STUDENT NAME _____*Solutions*_____

CHEMISTRY

Written Examination Unit 1

Reading time: 15 minutes
Writing time: 1 hour 30 minutes

QUESTION AND ANSWER BOOK

Structure of book

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A	20	20	20
B	8	8	70
			Total 90

- Students are permitted to bring into the examination room: pens, pencils, highlighters, erasers, sharpeners, rulers and one scientific calculator.
- Students are NOT permitted to bring into the examination room: blank sheets of paper and/or white out liquid/tape.

Materials supplied

- Question and answer book of 20 pages
- Data Book

Instructions

- Write your **student number (if provided) and student name** in the space provided above on this page.
- All written responses must be in English.

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

Circle the correct answer for each question on the answer sheet provided on page 1

Multiple choice answer sheet

1. A B C D
2. A B C D
3. A B C D
4. A B C D
5. A B C D
6. A B C D
7. A B C D
8. A B C D
9. A B C D
10. A B C D
11. A B C D
12. A B C D
13. A B C D
14. A B C D
15. A B C D
16. A B C D
17. A B C D
18. A B C D
19. A B C D
20. A B C D

SECTION A – Multiple-choice questions

Instructions for Section A

- A correct answer scores 1, an incorrect answer scores 0
- A scientific calculator is permitted in this test.
- Circle the correct answer for each question on the answer sheet provided on page 1.
- No marks will be given if more than one answer is selected.

Question 1

Select the correct statement about the structure of atoms.

A. Each element is one mass unit heavier than the previous element.
B. The mass of protons in an atom will equal the mass of the neutrons.
C. Protons and neutrons are held together by strong nuclear forces.
D. The number of neutrons in an atom will equal the number of electrons.

Question 2

Which of the following isotopes contain equal numbers of neutrons?

A. ^{37}Ar and ^{38}K
B. ^{39}Ar and ^{39}K
C. ^{40}Ar and ^{39}K
D. ^{38}Ar and ^{38}K

^{37}Ar and ^{38}K have equal neutrons because isotope number (mass) - atomic number = neutrons. Ar (Argon) has atomic number 18, K (Potassium) has 19.
37 - 18 = 19 neutrons in 37Ar
38 - 19 = 19 neutrons in 38K

Question 3

During a chemical reaction, the electron configuration of an element undergoes the following change:

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

The above change could occur when

The electron configuration changes from $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$ to $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$, which is a halogen gaining an electron to have a full p subshell. Chlorine forming chloride ion matches.

A. a fluorine atom forms a fluoride ion.
B. a chlorine atom forms a chloride ion.
C. an argon atom forms an ion.
D. a sulfur atom forms a sulfide ion.

Question 4

Which of the following has a higher value for argon than chlorine?

A. first ionisation energy
B. electronegativity
C. atomic radius
D. metallic character

Argon, being a noble gas, has a higher first ionisation energy than chlorine, a halogen.
Metallic character refers to how easily an element can lose electrons to form positive ions; metals have high metallic character, non-metals have low metallic character.

Question 5

The following information is known about element X

It does not conduct electricity
It can form a compound Na_2X
Its ion has the same number of electrons as an ion of calcium(Ca^{2+})

Element X is

A. magnesium
B. oxygen
C. chlorine
D. sulfur

Element X forms Na_2X , which means X must have charge of 2– (2 Na^+ ions). Its ion has same number of electrons as Ca^{2+}. Sulfur has 16 electrons, Ca^{2+} has 18 electrons. Sulfur forms S^{2-} ions with 18 electrons.

Question 6

Which of the following compounds has the correct formula?

A. sodium nitride (NaN_3)
B. aluminium phosphate ($Al_2(PO_4)_3$)
C. copper(I) sulfate ($CuSO_4$)
D. iron(II) nitrate $Fe(NO_3)_3$

Aluminium phosphate is $Al_2(PO_4)_3$. Others are incorrect formulas.

Question 7

Which bond is the most polar?

