learning Objective [1.10.3] Apply chromatography principles to Thin Layer Chromatography (TLC).

TLC uses a thin layer of polar silica gel coated onto glass sheet as stationary phase, whereas paper chromatography uses paper as stationary phase. D2