SYDNEY GRAMMAR SCHOOL

2020
ANNUAL EXAMINATION

CHEMISTRY
Form V

STRUCTURE OF PAPER

- Section I: Multiple Choice (17 marks)

  Answer all questions on the Multiple-choice Answer Sheet.

- Section II: Extended Response (73 marks)

  Answer all parts of the questions in the spaces provided in the Examination Paper.

- NESA-approved calculators may be used

EXAMINATION

Date: Wednesday 2nd September
Duration: 2 hours
Marks: 90

CHECKLIST

Each boy should have the following:

- ☐ 1 Examination Paper
- ☐ 1 Multiple Choice Answer Sheet
- ☐ 1 Data and Formula Sheet

EXAM INSTRUCTIONS

- Remove the centre staple and hand in all parts of the paper, in order, in one bundle.
- WRITE YOUR **CANDIDATE NUMBER** IN THE SPACE PROVIDED AT THE TOP OF EACH SEPARATE SECTION.

CLASS NUMBER	1	2	3	4	5	6	7	8
Class	5CY201	5CY202	5CY203	5CY204	5CY205	5CY206	5CY207	5CY208
Master Initials	JLS	BED	CXS	MTK	TW	MRB	CRMR	NAL

Examiners: NAL, BED, CXS, CRMR

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SECTION I: MULTIPLE CHOICE

Attempt ALL Questions
Use the Multiple-Choice Answer Sheet.

1 Which of the following compounds has the weakest intermolecular forces?

(A) CCl_4
(B) CH_4
(C) CBr_4
(D) CF_4

2 Identify the electron configuration of the chloride ion (Cl^-).

(A) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$
(B) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$
(C) $1s^2\ 2p^8\ 3d^7$
(D) $1s^2\ 2p^8\ 3d^8$

3 An atom has 20 neutrons and an atomic number of 19. Identify its name and mass number?

	Name	***Mass Number***
(A)	Potassium	39
(B)	Calcium	39
(C)	Potassium	20
(D)	Calcium	20

4 Which of the following has the highest concentration of potassium ions?

(A) 0.050 M $K_4[Fe(CN)_6]$
(B) 0.080 M K_3PO_4
(C) 0.15 M K_2CrO_4
(D) 0.20 M KCl

5 A 60.45 g sample of a compound was found to contain 49.98 g carbon and 10.47 g hydrogen. The molar mass of the compound is 58.12 g/mol. Determine the molecular formula of the compound.

(A) C_2H_2
(B) C_2H_5
(C) C_4H_{10}
(D) C_5H_6

6 100 mL of 0.100 M lead(II) nitrate was added to 100 mL of 0.100 M sodium iodide. What mass of precipitate formed?

(A) 1.67 g
(B) 2.31 g
(C) 3.34 g
(D) 4.61 g

7 Nitrogen gas and hydrogen gas react to form ammonia gas. At a constant temperature and pressure, 1.2 L of nitrogen reacts with 3.0 L of hydrogen. What volume of ammonia will be produced if the reaction goes to completion?

(A) 2.0 L
(B) 2.4 L
(C) 3.0 L
(D) 4.5 L

8 A chemist made a standard solution by dissolving 0.8928 g of anhydrous copper(II) sulfate in 250 mL of solution. They then transferred a 5.00 mL sample of this solution into a 100 mL volumetric flask and made up to the mark with water. What is the final concentration of this solution?

(A) 0.00112 mol L^{-1}
(B) 0.0224 mol L^{-1}
(C) 0.00559 mol L^{-1}
(D) 0.179 mol L^{-1}

9 An electrochemical cell is assembled based on the following reaction:

$$Cd(s) + 2AgNO_3(aq) \rightarrow Cd(NO_3)_2(aq) + 2Ag(s)$$

Which cation is undergoing oxidation?

(A) Ag^+
(B) Cd^{2+}
(C) NO_3^-
(D) There are no cations undergoing oxidation

10 Of the following, the best experimental evidence to show that iron metal is a better reducing agent than copper metal is that

(A) purple permanganate solution (MnO_4^-) reacts with Fe^{2+} ions but not with Cu^{2+} ions.
(B) hydrogen gas is produced when iron is added to dilute acid, but no reaction occurs between copper and dilute acid
(C) copper is a better electrical conductor than iron
(D) dilute acid reacts with iron(II)sulfide, but no reaction occurs between dilute acid and copper(II)sulfide

11 Which reaction is spontaneous at 25°C?

(A) Fe^{2+} (aq) + Cu (s) → Fe (s) + Cu^{2+} (aq)

(B) $2Fe^{3+}$ (aq) + Cu (s) → $2Fe^{2+}$ (aq) + Cu^{2+} (aq)

(C) Fe^{2+} (aq) + 2Cu (s) → Fe (s) + $2Cu^{+}$ (aq)

(D) Fe^{2+} (aq) + Cu^{+} (aq) → Fe^{3+} (aq) + Cu (s)

12 In which of the following compounds does nitrogen have the highest oxidation state?

(A) NO_2^-

(B) NO_2

(C) N_2O_5

(D) NO

13 Which one of the following reactions is an oxidation/reduction reaction?

(A) NaCl (aq) + $AgNO_3$ (aq) → AgCl (s) + $NaNO_3$ (aq)

(B) 3CuO (s) + $2NH_3$ (g) → 3Cu (s) + $3H_2O$ (l) + N_2 (g)

(C) $3CaSO_3$ (aq) + 2HCl (aq) → $CaCl_2$ (aq) + H_2O (l) + SO_2 (g)