A. F - F
B. O – H
C. H - Cl
D. O – Cl

O–H bond is highly polar due to difference in electronegativity and size of oxygen atom.
H-Cl may appear, when looking at the periodic table of electronegativity values, that it has a higher difference but its size compared to the oxygen atom disperses the charge and make it less affective.

Question 8

Element X forms an ionic compound $X(NO_3)_3$. The compound element X forms with a sulfate ion is likely to be:

A. XSO_4
B. $X_2(SO_4)_3$
C. X_2SO_4
D. X_3SO_4

If X forms $X(NO_3)_3$, X ion has charge 3+. Sulfate ion charge is 2–, so formula to balance charges is $X_2(SO_4)_3$

Question 9

Which of the following will have the highest melting point?

A. pentanol
B. pentane
C. pentanoic acid
D. methane

Pentanoic acid molecules can form dimers, which are pairs of molecules connected by two hydrogen bonds between their carboxyl (COOH) groups.

Question 10

The order of reactivity from highest (left) to lowest (right) is given below for select metals.

Li > K > Na > Ca > Mg > Zn > Fe > Cu

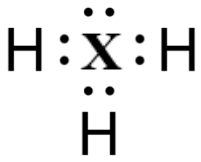
Which one of the following reactions will occur spontaneously?

A. copper + magnesium chloride solution
B. magnesium + zinc chloride solution
C. magnesium + sodium chloride solution
D. iron + lithium chloride solution

More reactive metals will displace less reactive metal ions. Magnesium (higher reactivity) will react with zinc chloride solution.

Question 11

The Lewis diagram below shows a compound formed by element X.



The identity of X and the shape of the molecule formed are, respectively

A. sulfur and V-shaped
B. nitrogen and tetrahedral
C. phosphorous and pyramidal
D. carbon and pyramidal

Phosporous has 5 valence electrons and forms molecule (like ammonia) with one lone pair, to form a pyramidal shape

Question 12

Which of the following liquids will be insoluble in water?

A. ethanol
B. propanoic acid
C. hydrochloric acid
D. hexane

Hexane is non-polar, thus insoluble in water.

Question 13

Nitrogen can form many different oxides. When analysing a sample of one of these oxides it is found that the number of mole of nitrogen is 0.346 and the number of mole of oxygen is 0.863.
The oxide is

A. NO
B. NO_2
C. N_2O_4
D. N_2O_5

Mole ratio N:O = 0.346 : 0.863 =>
Simplest ratio is 1 : 2.5 => 2 : 5
Thus formula is N_2O_5.

Question 14

Which molecule has the same empirical formula as molecular formula?

A. pentane
B. CH_3COOH
C. P_4O_{10}
D. pentene

Pentane has empirical formula same as molecular formula. C_5H_{12}

Question 15

The number of atoms in 0.50 mol of $CuSO_4$ is

A. 3
B. 6×10^{23}
C. 1.8×10^{24}
D. 9×10^{23}

0.50 mol $CuSO_4 \times 6 \times 10^{23} \times 6$ atoms in formula = approx 1.8×10^{24} atoms

Question 16

Which of one of the following statements is most correct when comparing compounds of the same homologous series.

Compounds in same the homologous series have similar chemical properties but different molecular formula/masses. The next molecule in sequence differs from the next by a CH_2

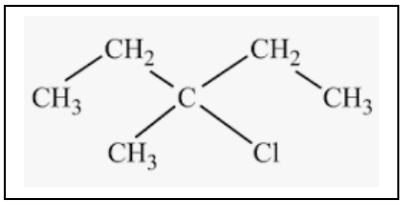
A. They have the same chemical properties

B. All compounds have the same molecular mass

C. All compounds have the same molecular formula

D. Options A and C are both correct.

Question 17



The IUPAC name for the molecule above is

A. 3-chlorobutanoic acid

B. 3-chloro-3-methylpentane

C. 3-ethyl-chlorobutane

D. 3-methyl,3,chloropentane

Question 18

Which of the following is a structural isomer of 2,2-dimethylpropane?

A. 2,3-dimethylbutane

B. 2-methylbutane

C. 2-methylpentane

D. hexane

Question 19

An organic molecule has the empirical formula CH_2O. Which is the formula mass of the compound given that 0.33 mol of this substance has a mass of 40.0 grams?

