Name: _____

Teacher: _____

NORTH SYDNEY GIRLS HIGH SCHOOL

2024

Year 11

Assessment Task 3

Chemistry

General Instructions

- Reading Time – 5 minutes
- Working Time – 2 hours
- Write using black pen
- Draw diagrams using pencil
- Board-approved calculators may be used
- **Write your name and your teacher's name at the top of this booklet AND the multiple choice answer sheet**

Total Marks – 70

Weighting – 40 %

Section I 15 Marks

- Attempt Questions 1 – 15
- Allow about 26 minutes for this section

Section 2 55 Marks

- Attempt question 16 – 27
- Allow about 94 minutes for this section

Write your answers in the space provided. Adequate lines have been provided. Additional writing space is provided on the last page.

Section 1 **15 marks**

Attempt Questions 1 – 15
Allow about 26 minutes for this section

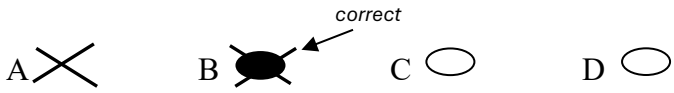
Use the multiple-choice answer sheet provided for Questions 1-15. If you must use blank paper instead, clearly indicate an answer of EITHER A, B, C or D for each question from 1-15.

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

If you have changed your mind and have crossed out what you consider to be the correct answer, then indicate this by writing the word *correct* and drawing an arrow as follows:



1. What trend is observed in atomic radius across a period in the periodic table?

A. Atomic radius increases as you move from left to right.

B. Atomic radius decreases as you move from left to right.

C. Atomic radius remains constant across a period.

D. Atomic radius fluctuates with no clear trend.

2. Which type of bond is expected between atoms with the greatest difference in electronegativity?

A. Metallic bond

B. Non-polar covalent bond

C. Polar covalent bond

D. Ionic bond

3. Which of the following atoms has the highest electronegativity?

A. Fluorine

B. Oxygen

C. Nitrogen

D. Chlorine

4. What is the concentration of a solution prepared by dissolving 0.5 moles of NaCl in 2 litres of water?

A. 0.25 mol L^{-1}

B. 0.50 mol L^{-1}

C. 1.00 mol L^{-1}

D. 2.00 mol L^{-1}

5. If 2 moles of nitrogen gas (N_2) react with 6 moles of hydrogen gas (H_2) to form ammonia (NH_3), how many moles of ammonia are produced?

A. 1 mole

B. 2 moles

C. 3 moles

D. 4 moles

6. A 1.0 L sample of gas at 300 K and 1 atm is compressed to 0.5 L. The vessel remains at a constant temperature. What is the new pressure?

A. 0.5 atm

B. 1 atm

C. 2 atm

D. 3 atm

7. What is the empirical formula of a compound with 40% carbon, 6.7% hydrogen, and 53.3% oxygen by mass?

A. CHO

B. CH_2O

C. $C_2H_4O_2$

D. C_2HO_2

8. Which of the following statements about Avogadro's law is correct?

A. Equal volumes of gases contain equal numbers of molecules at the same temperature and pressure.

B. Equal masses of gases contain equal numbers of molecules.

C. The volume of a gas is inversely proportional to the number of moles.

D. The pressure of a gas is directly proportional to the number of moles.

9. Which of the following metals is least reactive with water?

A. Sodium

B. Magnesium

C. Potassium

D. Calcium

10. Which of the following correctly defines a redox reaction?

A. A reaction in which energy is absorbed

B. A reaction involving the transfer of protons

C. A reaction involving the transfer of electrons

D. A reaction that results in the formation of a precipitate

11. In the reaction:

$$MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$

Which element is reduced?

A. Manganese

B. Iron

C. Hydrogen

D. Oxygen

12. What is the effect of increasing the concentration of an aqueous reactant on the rate of reaction?

A. Decreases the rate of reaction

B. Increases the rate of reaction

C. Has no effect on the rate of reaction

D. Decreases the activation energy

13. Which of the following statements is true regarding entropy (S)?

A. Entropy always decreases in a spontaneous reaction

B. Entropy is a measure of the disorder of a system

C. Entropy is the energy required to start a reaction

D. Entropy remains constant in all chemical reactions

14. If a reaction has a positive enthalpy change (ΔH) and a negative entropy change (ΔS), what can be inferred about the spontaneity of the reaction?

A. The reaction is spontaneous at all temperatures.

B. The reaction is non-spontaneous at all temperatures.

C. The reaction is spontaneous only at high temperatures.

D. The reaction is spontaneous only at low temperatures.

15. 1.50 litres of 1.85 mol L^{-1} sodium carbonate solution was allowed to react with 1.25 L of 2.00 mol L^{-1} calcium nitrate solution to form a white precipitate. The reaction proceeded to completion. This precipitate was filtered and dried. After drying, the white solid was decomposed to release a gas which was collected and stored at 35.5^{o} C and 250 kPa.

Calculate the volume of the stored gas in litres.

A. 25.7

B. 28.5

C. 51.2

D. 56.9

Section 2 **55 marks**

Attempt Questions 16 – 27
Allow about 94 minutes for this section

Please write all answers clearly in the spaces provided and show ALL working. The number of lines indicates the expected length of your response.

Question 16 (3 marks)

Write the correct IUPAC name for each of the three compounds below.