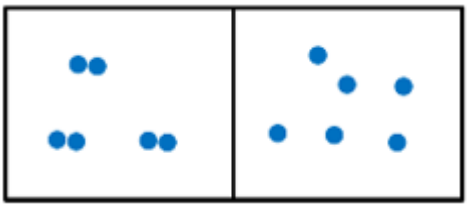
(D) $3Ca(OH)_2$ (s) + $2H_3PO_4$ (aq) → $Ca_3(PO_4)_2$ (aq) + $6H_2O$ (l)

14 Which combination of enthalpy (ΔH) and entropy (ΔS) will always give a spontaneous reaction?

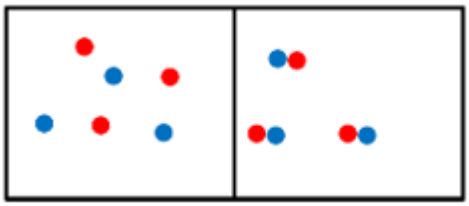
	ΔH	ΔS
(A)	negative	positive
(B)	negative	negative
(C)	positive	positive
(D)	positive	negative

15 Which of the following models, going from left to right, demonstrates the largest increase in entropy at a constant temperature?

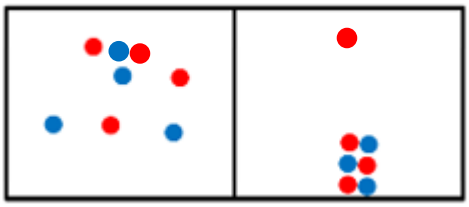
(A)



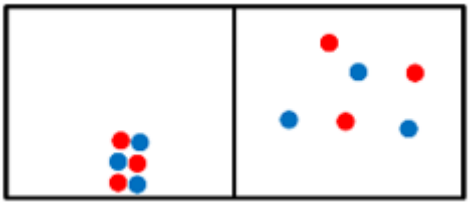
(B)



(C)



(D)



16 The reaction between sulfuric acid and sodium hydroxide has an enthalpy change of -111.68 kJ mol^{-1} and an entropy change 161.32 J K mol^{-1}. What is the Gibbs energy change at 395 K.

$$H_2SO_{4(aq)} + 2NaOH_{(aq)} \rightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)}$$

$$\Delta S = 161.32 \text{ J K mol}^{-1} \quad \Delta H = -111.68 \text{ kJ mol}^{-1}$$

(A) ΔG = -175.40 kJ mol^{-1}

(B) ΔG = +175.40 kJ mol^{-1}

(C) ΔG = -63609 kJ mol^{-1}

(D) ΔG = +63609 kJ mol^{-1}

17 Calculate the enthalpy change ($\Delta_r H$) for the following reaction of dinitrogen tetraoxide (N_2O_4) to nitrogen dioxide (NO_2) using the enthalpy data provided.

$$N_2O_{4(g)} \rightarrow 2NO_{2(g)}$$

$$N_{2(g)} + 2O_{2(g)} \rightarrow 2NO_{2(g)} \quad \Delta_r H = +67.8 \text{ kJ mol}^{-1}$$
$$N_{2(g)} + 2O_{2(g)} \rightarrow N_2O_{4(g)} \quad \Delta_f H = +9.6 \text{ kJ mol}^{-1}$$

(A) $\Delta_r H = +58.2 \text{ kJ mol}^{-1}$

(B) $\Delta_r H = +77.4 \text{ kJ mol}^{-1}$

(C) $\Delta_r H = -58.2 \text{ kJ mol}^{-1}$

(D) $\Delta_r H = -77.4 \text{ kJ mol}^{-1}$

SECTION II: Attempt ALL Questions

Candidate number:

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 18 (3 marks) **Marks**

Hydrogen sulfide and carbon dioxide are molecules with different shapes and different properties Their boiling points are identified below:

Compound	Hydrogen sulfide (H_2S)	Carbon dioxide (CO_2)
Boiling point (ºC)	-60°C	-78.5°C

By referring to molecular shape and intermolecular forces, explain the difference in the boiling points between hydrogen sulfide and carbon dioxide.

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SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 19 (5 marks) **Marks**

a) Naturally occurring boron exists as two isotopes, boron-10 and boron-11. Use the data in the table below to determine the percentage abundance of boron-10 in a natural sample of boron. *Show all working.*

Isotope	Relative isotopic mass
Boron-10	10.0129
Boron-11	11.0093

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b) Boron-12 is a radioisotope that can be produced via neutron (n) bombardment of boron-11. It then decays via negative beta decay.
Write two nuclear equations showing the synthesis and radioactive decay of boron-12.

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c) Is the decay product of boron – 12 stable or unstable. Give a reason for your answer.

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SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 20 (4 marks) **Marks**

a) Describe the trend in ionisation energy down a group on the periodic table.

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b) Explain why the atomic radius generally decreases across a period on the periodic table.

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SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 21 (7 marks) **Marks**

a) Ammonia, NH_3, is a small covalently bonded polar molecule. Explain, in terms of electronegativity, why it forms as a covalent molecule rather than an ionic compound.

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b) Draw the Lewis electron dot diagram for ammonia and identify its molecular shape

SHAPE

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c) Ammonia is a molecule that has hydrogen bonding. With the aid of a diagram, labelling the position of the hydrogen bond, explain the term *hydrogen bond* using ammonia as an example.

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SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 22 (3 marks) **Marks**

Write a balanced chemical equation for the reaction between the following chemicals.

Include all states.

(i) sodium sulfate and barium nitrate

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(ii) magnesium oxide and nitric acid

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SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

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SECTION II: Attempt ALL Questions

Candidate number:

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 23 (2 marks) **Marks**

The concentration of ethanol (C_2H_5OH) in blood, called the blood alcohol concentration (BAC), is reported in grams per 100 mL of blood. At a BAC of 0.020 g dissolved in 100 mL of blood, alcohol will start to have some measurable impact on the brain and body. What is the concentration of alcohol in **mol/L** at a BAC of 0.020?