A. CH_2O

B. $C_3H_6O_3$

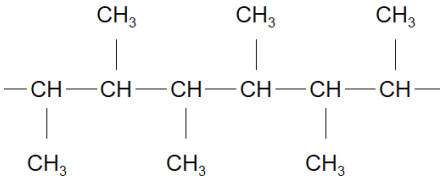
C. $C_2H_4O_2$

D. $C_4H_8O_4$

Molecular mass = mass / moles = 40 / 0.33 => approx 121 g/mol, for empirical CH_2O (30 g/mol) multiplied by 4 = $C_4H_8O_4$.

Question 20

A segment of a polymer is shown below



The monomer used to form this polymer is

A. propene
B. but-1-ene
C. 2,3-dimethylbutane
D. but-2-ene

END OF MULTIPLE-CHOICE QUESTIONS

SECTION B - Short-answer questions

Instructions for Section B

Questions must be answered in the spaces provided in this book.

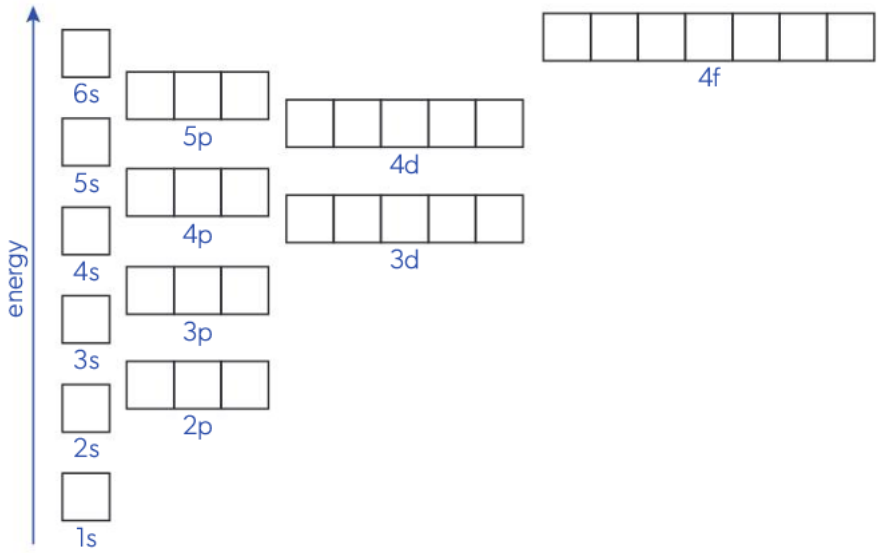
To obtain full marks for your responses you should

- Give simplified answers with an appropriate number of significant figures to all numerical questions; unsimplified answers will not be given full marks.
- Show all workings in your answers to numerical questions. No credit will be given for an incorrect answer unless it is accompanied by details of the working.

Make sure chemical equations are balanced and that the formulas for individual substances include an indication of state; for example, $H_2(g)$; NaCl(s)

Question 1 (5 marks)

a. The diagram below can be used to explain many aspects of the arrangement of electrons in atoms.



i. What aspect of electron configurations does each small square represent?

1 mark

1----- mark for naming an orbital as the square. Each small square represents one orbital, which can hold up to two electrons with opposite spins.

ii. How many orbitals are there in the 4f subshell and how many electrons can be placed there?

Number of orbitals: ___*7*___ Number of electrons: _____*14*__ 2 marks

iii. Use the squares provided on the diagram to show the electron configuration of nickel and to explain how this diagram informs you of the order of filling. 2 marks

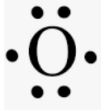
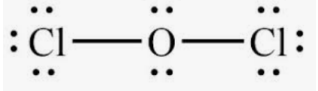
1-----mark for $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^8$
1-----mark 4s fills before 3d

Question 2 (7 marks)

a. A compound can be formed when oxygen and chlorine react.

i. In the space provided below, draw a Lewis diagram of each atom and use the diagrams to draw a Lewis structure of the likely compound that forms. 2 marks