	Formula	Name
a)	$Fe_2(SO_4)_3$	
b)	PCl_5	
c)	SiO_2	

Question 17 (5 marks)

a) Draw the Lewis dot diagram for hydrogen sulfide (H_2S). **2**

b) Explain why the hydrogen sulfide molecule is classified as polar. **3**

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Question 18 (3 marks)

Lustrous magnesium strips were mixed with powdered yellow sulfur. When the mixture was heated, a white solid formed. On cooling, it remained as a white solid. When heated again, it underwent no apparent change. When the experiment was repeated several times using different masses of magnesium strips and sulfur, the white solid always contained 43% magnesium.

Was the white solid a mixture or a compound? Justify your answer.

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Question 19 (3 marks)

a) Write an equation for the reaction of sulfuric acid and magnesium. **1**

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b) Calculate the mass of magnesium that would react completely with 100 mL of 0.50 mol L^{-1} sulfuric acid solution. **2**

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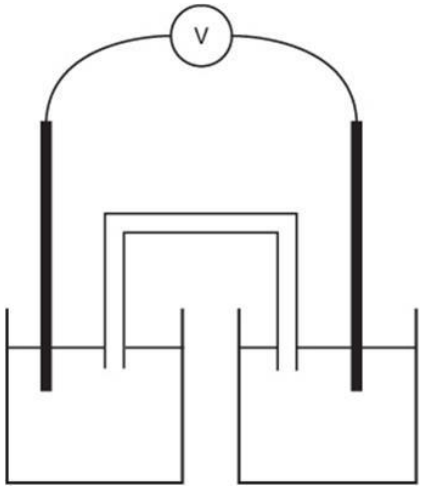
Question 20 (7 marks)

The diagram below shows a Zn | Zn^{2+} || Ag^{+} | Ag galvanic cell under standard conditions.



a) **On the diagram**, label the anode, cathode, direction of electron flow, and direction of ion movement in the salt bridge. **3**

b) Write both the half-cell reactions for the cell AND the net ionic equation for the reaction. **2**

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c) Predict the voltage of this cell under standard conditions. **1**

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d) State one observation you would expect to make in the cathode half-cell after the galvanic cell has operated for a few hours. **1**

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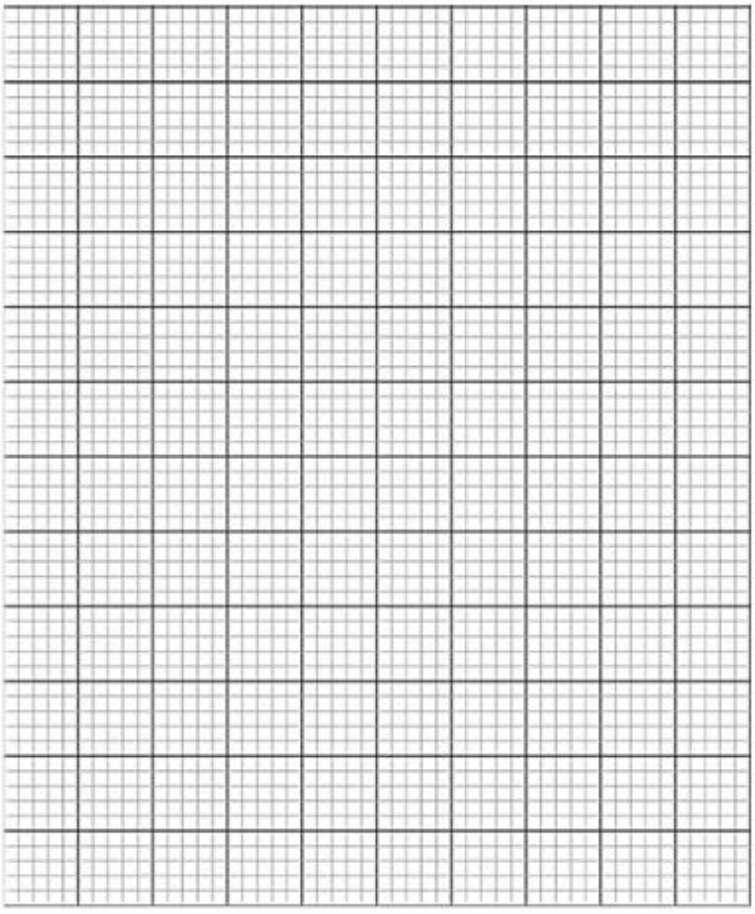
Question 21 (7 marks)

A student measured the pressure generated at 65°C in a cylinder of fixed volume by different masses of different gases. The results are shown in the table below.

GAS USED	SO_2	NO	HCl	CO_2	NH_3
MASS OF GAS (g)	4.50	3.00	4.20	6.00	2.50
PRESSURE (kPa)	170	281	326	383	414

The student wanted to graph pressure against the number of moles of gas in order to confirm the ideal gas law.

a) Draw an appropriate graph for the student on the grid below, including a line of best fit. **4**



b) Explain whether the student was successful in confirming the ideal gas law. **3**

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QUESTION 22 BEGINS ON THE NEXT PAGE

Question 22 (4 marks)

The following reaction can result in an explosion when potassium chlorate powder is decomposed, rather than larger chunks of potassium chlorate.

$$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$$

Using collision theory, explain how increasing the surface area of potassium chlorate (by using the powdered form) increases the rate of reaction.

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Question 23 (5 marks)

The table below shows the boiling point, melting point, electrical conductivity in the solid state, and electrical conductivity in the liquid state for three substances: A, B and C. One of the unknown substances is a covalent molecular compound, one is a covalent network compound, and one is an ionic compound.