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Question 24 (3 marks)

Acid spills can be neutralised by adding a base such as sodium hydrogen carbonate. The resultant mixture can then be safely cleaned. 50.00 mL of 6.00 M sulfuric acid, H_2SO_4, was spilled.

$$H_2SO_4(aq) + 2NaHCO_3(s) \rightarrow Na_2SO_4(aq) + 2CO_2(g) + 2H_2O(l)$$

a) Identify one observation you could make to indicate that all of the acid had been neutralised

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b) What is the minimum mass of sodium hydrogen carbonate required to neutralise the acid?

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SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 25 (3 marks) **Marks**

A particular coal contains 3.0 % sulfur by mass. When the coal is burned in a power plant, the sulfur is converted into sulfur dioxide, which is a pollutant. To reduce sulfur dioxide emissions, calcium oxide is added, which reacts with the sulfur dioxide to produce calcium 16ulphite as per the chemical equations below.

$$S\ (s) + O_2\ (g) \rightarrow SO_2\ (g)$$
$$CaO\ (s) + SO_2\ (g) \rightarrow CaSO_3\ (s)$$

If a power plant uses 2 500 000 kg of coal a day, what mass of calcium oxide is required to eliminate the sulfur dioxide emissions?

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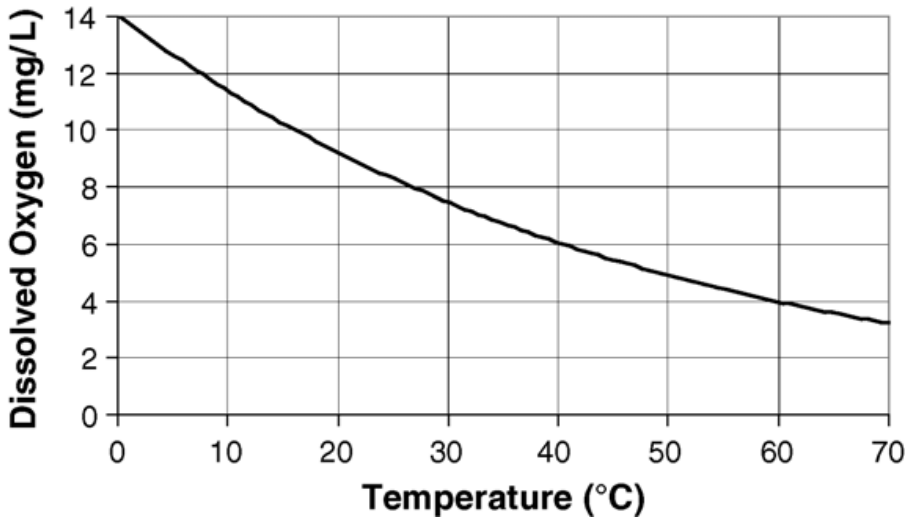
SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 26 (4 marks) **Marks**

Oxygen becomes less soluble in water as the temperature of water increases. Use the information on the accompanying graph, where the amount of oxygen dissolved in water at different temperatures is measured (pressure at 100 kPa), to answer the following question.



Calculate the volume of oxygen gas (at 50.0°C) is released when 2.50 L of water saturated with oxygen at 25°C is heated to 50.0°C at 100 kPa?

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SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 27 (8 marks) **Marks**

An experiment was performed with lead nitrate solution being added to different volumes of sodium chloride solution. After each reaction the precipitate of lead chloride was produced, extracted and weighed.

$$Pb(NO_3)_2\ (aq) + 2\ NaCl\ (aq) \rightarrow PbCl_2\ (s) + 2\ NaNO_3\ (aq)$$

The results are expressed in the table.

Volume of sodium chloride (mL)	Volume of lead (II) nitrate (mL)	Mass of precipitate (g)
20.0	50.0	0.3
40.0	50.0	0.6
60.0	50.0	0.9
80.0	50.0	1.2
100.0	50.0	1.4
120.0	50.0	1.4
140.0	50.0	1.5
160.0	50.0	1.4