1-----mark for correct drawing of Lewis dot structures of Cl and O
1-----mark for correct Lewis dot diagram of OCl_2

Chlorine	Oxygen	Compound formed
		

ii. Show the dipoles on the molecule. 1 mark

1-----mark clearly showing, dipoles on chlorine (δ+) to oxygen (δ−) because oxygen is more electronegative. Even though the periodic table shows the electronegativity of Cl to be 3.2 and O to be 3.0 Cl is a bigger atom and hence the dipole created is over a larger surface area reducing its capacity to attract electrons. Students may have linked that oxygen is one of the three atoms, nitrogen and fluorine being the other two, that forms hydrogen bonding when bonded to hydrogen and chlorine does not.

iii. Describe the shape of the molecule formed. 1 mark

"V" shaped

b. Consider the two molecules oxygen dichloride (OCl_2) with a boiling temperature of 2°C and water (H_2O) which boils at 100°C.

i. Briefly describe the intramolecular bonding found in both compounds. 1 mark

_1-----mark for stating "polar covalent" no extra detail was required ___
a number of students used the extra space provided to detail the reasons why polar covalent was present. This was not necessary. Just "covalent" was not accepted.

ii. Oxygen dichloride is a bigger molecule than water and yet it has a much lower boiling temperature. Explain why students would expect OCl_2 to have higher boiling point than H_2O and explain why in reality, H_2O has a greater boiling point than OCl_2. 2 marks

1-----mark OCl2 is a larger , so expected to have higher boiling point due to stronger Van der Waals forces.
1-----mark But water has higher boiling point due to hydrogen bonding, which is stronger than Van der Waals forces, hence more energy is needed to break the intermolecular forces.

Question 3 (8 marks)

a. Ammonium hydrogencarbonate is used in foods and in the production of pharmaceuticals

i. Write the chemical formula of ammonium hydrogencarbonate. 1 mark

_____*NH_4HCO_3*_____

ii. Determine the percentage composition of chalcopyrite ($CuFeS_2$). Show all working in the space provided below. 2 marks

1-----mark for correct molar mass.
1-----mark for correct percentage calculations

Molar mass Cu = 63.5, Fe = 55.8, S = 32
Molar mass = 63.5 + 55.8 + (2 × 32) = 183.3 g/mol
%Cu = (63.5 /183.3) × 100 = 34.64%
%Fe = (55.8 /183.3) × 100 = 30.44%
%S = (64 /183.3) × 100 = 34.92%

iii. Calculate the total number of atoms in 100 g of chalcopyrite. Show all working in the space provided below. 2 marks

1-----mark for calulating the mol of chalcopyrite.
Moles = 100 / 183.3 = 0.545 mol
1-----mark for calculating the total number of atoms.
Atoms per formula unit = 1 Cu + 1 Fe + 2 S = 4 atoms
Total atoms = 0.545 × 4 × (6.02×10^{23}) = 1.31×10^{24} atoms

b. A mining company discovered a deposit of the copper ore, malachite ($Cu_2CO_3(OH)_2$), in a neighbouring mine. Which site, the malachite or the chalcopyrite, is economically viable for extraction of copper? Justify your answer with a calculation. 3 marks

1-----mark for correctly working out the % of copper in malachite
1-----mark of comparing the percentage to chalcopyrite
1-----mark for suggesting based on the %difference of copper in each ore that malachite is the most economical site. An explanation as to the amount of ore extracted as aration of the amount by mass of copper extracted was needed for this mark.