Property	Substance A	Substance B	Substance C
Boiling Point (°C)	153	1412	3600
Melting Point (°C)	146	714	1700
Electrical Conductivity (Solid State)	None	None	None
Electrical Conductivity (Liquid State)	None	High	None

Identify the substance A, B or C most likely to belong to each category. Justify your answer with reference to the bonding present in each substance.

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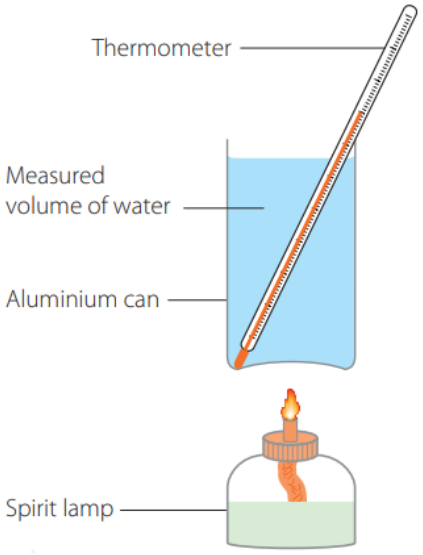
Question 24 (8 marks)

The apparatus in the figure below was used to measure the molar heat of combustion of methanol (CH_3OH). An aluminium drink container with its top cut out was suspended above the burner with a clamp in a retort stand. The thermometer was used to gently stir the water, so that it was not touching the bottom of the can. The table below shows the data collected from the experiment.



Initial mass of spirit burner (g)	160.00
Final mass of spirit burner (g)	158.90
Mass of water in container (g)	200.00
Initial temperature of water (°C)	20.0
Final temperature of water (°C)	32.0

a) Calculate the molar heat of combustion of methanol in kJ mol^{-1}. **3**

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b) Calculate the percentage error in the experiment (theoretical value = 726 kJ mol^{-1}). **1**

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c) Outline TWO ways in which the accuracy of the experiment could be improved. **2**

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d) Assess the reliability of the experiment. **2**

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QUESTION 25 BEGINS ON THE NEXT PAGE

Question 25 (3 marks)

The equation below shows the reaction of methyl chloride with water to produce methanol and hydrogen chloride.

$$CH_3Cl(g) + H_2O(g) \rightarrow CH_3OH(g) + HCl(g)$$

The bond energies for the relevant bonds are provided below.

Bond	Bond Energy (kJ mol^{-1})
C–Cl	338
O–H	463
C–O	358
H–Cl	431
C–H	412

Calculate the change in enthalpy for the reaction and hence determine whether the reaction is exothermic or endothermic.

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Question 26 (4 marks)

Consider the equation given below.

$$2C(s) + H_2(g) \rightarrow C_2H_2(g)$$

Use the following equations and their enthalpies to calculate the enthalpy of reaction for the reaction given above at the same temperature and pressure, and hence determine whether this reaction is exothermic or endothermic.

Reaction	ΔH (kJ mol^{-1})
$C(s) + O_2(g) \rightarrow CO_2(g)$	-393.5
$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$	-285.8
$C_2H_2(g) + \frac{5}{2}O_2(g) \rightarrow 2CO_2(g) + H_2O(l)$	-1299.5

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Question 27 (3 marks)

The process below shows diamond returning to carbon's standard state, graphite.

$$2C(s)_{\text{diamond}} \rightarrow 2C(s)_{\text{graphite}}$$

Using the information provided below, determine whether the process is spontaneous under laboratory conditions.

$\Delta H_f^\circ(C(s)_{\text{diamond}}) = 1.9 \text{ kJ mol}^{-1}$

$S°(C(s)_{\text{diamond}}) = 2.38 \text{ J mol}^{-1} \text{ K}^{-1}$

$S°(C(s)_{\text{graphite}}) = 5.74 \text{ J mol}^{-1} \text{ K}^{-1}$

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END OF EXAM. EXTRA WRITING SPACE PROVIDED ON THE NEXT PAGE.

EXTRA WRITING SPACE. CLEARLY INDICATE INSIDE YOUR EXAM BOOKLET IF THIS SPACE IS USED FOR A PARTICULAR QUESTION.

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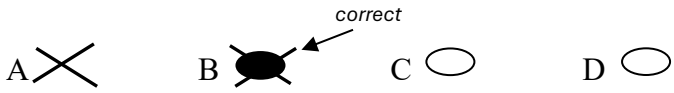

1. What trend is observed in atomic radius across a period in the periodic table?

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2. Which type of bond is expected between atoms with the greatest difference in electronegativity?

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C. Polar covalent bond

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3. Which of the following atoms has the highest electronegativity?

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B. Oxygen

C. Nitrogen

D. Chlorine

4. What is the concentration of a solution prepared by dissolving 0.5 moles of NaCl in 2 litres of water?

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A. 1 mole

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7. What is the empirical formula of a compound with 40% carbon, 6.7% hydrogen, and 53.3% oxygen by mass?

A. CHO

B. CH_2O

C. $C_2H_4O_2$

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8. Which of the following statements about Avogadro's law is correct?