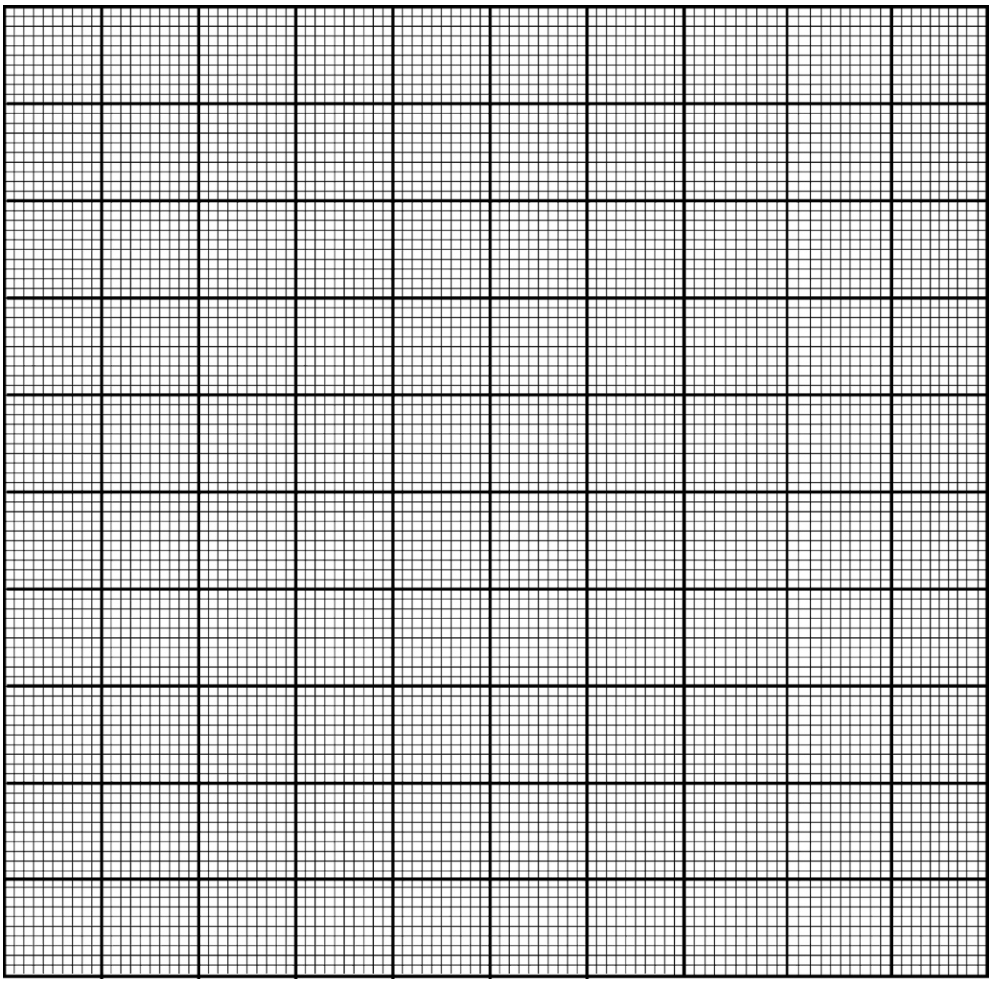
(a) Construct a line graph to show the relationship between the mass of lead chloride precipitate formed vs volume of sodium chloride solution used. **4**

CONSTRUCT GRAPH OVER PAGE

SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Marks



(b) Calculate the concentration of the sodium chloride solution in mol L^{-1}.

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SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

SECTION II: Attempt ALL Questions

Candidate number:

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 28 (3 marks) **Marks**

Strips of three metals, A, B and C were placed into solutions of the metal ions A^+, B^{2+} and C^{2+}. The observations made are listed in the table below.

Metal	In a solution of:		
	A^+ (aq)	B^{2+} (aq)	C^{2+} (aq)
A (s)	No reaction	Crystals formed	Crystals formed
B (s)	No reaction	No reaction	Crystals formed
C (s)	No reaction	No reaction	No reaction

(a) Use the results in the table to determine which of the above is:

(i) The strongest oxidising agent

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(ii) The strongest reducing agent

..... **1**

(b) Write a net ionic equation for the electrochemical reaction between two substances from the table which produce the highest voltage. *(Include all states)*

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SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 29 (8 marks) **Marks**

An electrochemical cell is designed using an aluminium rod placed in a solution of aluminium ions, Al^{3+}, and a nickel rod placed in a solution of nickel ions, Ni^{2+}.
The two half cells are connected by a salt-bridge and a voltmeter is placed in the external circuit.

(a) Write the half-equation for the reaction occurring in each half-cell.

Oxidation: **1**

Reduction: .....

(b) Write the net ionic equation for the reaction.

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(c) Draw a diagram to represent the cell, and label:

(i) The direction of electron flow

(ii) The metals and anode and cathode

(iii) The direction of flow of positive and negative ions

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SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Marks

(d) Over a period of time the nickel electrode changes in mass by 1.86 g. Is this an *increase* or a *decrease* in mass?

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(e) Calculate the change in mass of the aluminium electrode over the same period of time.

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SECTION II: Attempt ALL Questions

Candidate number:

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

SECTION II: Attempt ALL Questions

Candidate number:

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 30 (5 marks) **Marks**

A pupil found an unknown potassium salt whose label had faded and wanted to use the molar enthalpy change of solution to figure out which potassium salt it was. The pupil found the molar enthalpy changes for the following potassium salts:

Potassium salt	$\Delta_{sol}H$ kJ mol^{-1}	Molar Mass g mol^{-1}
Potassium iodide	20.3	166.00
Potassium chloride	17.2	74.55
Potassium hydroxide	-57.1	56.11
Potassium sulfate	34.9	174.27
Potassium carbonate	-30.9	138.21

a) 1.50 g of the potassium salt was added to 70.0 g of water which had an initial temperature of 19.8 °C, the maximum temperature reached by the solution was 25.0 ˚C. Calculate the enthalpy change of solution (in kJ g^{-1}) for the salt and using the information provided suggest which potassium salt it is.

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b) Give one reason the molar enthalpy of the solution measured does not match the standard molar enthalpy of solution?

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SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 31 (2 marks) **Marks**

Given the following information:

$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ $\Delta H = -116$ kJ mol^{-1}

$2N_2(g) + 5O_2(g) + 2H_2O(l) \rightarrow 4HNO_3(aq)$ $\Delta H = -256$ kJ mol^{-1}

$N_2(g) + O_2(g) \rightarrow 2NO(g)$ $\Delta H = +183$ kJ mol^{-1}

Calculate the enthalpy change for the reaction below:

$3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(aq) + NO(g)$

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SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 32 (8 marks) **Marks**

Enthalpy changes depend on the number and type of bonds broken and formed.
Use the average bond enthalpies in the table to answer the following question.

Bond	Bond Energy (kJ/ mol^{-1})	Bond	Bond Energy (kJ mol^{-1})
O=O	498	C–C	347
C=O	732	C–H	413
C–O	336	O–H	464
C ≡ O	1077	H-H	432

(a) Hydrogen gas can be formed industrially by the reaction of natural gas with steam.

$$CH_4\,(g) + H_2O\,(g) \rightarrow 3H_2\,(g) + CO\,(g)$$

Determine the enthalpy change, ΔH, for the reaction, in kJ mol^{-1}, using average bond enthalpies.