Calculate copper percentage:
In chalcopyrite: 34.62% Cu
In malachite $Cu_2CO_3(OH)_2$
Molar mass
Cu = 63.5×2=127
C=12, O=16×3=48, OH=17×2=34
Total = 127+12+48+34=221 g/mol
%Cu = (127 /221) × 100 = 57.47%

Question 4 (6 marks)
The diagram below shows a representation of a lithium atom and a nitrogen atom.

a. Which atom has the greater atomic radius? Justify your answer. 2 marks

1-----mark Lithium has the greater radius.
1-----mark for a chemically correct justification.

eg. The core charge that both sets of valence electrons see is 2+ for lithium and 5+ for nitrogen. The greater core charge pulls the nitrogen's valence electrons closer to the nucleus giving it a smaller atomic radius to lithium whose valence electrons experience less pull towards the nucleus.

b. Lithium and fluorine can react to form a compound.

i. Give the shell electron configurations of lithium and fluorine after the reaction. 1 mark

1-----mark For the correct electronic configuration after the reaction.
$Li^+ = 1s^2$, $F^- = 1s^22S^22p^6$

ii. State the formula and name of this compound. 1 mark

formula: __*LiF*___ name: _____*Lithium fluoride*_____

iii. Describe the properties of this compound by circling the correct response in the table below. 2 marks

Students needed to remember that a reaction between a metal and a non-metal produces an ionic compound. The properties chosen needed to reflect this.

Property	Response
Electrical conductivity	In the solid state In the liquid state In the gas state
Behaviour under high impact	Malleable Brittle Turns to liquid

Question 5 (11 marks)

A student is investigating a set of chemical reactions.

The student's tests and observations are shown below.

Test	**Reactants**	**Observations**
1	magnesium and oxygen are heated	magnesium ignites quickly and burns vigorously producing a white powder
2	butane gas (C_4H_{10}) is burnt in excess oxygen at room temperature.	A great deal of heat is formed with the production of carbon dioxide and water.
3	hydrogen gas (H_2) and nitrogen gas (N_2) are mixed and ignited	a strong smell of ammonia (NH_3) gas is noticed after the reaction is complete and is the only product.
4	calcium chloride and sodium nitrate solutions	no reaction
5	calcium chloride and sodium carbonate solutions	a white precipitate forms

a. Write balanced equations for the reactions occurring in tests 1 and 2. States included.

1-----mark for correct states and formulae
1-----mark for balanced

1. ___*$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$*_____ 2 marks

2. ___*$2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(l)$* _____ 2 marks

b. A further test shows calcium reacts more vigorously in water than magnesium. Using the relative position of each metal in the periodic table, discuss the nature of metal reactivity. In your response refer to what determines metal reactivity and whether the relative reactivity can be predicted. 3 marks

Calcium is above magnesium in the periodic table and loses its outer electrons more easily due to lower ionization energy.
Metal reactivity depends on how easily an atom loses electrons to form positive ions.
Because calcium has fewer energy shells and weaker nuclear attraction to its valence electron, it reacts more vigorously with water.
Reactivity trends in groups and periods allow prediction of relative reactivities.

c. Write an overall equation and a partial ionic equation for reaction 5 in the table. 2 marks

1-----mark for correct formulas and states
1-----mark for balanced equation.

overall equation : _____*$CaCl_2(aq) + Na_2CO_3(aq) \rightarrow CaCO_3(s) + 2NaCl(aq)$*____

net ionic equation: _____ *$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s)$*

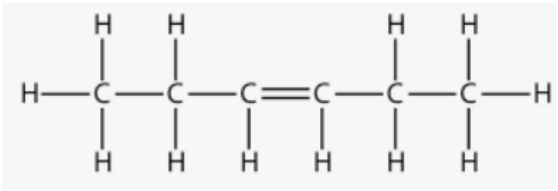
d. Explain how you can predict whether a reaction will occur in the final two tests. In your response, refer to the student results. 2 marks

1-----mark in reaction 4 both products are soluble according to the 2026 data booklet page 10 item 28 solubility table.
1-----mark in reaction 5 the product calcium carbonate is insoluble according to the solubility table in the 2026 data booklet ad hence a precipitate is produced.