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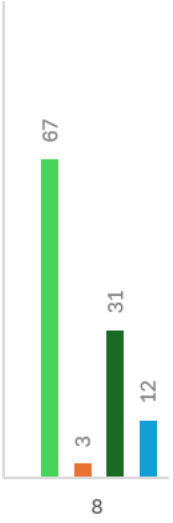
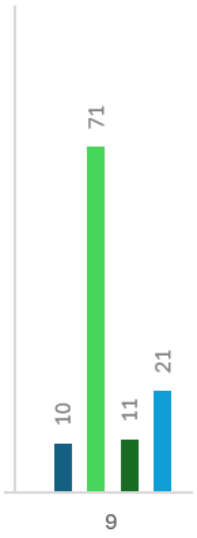


9. Which of the following metals is least reactive with water?



A. Sodium

B. Magnesium

C. Potassium

D. Calcium

10. Which of the following correctly defines a redox reaction?

A. A reaction in which energy is absorbed

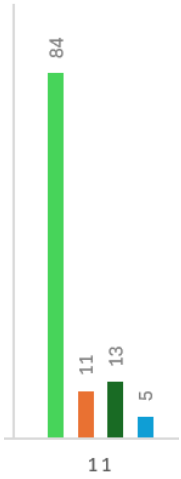
B. A reaction involving the transfer of protons

C. A reaction involving the transfer of electrons

D. A reaction that results in the formation of a precipitate

11. In the reaction:

$$MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$



Which element is reduced?

A. Manganese

B. Iron

C. Hydrogen

D. Oxygen

12. What is the effect of increasing the concentration of an aqueous reactant on the rate of reaction?

A. Decreases the rate of reaction

B. Increases the rate of reaction

C. Has no effect on the rate of reaction

D. Decreases the activation energy

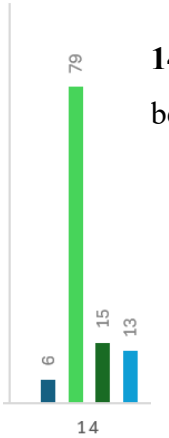
13. Which of the following statements is true regarding entropy (S)?

A. Entropy always decreases in a spontaneous reaction

B. Entropy is a measure of the disorder of a system

C. Entropy is the energy required to start a reaction

D. Entropy remains constant in all chemical reactions



14. If a reaction has a positive enthalpy change (ΔH) and a negative entropy change (ΔS), what can be inferred about the spontaneity of the reaction?

A. The reaction is spontaneous at all temperatures.

B. The reaction is non-spontaneous at all temperatures.

C. The reaction is spontaneous only at high temperatures.

D. The reaction is spontaneous only at low temperatures.

15. 1.50 litres of 1.85 mol L^{-1} sodium carbonate solution was allowed to react with 1.25 L of 2.00 mol L^{-1} calcium nitrate solution to form a white precipitate. The reaction proceeded to completion. This precipitate was filtered and dried. After drying, the white solid was decomposed to release a gas which was collected and stored at 35.5° C and 250 kPa.

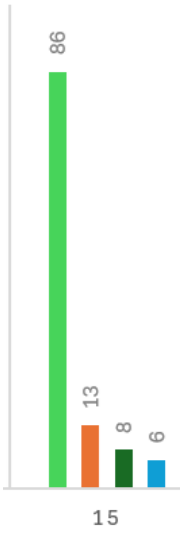
Calculate the volume of the stored gas in litres.

A. 25.7

B. 28.5

C. 51.2

D. 56.9



Section 2 **55 marks**

Attempt Questions 16 – 27
Allow about 94 minutes for this section

Please write all answers clearly in the spaces provided and show ALL working. The number of lines indicates the expected length of your response.

Question 16 (3 marks)

Write the correct IUPAC name for each of the three compounds below.

	Formula	Name
a)	$Fe_2(SO_4)_3$	Iron(III) sulfate
b)	PCl_5	Phosphorus pentachloride
c)	SiO_2	Silicon dioxide

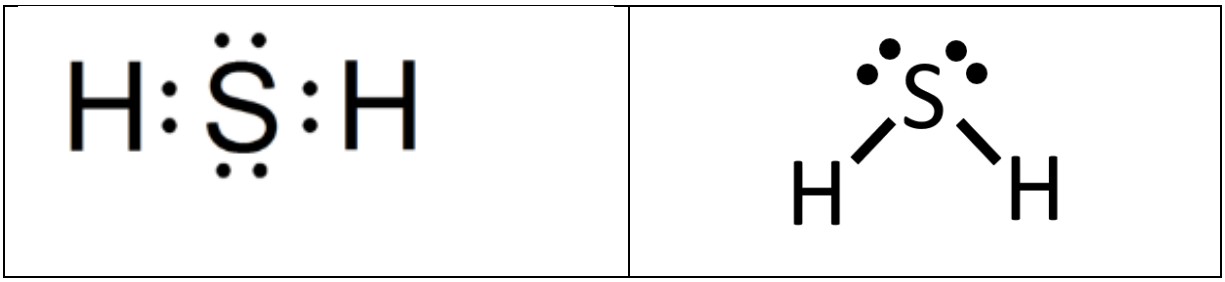
Well answered. Most common mistake was leaving out the (III) in iron (III) sulfate.

Question 17 (5 marks)

a) Draw the Lewis dot diagram for hydrogen sulfide (H_2S). **2**

Anything similar to below. Bent structure does not need to be shown in Lewis dot.

-1 mark per error.



b) Explain why the hydrogen sulfide molecule is classified as polar. **3**

electronegativity difference between sulfur and hydrogen (1 mark)

leads to uneven distribution of electrons between H and S / bond is polar / partial negative charge on S and partial positive charge on H (1 mark)

two lone pairs on sulfur mean that there is bent molecular shape which causes asymmetrical dipole moment (1 mark)

Marker notes/common errors:

- You must relate the polar bonds to the shape of the molecule. CO_2 has polar bonds but is not a polar molecule… this difference is key to explaining this question.
- This question was **NOT** about intermolecular forces. Many students noted that this substance would have 'dipole-dipole forces and thus it is a polar molecule'. While it is true that it will have dipole-dipole forces, this is circular logic and does not relate to what the question is asking.
- Do not say there is a 'dipole' at sulfur… 'di-pole' means a pair of equal and oppositely charged poles. Sulfur has a partial negative charge.