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(b) The table lists the standard enthalpies of formation, $\Delta_f H$ (kJ mol^{-1}) for some of the species in the reaction above.

	$CH_4(g)$	$H_2O(g)$	$CO(g)$
$\Delta_f H$ (kJ mol^{-1})	-74.0	-242	-111

(i) Outline why no value is listed for $H_2(g)$.

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SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Marks

(ii) Determine the value of $\Delta_r H$, in kJ mol^{-1}, for the reaction using the values in the table.

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(iii) Outline why the value of enthalpy of reaction calculated from bond energies is less accurate.

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(c) The table lists standard entropy, S°, values in J K^{-1} mol^{-1}.

	$CH_4(g)$	$H_2O(g)$	$CO(g)$	$H_2(g)$
S° / J K^{-1} mol^{-1}	+186	+189	+198	+131

Calculate the standard entropy change, $\Delta S°$, in J K^{-1} mol^{-1}.

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(d) Calculate the standard Gibbs energy change, $\Delta G°$, in kJ mol^{-1}, for the reaction at 298 K, using your answer to (b)(ii).

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Marks

(e) Determine the temperature, in K, above which the reaction becomes spontaneous. **1**

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Question 33 OVER PAGE

SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

SECTION II: Attempt ALL Questions

Candidate number:

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 33 (5 marks) **Marks**

Binary compound **A** can be synthesised by heating elements **B** and **C**.

2.158 g of **A** reacts rapidly with excess water to form 1.406 g of a solid (containing 46.75% **B** by mass) and 1.158 L (measured at 302.7 K and 101.7 kPa) of the toxic gas **D**, which contains 94.09% **C** by mass. **D** can also be formed from the reaction of aluminium sulfide with water; aluminium hydroxide is the only other product of this reaction.

The molar masses of **B**, **C** and **D** differ by less than 6 g mol^{-1}.

Identify substances **A** to **D**, showing all relevant working.

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END OF EXAMINATION

SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Chemistry

FORMULAE SHEET

$$n = \frac{m}{MM} \qquad c = \frac{n}{v} \qquad PV = nRT$$

$$q = mC\Delta T \qquad \Delta G^\circ = \Delta H^\circ - T\Delta S^\circ \qquad \text{pH} = -\log_{10}[\text{H}^+]$$

$$pK_a = -\log_{10}[K_a] \qquad A = \varepsilon lc = \log_{10}\frac{I_o}{I}$$

Avogadro constant, N_A ..... 6.022×10^{23} mol^{-1}

Volume of 1 mole ideal gas: at 100 kPa and
at 0°C (273.15 K) ..... 22.71 L
at 25°C (298.15 K) ..... 24.79 L

Gas constant ..... 8.314 J mol^{-1} K^{-1}

Ionisation constant for water at 25°C (298.15 K), K_w ..... 1.0×10^{-14}

Specific heat capacity of water ..... 4.18×10^3 J kg^{-1} K^{-1}

DATA SHEET

Solubility constants at 25°C

Compound	K_{sp}	*Compound*	K_{sp}
Barium carbonate	2.58×10^{-9}	Lead(II) bromide	6.60×10^{-6}
Barium hydroxide	2.55×10^{-4}	Lead(II) chloride	1.70×10^{-5}
Barium phosphate	1.3×10^{-29}	Lead(II) iodide	9.8×10^{-9}
Barium sulfate	1.08×10^{-10}	Lead(II) carbonate	7.40×10^{-14}
Calcium carbonate	3.36×10^{-9}	Lead(II) hydroxide	1.43×10^{-15}
Calcium hydroxide	5.02×10^{-6}	Lead(II) phosphate	8.0×10^{-43}
Calcium phosphate	2.07×10^{-29}	Lead(II) sulfate	2.53×10^{-8}
Calcium sulfate	4.93×10^{-5}	Magnesium carbonate	6.82×10^{-6}
Copper(II) carbonate	1.4×10^{-10}	Magnesium hydroxide	5.61×10^{-12}
Copper(II) hydroxide	2.2×10^{-20}	Magnesium phosphate	1.04×10^{-24}
Copper(II) phosphate	1.40×10^{-37}	Silver bromide	5.35×10^{-13}
Iron(II) carbonate	3.13×10^{-11}	Silver chloride	1.77×10^{-10}
Iron(II) hydroxide	4.87×10^{-17}	Silver carbonate	8.46×10^{-12}
Iron(III) hydroxide	2.79×10^{-39}	Silver hydroxide	2.0×10^{-8}
Iron(III) phosphate	9.91×10^{-16}	Silver iodide	8.52×10^{-17}
		Silver phosphate	8.89×10^{-17}
		Silver sulfate	1.20×10^{-5}

Aylward and Findlay, *SI Chemical Data* (5th Edition) is the principal source of data for this examination paper. Some data may have been modified for examination purposes.

SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Some standard potentials

$K^+ + e^-$	$\rightleftharpoons$	$K(s)$	–2.94 V
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	$Ba(s)$	–2.91 V
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	$Ca(s)$	–2.87 V
$Na^+ + e^-$	$\rightleftharpoons$	$Na(s)$	–2.71 V
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	$Mg(s)$	–2.36 V
$Al^{3+} + 3e^-$	$\rightleftharpoons$	$Al(s)$	–1.68 V
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	$Mn(s)$	–1.18 V
$H_2O + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g) + OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn(s)$	–0.76 V
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe(s)$	–0.44 V
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni(s)$	–0.24 V
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn(s)$	–0.14 V
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb(s)$	–0.13 V
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g)$	0.00 V
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(aq) + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	$Cu(s)$	0.34 V
$\frac{1}{2}O_2(g) + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	0.40 V
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu(s)$	0.52 V
$\frac{1}{2}I_2(s) + e^-$	$\rightleftharpoons$	I^-	0.54 V
$\frac{1}{2}I_2(aq) + e^-$	$\rightleftharpoons$	I^-	0.62 V
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	0.77 V
$Ag^+ + e^-$	$\rightleftharpoons$	$Ag(s)$	0.80 V
$\frac{1}{2}Br_2(l) + e^-$	$\rightleftharpoons$	Br^-	1.08 V
$\frac{1}{2}Br_2(aq) + e^-$	$\rightleftharpoons$	Br^-	1.10 V
$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O	1.23 V
$\frac{1}{2}Cl_2(g) + e^-$	$\rightleftharpoons$	Cl^-	1.36 V
$\frac{1}{2}Cr_2O_7^{2-} + 7H^+ + 3e^-$	$\rightleftharpoons$	$Cr^{3+} + \frac{7}{2}H_2O$	1.36 V
$\frac{1}{2}Cl_2(aq) + e^-$	$\rightleftharpoons$	Cl^-	1.40 V
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2}F_2(g) + e^-$	$\rightleftharpoons$	F^-	2.89 V

PERIODIC TABLE OF THE ELEMENTS

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

KEY

Atomic Number: 79
Symbol: Au
Standard Atomic Weight: 197.0
Name: Gold

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Standard atomic weights are abridged to four significant figures.
Elements with no reported values in the table have no stable nuclides.
Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).
The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.

SYDNEY GRAMMAR SCHOOL

CANDIDATE NUMBER

CRIB

Q1. to 17

2020
FORM V ANNUAL EXAMINATION

CRIB

Chemistry

Section I - Multiple Choice

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

A ○ B ● C ○ D ○

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

A ● B ⊗ C ○ D ○

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word ~~correct~~ and drawing an arrow as follows.

correct

A ⊗ B ⊗ C ○ D ○

Start Here →

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 ○

Question 18 (3 marks) **Marks**

Hydrogen sulfide and carbon dioxide are molecules with different shapes and different properties Their boiling points are identified below:

Compound	Hydrogen sulfide (H_2S)	Carbon dioxide (CO_2)
Boiling point (°C)	-60°C	-78.5°C

By referring to molecular shape and intermolecular forces, explain the difference in the boiling points between hydrogen sulfide and carbon dioxide.

- ID both molecular shapes
- ID at least the major IMF CO_2 disp, H_2S dipole
- Relate the greater IMF of H_2S to a greater boiling point

Question 19 (5 marks) **Marks**

a) Naturally occurring boron exists as two isotopes, boron-10 and boron-11. Use the data in the table below to determine the percentage abundance of boron-10 in a natural sample of boron. *Show all working.*

Isotope	Relative isotopic mass
Boron-10	10.0129
Boron-11	11.0093

1 working: $10.81 = (x)10.0129 + (1-x)11.093$

1 correct answer

$x = 20.00\%$

Some students had carry through errors or the numbers in their working or the answer provided was not the solution when the equation was solved.

b) Boron-12 is a radioisotope that can be produced via neutron (n) bombardment of boron-11. It then decays via negative beta decay.

Write two nuclear equations showing the synthesis and radioactive decay of boron-12.

1 mark for each equation

$^{11}_{5}B + {}^{1}_{0}n \rightarrow {}^{12}_{5}B$ (synthesis)

$^{12}_{5}B \rightarrow {}^{12}_{6}C + {}^{0}_{-1}e$ (decay)

c) Is the decay product of boron – 12 stable or unstable. Give a reason for your answer.

stable (1:1 proton ratio)

ECF awarded if a reasonable answer is provided but the decay product was different to C12

Question 20 (4 marks) **Marks**

a) Describe the trend in ionisation energy down a group on the periodic table.

decreases

b) Explain why the atomic radius generally decreases across a period on the periodic table.

- Identify an increase in positive charge of the nucleus as you move from left to right across a period.
- Electrons are added to the same shell as you move along a period.
- Electrostatic attraction increases causing the outer electrons to move closer to the nucleus. Decreasing atomic radius.

As you move across the period, the number of positively charge protons in the nucleus increases. The number of electrons also increases, but across a period they are added into the same shell so the electron shielding effect does not significantly impact the attraction of the valence electrons to the nucleus. As a result of greater nuclear charge and no significant impact of the electron shielding, the electrostatic force between the nucleus and the valence electrons increases across a period and hence nucleus pulls the outer electrons closer to the nucleus. This reduces the atomic radius as you move from left to right across the period.

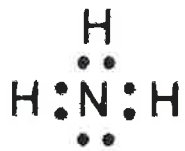
Question 21 (7 marks) **Marks**

a) Ammonia, NH_3, is a small covalently bonded polar molecule. Explain, in terms of electronegativity, why it forms as a covalent molecule rather than an ionic compound.

Identify that N and H must have a low enough difference in electronegativity.

As a result of low difference in electronegativity, the electrons are shared between atoms in the covalent bond.

b) Draw the Lewis electron dot diagram for ammonia and identify its molecular shape



Give dots OR dots + crosses OR a line representing bonding pair.

SHAPE

Trigonal pyramidal 2

c) Ammonia is a molecule that has hydrogen bonding. With the aid of a diagram, labelling the position of the hydrogen bond, explain the term *hydrogen bond* using ammonia as an example.