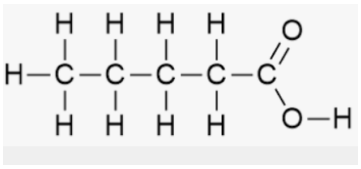
Question 6 (8 marks)

a. In the boxes below, draw structural diagrams of

i. hex-3-ene **ii**. pentanoic acid 2 marks

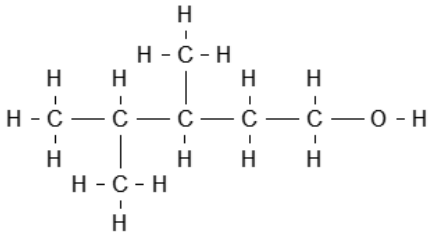


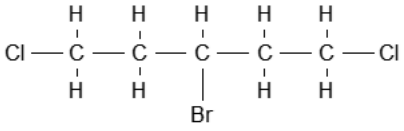
1-----mark for correct structure with all atoms and bonds shown correctly



1-----mark for correct structure with all atoms and bonds shown correctly

b. Write the systematic name of 2 marks

i. 

ii. 

3,4-dimethylpentan-1-ol *3-bromo-1,5-dichloropentane*

1-----mark for correctly naming each compound according to IUPAC protocol.

c. Draw and name a branched structural isomer of but-2-ene. 2 marks

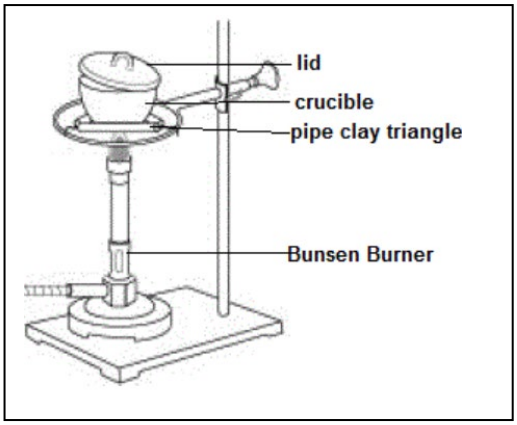
1-----mark for any correct structure of any isomer with 4 carbons and a C=C bond.
1-----mark for correct name

d. Both ethanol and ethanoic acid are polar molecules with the dominant intermolecular force being that of hydrogen bonding, but the boiling point of ethanoic acid is significantly higher than ethanol. Explain why. 2 marks

*1-----mark Ethanoic acid forms **dimers** via two hydrogen bonds, making its intermolecular forces stronger. Ethanol only forms single hydrogen bonds.*
1-----mark Therefore, ethanoic acid requires more energy to break the intermolecular bonds than ethanol hence it has a higher boiling point.

Question 7 (13 marks)

A student performed an experiment to calculate the empirical formula of magnesium oxide. The experimental setup is shown on the right.



Results and calculations

Item weighed	Mass (g)
Crucible + lid	24.836
Crucible + lid + Mg (before heating)	25.112
Crucible + lid + product (after heating)	25.250

a. Calculate the empirical formula from the data obtained by the student given in the table above. 4 marks

1-----mark => Find the mass of Mg and O
Mass of Mg = (25.112 - 24.836) = 0.276 g
Mass of M = (25.250 - 25.112) = 0.138 g
1-----mark => convert to mol
Moles Mg = 0.276 / 24.3 = 0.01136 mol
Moles O = 0.138 / 16 = 0.008625 mol
1-----mark => Find the simplest mol ratio
Mg : O = 0.01136 : 0.008625
=>1.32 : 1
1-----mark => multiply by 3 to convert to whole numbers
Mg_4O_3

b. Before the experiment, the student predicted that the empirical formula of magnesium oxide would be MgO.

i. What chemical knowledge did the student use to make their prediction that the empirical formula of magnesium oxide would be MgO. 1 mark

1-----mark => Mg^{2+} and O^{2-} => MgO

ii. How did the student derived empirical formula of magnesium oxide differ from their expected empirical formula? Clearly explain a possible error that may have occurred to justify the student's final outcome. 3 marks

1-----mark for suggesting that the ratio of magnesium to oxygen is higher at Mg4 : O3.
1-----mark for an error that could have resulted in a greater amount of magnesium being measured or a lower amount of oxygen being measured. Eg. A greater loss of MgO as a result of leaving the lid open, thus resulting in lower amount of oxygen. Or incomplete combustion of Mg. Any error mentioned must result in the ratio derived by the student and not a 1:1 as predicted.
1-----mark clear explanation how this error caused the results of more mol of Ma than mol of O.