Question 18 (3 marks)

Lustrous magnesium strips were mixed with powdered yellow sulfur. When the mixture was heated, a white solid formed. On cooling, it remained as a white solid. When heated again, it underwent no apparent change. When the experiment was repeated several times using different masses of magnesium strips and sulfur, the white solid always contained 43% magnesium.

Was the white solid a mixture or a compound? Justify your answer.

Identifies that white solid is a compound (1 mark)

Compounds have fixed ratios by mass, fixed composition of 43% magnesium indicates compound, not mixture (1 mark)

Other relevant justification i.e., new substance has a different colour indicating chemical change, heating or cooling a mixture would change the composition due to differences in phases (melting point) (1 mark)

Question 19 (3 marks)

a) Write an equation for the reaction of sulfuric acid and magnesium. **1**

$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq \text{ or } s) + H_2(g)$

b) Calculate the mass of magnesium that would react completely with 100 mL of 0.50 mol L^{-1} sulfuric acid solution. **2**

Moles of H_2SO_4 = (0.50 mol L^{-1}) x (0.1 L) = 0.05 mol → Mg required = 0.05 mol (1:1 ratio from balanced equation) (1 mark)

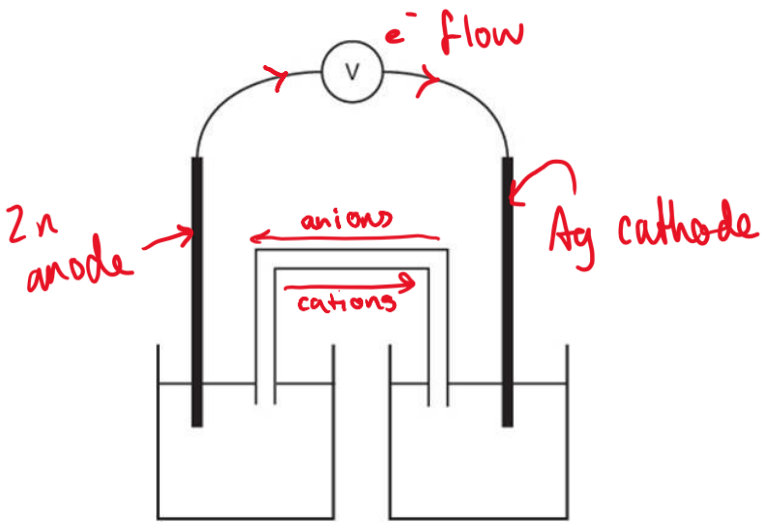
Mass of Mg = 0.05 mol x 24.31 g/mol = 1.22 g (1 mark)

Marker notes:

- Revise sig. figs. The lowest number of significant figures is found from the concentration of sulfuric acid (0.50 mol L^{-1}). The 0 before does not affect the accuracy of the values. Remember that the purpose of significant figures is to ensure that we are reporting to the value to most accurate possible from our information. The s.f. is 2.
- Some students calculated the mass of H_2SO_4 to be the final mass required. Ensure that you read the question carefully. If it is asking for the mass of magnesium, that is what you should be using in your n = m/MM equation.

Question 20 (7 marks)

The diagram below shows a Zn | Zn^{2+} || Ag^{+} | Ag galvanic cell under standard conditions.



a) **On the diagram**, label the anode, cathode, direction of electron flow, and direction of ion movement in the salt bridge. **3**

Correctly labeled anode and cathode (1 mark) – metals needed to be included.

Correct direction of electron flow (1 mark)

Correct ion movement in the salt bridge (1 mark) – both +ve and -ve needed.

b) Write both the half-cell reactions for the cell AND the net ionic equation for the reaction. **2**

$Zn \rightarrow Zn^{2+} + 2e^{-}$

$Ag^{+} + e^{-} \rightarrow Ag$ (1 mark)

Net ionic equation: $Zn + 2Ag^{+} \rightarrow Zn^{2+} + 2Ag$ (1 mark)

c) Predict the voltage of this cell under standard conditions. **1**

0.76 V + 0.80 V = 1.56 V

d) State one observation you would expect to make in the cathode half-cell after the galvanic cell has operated for a few hours. **1**

Silver metal forms at cathode (1 mark)

Other answers were not accepted. It is not reasonable to expect to observe concentration changes (both solutions are colourless) or ion flow rate changes.