Each point was assigned 1 mark each:

- ID internal N-H bond is very polar due to their difference in electronegativity.
- Interaction of the N on one molecule with the H on another.
- Correct diagram (clearly labelling the h-bond)

The significant difference in electronegativity in N and H make the covalent N-H bond in ammonia highly polar. N has a significant **partial** negative charge and H has a significant **partial** positive charge. The partial positive charge of the hydrogen on one ammonia molecule causes to the partially negative charge of the nitrogen on a **neighbouring molecule** at the lone pair.
Many students did not clearly specify which N and which H were being referenced when going from describing the internal bond to describing the location of the h bond from one molecule to the next. Many students did not label the h bond as the questions prescribes.

Question 22 (3 marks)

Marks

Write a balanced chemical equation for the reaction between the following chemicals.

Include all states.

(i) sodium sulfate and barium nitrate

.....

3

(ii) magnesium oxide and nitric acid

.....

(1 for each correct equation, 1 for completely correct states for both)

$Na_2SO_4(aq) + Ba(NO_3)_2(aq) \rightarrow BaSO_4(s) + 2NaNO_3(aq)$

$MgO(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + H_2O(l)$

SECTION II: Attempt ALL Questions

Candidate number:

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 23 (2 marks) **Marks**

The concentration of ethanol (C_2H_5OH) in blood, called the blood alcohol concentration (BAC), is reported in grams per 100 mL of blood. At a BAC of 0.020 g dissolved in 100 mL of blood, alcohol will start to have some measurable impact on the brain and body. What is the concentration of alcohol in **mol/L** at a BAC of 0.020? **2**

Method 1:

$0.020\ g/100\ mL = 0.2\ g/L$

$[C_2H_5OH] = \frac{0.2\ g\ L^{-1}}{46.068\ g\ mol^{-1}} = 0.00434\ mol/L$

Method 2:

$n = \frac{m}{M} = \frac{0.020}{46.068} = 0.000434\ mol/100\ mL$

$[C_2H_5OH] = \frac{0.0004341}{0.1} = 0.00434\ mol/L$

Many boys struggled with the unit conversion aspect within this question.

(1) for each step. Units not required.

Question 24 (3 marks)

Acid spills can be neutralised by adding a base such as sodium hydrogen carbonate. The resultant mixture can then be safely cleaned. 50.00 mL of 6.00 M sulfuric acid, H_2SO_4, was spilled.

$$H_2SO_4(aq) + 2NaHCO_3(s) \rightarrow Na_2SO_4(aq) + 2CO_2(g) + 2H_2O(l)$$

a) Identify one observation you could make to indicate that all of the acid had been neutralised **1**

e.g. bubbles/effervescence stops or solid remains (stating an observation e.g. bubbles, is insufficient, you must highlight the change).

Note: you are asked for an **observation.** Therefore, saying the base is in excess is insufficient. What would you observe if this is the case? Gas stops was **just** accepted, but your answer should highlight what this looks like – no bubbles.

b) What is the minimum mass of sodium hydrogen carbonate required to neutralise the acid? **2**

$H_2SO_4 =$ CV = 6 x 0.05 = 0.3 mol/L (1)

$nNaHCO_3 = 2nH_2SO_4 = 0.6$ mol/L

$mNaHCO_3 = n \times M = 0.6 \times 84.008 = 50.4$ g (to 3sf) (1) for both answer AND sig figs

Question 25 (3 marks) **Marks**

A particular coal contains 3.0 % sulfur by mass. When the coal is burned in a power plant, the sulfur is converted into sulfur dioxide, which is a pollutant. To reduce sulfur dioxide emissions, calcium oxide is added, which reacts with the sulfur dioxide to produce calcium sulphite as per the chemical equations below.

$$S\ (s) + O_2\ (g) \rightarrow SO_2\ (g)$$
$$CaO\ (s) + SO_2\ (g) \rightarrow CaSO_3\ (s)$$

If a power plant uses 2 500 000 kg of coal a day, what mass of calcium oxide is required to eliminate the sulfur dioxide emissions? **3**

mS = 2 500 000 x $\frac{3}{100}$ = 75 000 kg = 75 000 000 g (1)

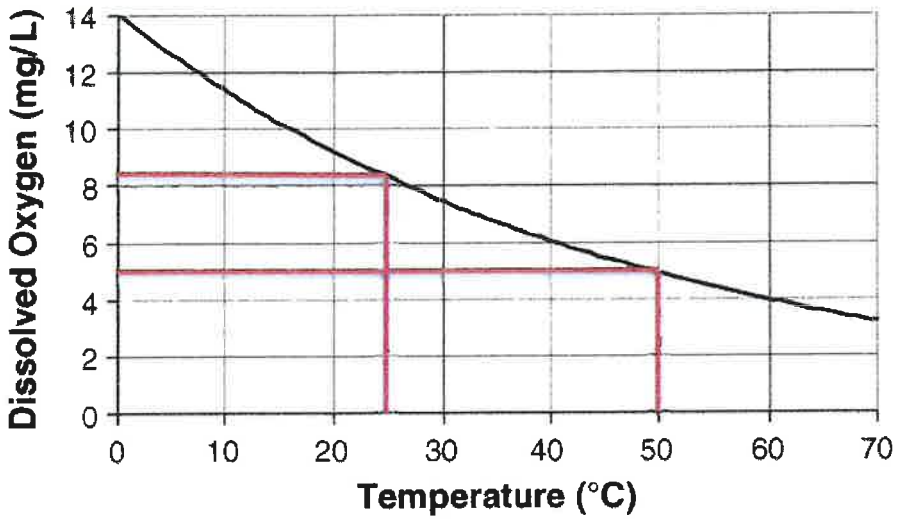
nS = nCaO = $\frac{m}{M} = \frac{75\,000\,000}{32.07} = 2\,338\,634\ mol$ (1)

mCaO = n x M = 2 338 634 x 56.08 = 131 150 608 = 130 000 000 g or 130 000 kg (1)

Units **required** for final mark.