c. Explain why the experimental setup shows the crucible lid slightly open during heating. 1 mark

1-----mark The lid is slightly open to allow oxygen gas in for reaction, but minimize loss of magnesium oxide powder

d. A student suggested that the lid be kept completely open at all times during heating.
i. Describe how this would impact the final calculation of the empirical formula by circling the possible outcome from the list below. 1 mark

MgO, MgO_2, Mg_2O

ii. Justify your answer to question i. above. 2 marks

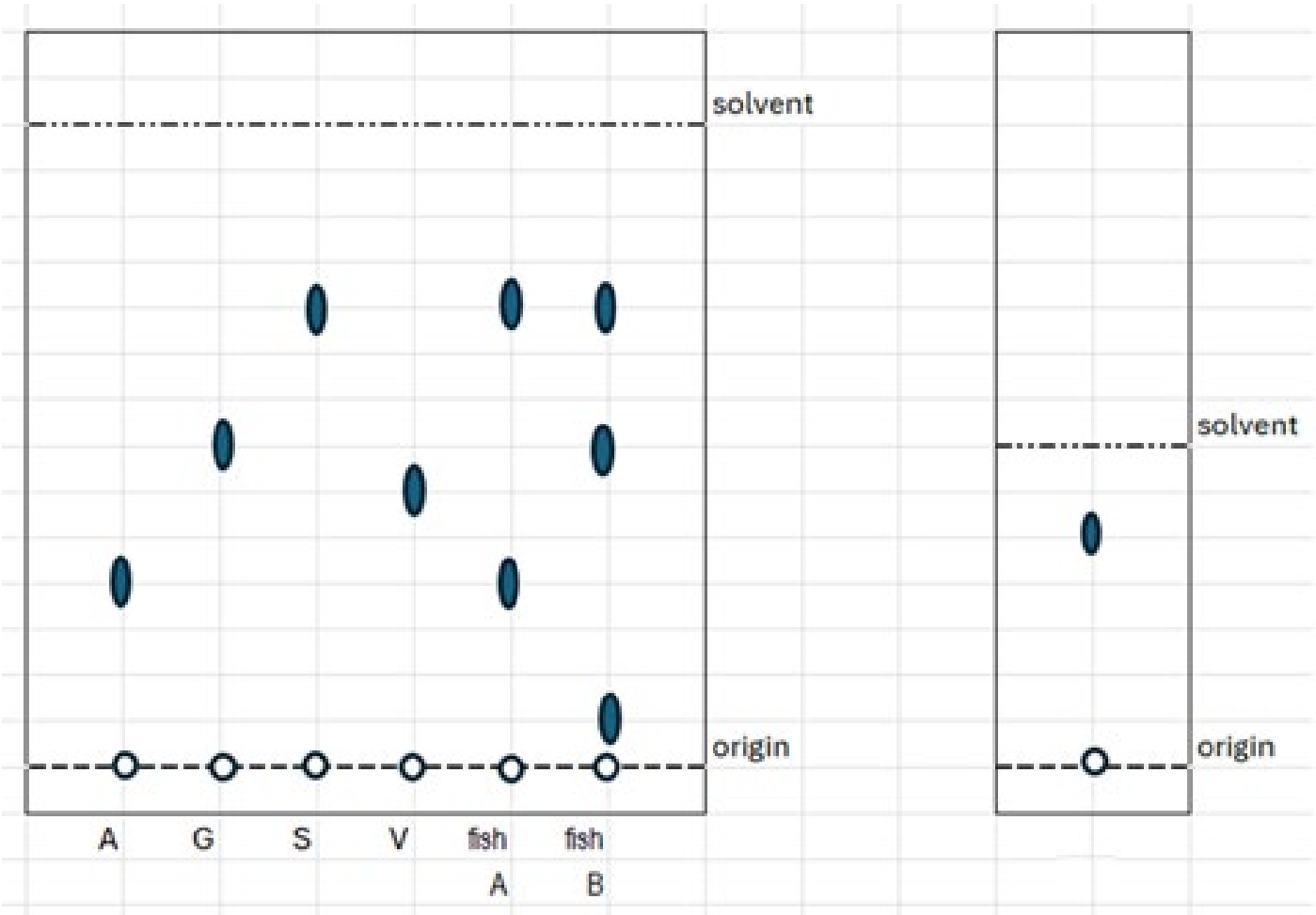
1-----mark More MgO would be lost if the lid remained open.
1-----mark The final mass of MgO would indicate a lower mol of oxygen was used hence the ratio would favour more Mg present relative to O. Hence Mg_2O