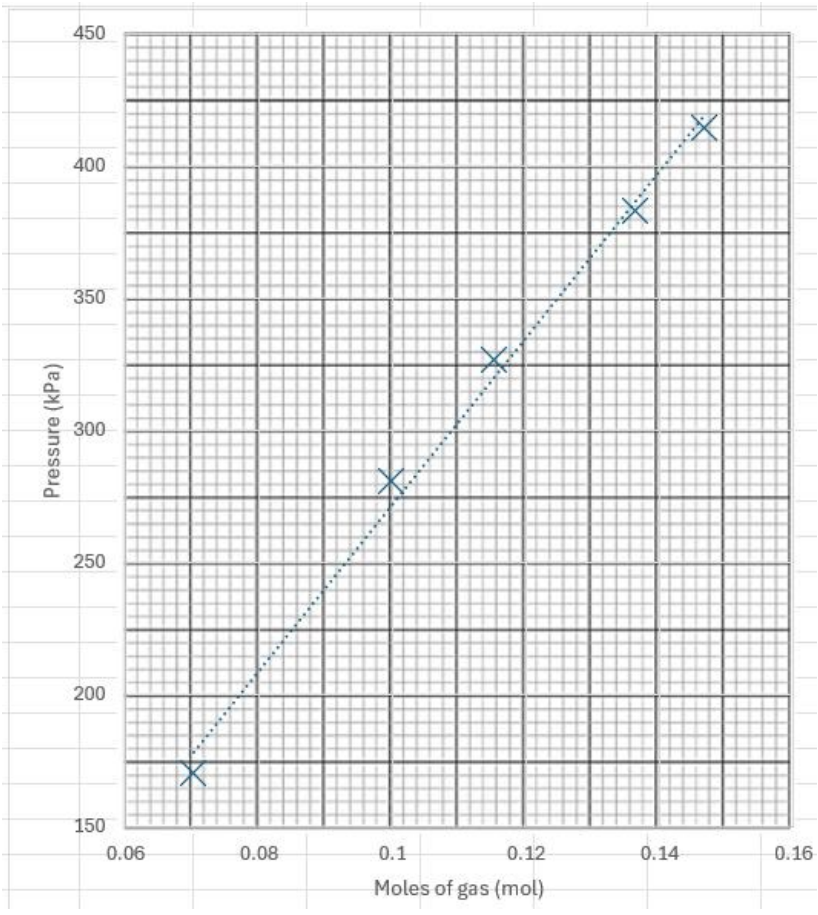
Question 21 (7 marks)

A student measured the pressure generated at 65°C in a cylinder of fixed volume by different masses of different gases. The results are shown in the table below.

GAS USED	SO_2	NO	HCl	CO_2	NH_3
MASS OF GAS (g)	4.50	3.00	4.20	6.00	2.50
PRESSURE (kPa)	170	281	326	383	414
MOLES (mol)	0.070	0.099	0.115	0.136	0.147

The student wanted to graph pressure against the number of moles of gas in order to confirm the ideal gas law.

a) Draw an appropriate graph for the student on the grid below, including a line of best fit. **4**



One mark per:

- axis labels (A)	- appropriate scale (S)
- correct plot (P)	- line of best fit (L)

b) Explain whether the student was successful in confirming the ideal gas law. **3**

They were successful (1 mark)

Ideal gas law: P/n = RT/V where RT/V is constant (1 mark) (needed to distinguish between ideal gas law and other laws eg Avogadro's Law – stating the formula was sufficient)

Gradient (pressure/number of moles) demonstrates linear relationship OR direct proportionality which confirms the above (1 mark)

Some students did not read the question closely and plotted mass rather than number of moles. Some students plotted moles to fewer sig figs than was reasonable. Marking was lenient here but please be careful in future.

QUESTION 22 BEGINS ON THE NEXT PAGE

Question 22 (4 marks)

The following reaction can result in an explosion when potassium chlorate powder is decomposed, rather than larger chunks of potassium chlorate.

$$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$$

Using collision theory, explain how increasing the surface area of potassium chlorate (by using the powdered form) increases the rate of reaction.

4 marks- makes explicit reference to all of the following:

- Increased surface area of powder exposes *more particles to collisions*
- This leads to more frequent collisions between particles
- Therefore a higher chance of successful (correct orientation/sufficient energy) collisions per second
- therefore increased rate of reaction

No need for definition. It will not gain any marks.

It is the PARTICLE collision theory.....the collisions are between particles....not surfaces

The proportion/percentage of successful collisions will not increase but the number will

Collision theory is not specific to molecules

This has nothing to do with space

You must relate increased frequency of collisions to increased likelihood of successful collisions. Just because there are more collisions, doesn't mean they will all be successful.

Oxygen is a product not a reactant.

The potassium chlorate is not reacting with air!

You MUST relate increased surface area to increased number of particles. Not enough just to say increased surface area leads to increased frequency of collisions. The question has given you that information already.....it is asking you why?

You don't know whether orientation is a requirement here so don't answer about that on its own.

Try to use chem terminology: more particles= increased number of reactant particles

More collisions= increased frequency of collisions

Question 23 (5 marks)

The table below shows the boiling point, melting point, electrical conductivity in the solid state, and electrical conductivity in the liquid state for three substances: A, B and C. One of the unknown substances is a covalent molecular compound, one is a covalent network compound, and one is an ionic compound.

Property	Substance A	Substance B	Substance C
Boiling Point (°C)	153	1412	3600
Melting Point (°C)	146	714	1700
Electrical Conductivity (Solid State)	None	None	None
Electrical Conductivity (Liquid State)	None	High	None

Identify the substance A, B or C most likely to belong to each category. Justify your answer with reference to the bonding present in each substance.

5	Correctly identifies all 3 compounds Justifies all 3 conclusions with reference to bonding present in the respective substance
4	Correctly identifies all 3 compounds With 2 valid justifications for conclusions with reference to bonding present in the respective substance
3	Correctly identifies all 3 compounds With 1 valid justification for conclusions with reference to bonding present in the respective substance
2	Correctly identifies all 3 compounds with no valid justification with reference to bonding. OR Correctly identifies 1 compound Justifies conclusion with reference to bonding present in the substance
1	Provides some relevant information

Marks were deducted for incorrect Chemistry.

Students made the following incorrect statements:

Stating that bond breaking occurs in covalent molecules when there is a change of state, it is the weak intermolecular forces that are overcome.