e. The method required the student to repeat the steps, heating , cooling and weighing, several times before recording the final mass. Explain why. 1 mark
1-----mark Any suggestion that states that this ensures the reaction is complete and no further mass gain is taking place.

Question 8 (8 marks)

Fish are considered a rich source of amino acids, the building blocks required for the body to produce proteins. The thin layer chromatograms below show an analysis of two fish samples for four particular amino acids. The solvent used is ethanol.

Student A: chromatogram 1 Student B: chromatogram 2



A = alanine G = glycine S = serine V = valine

a. What conclusions can you draw from chromatogram 1 about:

i. Fish A 1 mark

_____*contains alanine and serine*_____

ii. Fish B 1 mark

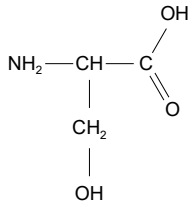
_____ *contains glycine and serine or contains other material that is not soluble in ethanol as there is a significant spot still present at the origin*

b. With reference to the 2026 data booklet, explain why alanine and glycine produce different spots on the chromatogram.

2 marks

1-----mark => for describing any difference in structure. Either by writing or drawing. Alanine has a non-polar CH_3 group off carbon number 2 whilst glycine has a H.
1-----mark => For describing the impact of this difference in structure to the solubility of alanine and glycine in the mobile phase (ethanol).

c. The structure of serine is shown below.



Will you expect serine to be more soluble in a polar or non-polar solvent? Justify your answer. 2 marks.

1-----mark => for describing the strong polar nature of serine. Eg NH_2 OH and COOH .

1-----mark => Hence the strong hydrogen bonding exhibited by serine is best suited to strong interactions between polar molecules, hence a more polar molecule is best suited to dissolve serine.

d. Student B ran a different chromatogram under exactly the same conditions as student A. Identify the amino acid that student B analysed. Justify your answer with a calculations.

2 marks

1-----mark for identifying an amino acid present in both(serine)
1-----mark for supporting this with an R_f calculation of both amino acids which should be exactly the same. (0.714)

Question 9 (4 marks)
Analysis of an unknown molecular compound was found to contain only carbon, hydrogen, sulfur, and oxygen. Analysis of the compound shows it has the following percentage composition by mass:

- Carbon = 40.0%
- Hydrogen = 6.7%
- Sulfur = 26.7%
- Oxygen = 26.6%

a. Find the empirical formula for this compound. 2 marks

1-----mark Assume 100 g sampleand find the mol of each element:
C: 40.0 g / 12 = 3.33 mol
H: 6.7 g / 1 = 6.7 mol
S: 26.7 g / 32 = 0.834 mol
O: 26.6 g / 16 = 1.66 mol
1-----mark find the simplest ratio
Divide by smallest (0.834):
C: 3.33 / 0.834 = 4
H: 6.7 / 0.834 = 8
S: 0.834 / 0.834 = 1
O: 1.66 / 0.834 = 2
Empirical formula: $C_4H_8SO_2$

b. Given that 4.800 grams of this substance contains 1.204 X 10^{22} molecules, find the molecular formula.
2 marks

1-----mark for finding the molar mass.
=> Molar mass of formula mass = 4.800 grams / 0.0200 = 240g/mol
1-----mark find the molecular formula
=> molecular formula mass / empirical formula mass = 240 =120 =2
=> molecular formula = $C_8H_{16}S_2O_4$

End of assessment task