Stating/implying that ionic compounds are molecular, they are lattices.

Stating that ionic compounds have delocalised electrons when in the molten state, the ions are now mobile.

Sample Response:

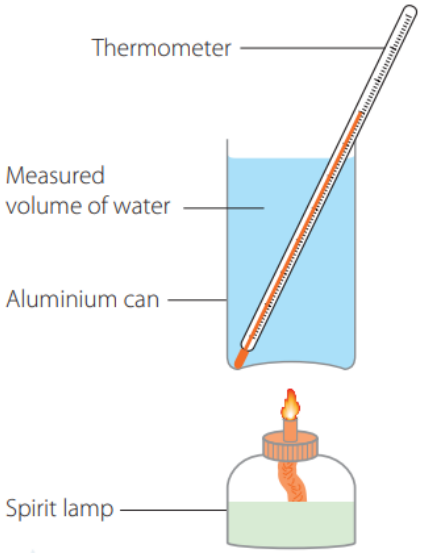
A = covalent molecular → low MP and BP due to molecules being held together by weak intermolecular forces (dispersion forces) which require little input of thermal energy to overcome

B = ionic compound → high MP/BP, no conductivity as solid but high conductivity as liquid due to presence of strong ionic bonds (high energy input to overcome) which, when broken during melting, allow charged ions to move freely and conduct electricity, but which prevent movement of the charged particles when in the solid state.

C = covalent network compound → very high MP/BP but no conductivity in any state due to the particles in the substance being held in a rigid lattice by strong covalent bonds. Melting/boiling requires breaking these bonds, and thus a large energy input. When the substance has melted and the particles able to move more freely, the particles lack a charge, and thus no conductivity occurs.

Question 24 (8 marks)

The apparatus in the figure below was used to measure the molar heat of combustion of methanol (CH_3OH). An aluminium drink container with its top cut out was suspended above the burner with a clamp in a retort stand. The thermometer was used to gently stir the water, so that it was not touching the bottom of the can. The table below shows the data collected from the experiment.



Initial mass of spirit burner (g)	160.00
Final mass of spirit burner (g)	158.90
Mass of water in container (g)	200.00
Initial temperature of water (°C)	20.0
Final temperature of water (°C)	32.0

a) Calculate the molar heat of combustion of methanol in kJ mol^{-1}. **3**

Heat absorbed by water = m x c x ΔT = 200 g x 4.18 J/g°C x 12°C = 10,032 J = 10.032 kJ (1 mark)

Moles of methanol burned = (160.00 g - 158.90 g) ÷ 32.05 g/mol = 0.0343 mol (1 mark)

Molar heat of combustion = 10.032 kJ ÷ 0.0343 mol = 292.5 kJ/mol (1 mark)

Combustion is always exothermic so this value is negative. If presented as a ΔH value then the negative sign should be used to indicate a negative change in enthalpy. If ,and only if, the words "heat of combustion" "molar heat of combustion" or the symbol ΔH_c is used is it acceptable to present the value without the negative.

Negative number of moles?????

b) Calculate the percentage error in the experiment (theoretical value = 726 kJ mol^{-1}). **1**

Error = |(292.5 - 726) ÷ 726| x 100 = 59.7% (1 mark)

c) Outline TWO ways in which the accuracy of the experiment could be improved. **2**

A relevant- sensible- example to minimise heat loss to the surroundings e.g put a lid on the can (1 mark)

A relevant- sensible- example to minimise incomplete combustion e.g ensure adequate airflow to spirit burner (1 mark)

Best answers had One example for heat loss. One example for more complete combustion

Styrofoam OVER A FLAME???

Beaker of water??????

Repeat the experiment in a closed system…what does that even mean???

Trade off with distance between spirit burner and can. Cant say keep it close as this might impede complete combustion.

Give big reasons first……..standard conditions long way down the list and our labs are nearly standard conditions anyway

The main issue is not really the can losing heat……..it is the heat not making it in to the can/water in the first place.

Insulating the outside of the aluminium can will stop the heat getting in!!!

d) Assess the reliability of the experiment. **2**

Not reliable (1 mark)
Because the experiment was only conducted once / only one trial carried out (1 mark)

We don't say "not that reliable"….."somewhat reliable" "a little bit reliable"….its either reliable or its not.

A LOT of confusion here as to what constitutes reliability.

The effect of random errors/diff between experimental and theoretical values/large percentage error/ results not averaged/having no values is accuracy not reliability.

Careful with terminology….if there has only been one trial it has not been *repeated* once!!

Repeating the experiment DOES NOT reduce the probability of/eliminate random errors. It just makes it easier to identify them.

Controlling variables is validity.

You can have a reliable experiment that is not accurate

QUESTION 25 BEGINS ON THE NEXT PAGE

Question 25 (3 marks)

The equation below shows the reaction of methyl chloride with water to produce methanol and hydrogen chloride.

$$CH_3Cl(g) + H_2O(g) \rightarrow CH_3OH(g) + HCl(g)$$

The bond energies for the relevant bonds are provided below.

Bond	Bond Energy (kJ mol^{-1})
C–Cl	338
O–H	463
C–O	358
H–Cl	431
C–H	412

Calculate the change in enthalpy for the reaction and hence determine whether the reaction is exothermic or endothermic.

ΔH = Energy to break bonds − Energy released when bonds form (1 Mark)

Total energy required to break bonds = 3x C-H + 1x C-Cl + 2x O-H = 3(412) + 338 + 2(463) = 2500 kJ/mol

Total energy released when bonds form = 3x C-H + 1x C-O + 1x O-H + 1x H-Cl = 3(412) + 358 + 463 + 431 = 2488 kJ/mol

ΔH = 2500 – 2488 = 12 kJ/mol (1 mark)

Thus the reaction is endothermic. (1 mark)

Examiners comment:

Students needed to provide valid expression of enthalpy change for a reaction with respect to the energy involved in the making and breaking of bonds. Some students provided an expressions using Heats of Formation or Hess's Law, this was not appropriate for this question.

Some students calculated ΔH without then stating if the reaction was endothermic or exothermic.

Question 26 (4 marks)

Consider the equation given below.

$$2C(s) + H_2(g) \rightarrow C_2H_2(g)$$

Use the following equations and their enthalpies to calculate the enthalpy of reaction for the reaction given above at the same temperature and pressure, and hence determine whether this reaction is exothermic or endothermic.

Reaction	ΔH (kJ mol^{-1})
$C(s) + O_2(g) \rightarrow CO_2(g)$	-393.5
$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$	-285.8
$C_2H_2(g) + \frac{5}{2}O_2(g) \rightarrow 2CO_2(g) + H_2O(l)$	-1299.5

Reversing Reaction 3 and assigning the correct ΔH (+1299.5 kJ/mol) (1 mark)

Correctly calculating ΔH for Reaction 1 and Reaction 2 (1 mark)

Summing enthalpies correctly to get the final ΔH (1 mark)

Conclusion that the reaction is endothermic (1 mark)

First, reverse Reaction 3 to form C_2H_2. This changes the sign of ΔH:
$2CO_2(g) + H_2O(l) \rightarrow C_2H_2(g) + {}^5/_2O_2(g)$
ΔH = +1299.5 kJ/mol

Now apply Reaction 1 twice to form $2CO_2$:
$2C(s) + 2O_2(g) \rightarrow 2CO_2(g)$
ΔH = 2 × (-393.5) = -787.0 kJ/mol

Next, apply Reaction 2 once to form H_2O:
$H_2(g) + ½O_2(g) \rightarrow H_2O(l)$
ΔH = -285.8 kJ/mol

Now sum all the enthalpies:
ΔH = 1299.5 - 787.0 - 285.8 = +226.7 kJ/mol

Since ΔH is positive, the reaction is **endothermic**.

Examiners comment:

Question well done except once again, some students calculated ΔH without then stating if the reaction was endothermic or exothermic.

Question 27 (3 marks)

The process below shows diamond returning to carbon's standard state, graphite.

$$2C(s)_{\text{diamond}} \rightarrow 2C(s)_{\text{graphite}}$$

Using the information provided below, determine whether the process is spontaneous under laboratory conditions.

$\Delta H_f^\circ(C(s)_{\text{diamond}}) = 1.9 \text{ kJ mol}^{-1}$

$S°(C(s)_{\text{diamond}}) = 2.38 \text{ J mol}^{-1} \text{ K}^{-1}$

$S°(C(s)_{\text{graphite}}) = 5.74 \text{ J mol}^{-1} \text{ K}^{-1}$

Correct calculation of ΔS AND ΔH (1 mark)

Correct calculation of ΔG using the Gibbs free energy equation with **correct units** (1 mark)

Conclusion that the process is spontaneous based on negative ΔG (1 mark)

As written:

$\Delta H = \Delta H_f(\text{products}) - \Delta H_f(\text{reactants}) = 0 - 2(1.9) \text{ kJ/mol} = -3.8 \text{ kJ/mol}$

$\Delta S = 2(5.74 - 2.38) \text{ J/mol·K} = 6.72 \text{ J/mol·K}$

$\Delta G = \Delta H - T\Delta S = -3.8 \text{ kJ/mol} - (298.15 \text{ K} \times 6.72/1000 \text{ kJ/mol·K}) = -5.8 \text{ kJ/mol}$

OR for 1 mol only:

$\Delta H = \Delta H_f(\text{products}) - \Delta H_f(\text{reactants}) = 0 - 1.9 \text{ kJ/mol} = -1.9 \text{ kJ/mol}$

$\Delta S = 5.74 - 2.38 \text{ J/mol·K} = 3.36 \text{ J/mol·K}$

$\Delta G = \Delta H - T\Delta S = -1.9 \text{ kJ/mol} - (298.15 \text{ K} \times 3.36/1000 \text{ kJ/mol·K}) = -2.9 \text{ kJ/mol}$

Marker notes:

- Many students forgot to include units for their ΔG value. Please note that ΔH is in kJ mol^{-1} and TΔS is in kJ mol^{-1}…so if you're using ΔG = ΔH – TΔS your ΔG must also be in kJ mol^{-1}.
- ΔH_f of graphite (product) is 0 as this is the simplest elemental carbon. Thus $\Delta H_{rxn} = 0 - 1.9 = -1.9 \text{ kJ mol}^{-1}$.
- Some students did not include a ΔG at all… for you to completely determine the spontaneity of the reaction, you needed to demonstrate some understanding of the Gibbs' Free Energy Equation. If you simply state that 'TΔS is +ve, and ΔH is -ve

therefore reaction must be spontaneous' this **does not** demonstrate your understanding of Gibbs' Free Energy and spontaneity of reactions.

END OF EXAM. EXTRA WRITING SPACE PROVIDED ON THE NEXT PAGE.

EXTRA WRITING SPACE. CLEARLY INDICATE INSIDE YOUR EXAM BOOKLET IF THIS SPACE IS USED FOR A PARTICULAR QUESTION.

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