Question 26 (4 marks) **Marks**

Oxygen becomes less soluble in water as the temperature of water increases. Use the information on the accompanying graph, where the amount of oxygen dissolved in water at different temperatures is measured (pressure at 100 kPa), to answer the following question.



Calculate the volume of oxygen gas (at 50.0°C) is released when 2.50 L of water saturated with oxygen at 25°C is heated to 50.0°C at 100 kPa? **4**

Dissolved O_2	At 25°C	8.4 mg/L x 2.5 =	21 mg
	At 50°C	5 mg/L x 2.5 =	12.5 mg

(1) for providing mg/L readings from graph for both temperatures (ranges accepted are 8.2 – 8.5, 4.9-5.1)

Mass of oxygen lost = 21 – 12.5 = 8.5 mg (1)

$$nO_2 = \frac{m}{M} = \frac{8.5/1000}{32} = 0.00026562\ mol\ (1)$$

$$VO_2 = \frac{nRT}{P} = \frac{0.00026562 \times 8.314 \times (50+273.15)}{100} = 0.007136\ L\ (1)$$

Note:

- Only 18 % of boys got full marks in this question.
- Boys frequently used monatomic oxygen rather than diatomic oxygen
- A mark was not deducted for using 273 instead of 273.15 (the value on your data sheet).
- Some boys went down the route of $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$, incorrectly using the volume of water, a liquid, as a gas. In doing so, the graph was not used. When a stimulus is provided, it ***must*** be referred to in the question. Such boys were awarded 1/4 *if* they converted °C to K correctly.
- Other boys only considered the data at 50°C. You are asked to calculate the volume ***released***, which means you must consider both temperatures.

Question 27 (8 marks) **Marks**

An experiment was performed with lead nitrate solution being added to different volumes of sodium chloride solution. After each reaction the precipitate of lead chloride was produced, extracted and weighed.

$$Pb(NO_3)_2\ (aq) + 2\ NaCl\ (aq) \rightarrow \mathbf{PbCl_2\ (s) + 2\ NaNO_3\ (aq)}$$

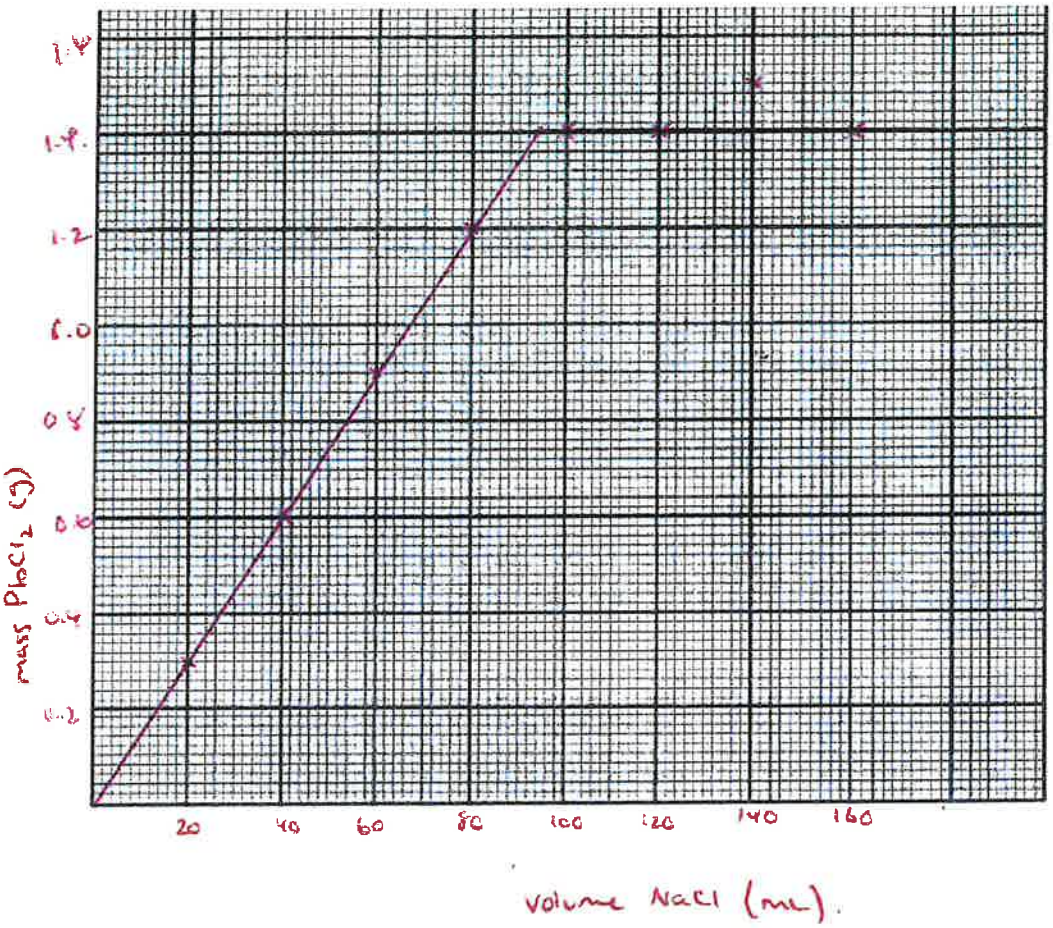
The results are expressed in the table.

Volume of sodium chloride (mL)	**Volume of lead (II) nitrate (mL)**	**Mass of precipitate (g)**
20.0	50.0	0.3
40.0	50.0	0.6
60.0	50.0	0.9
80.0	50.0	1.2
100.0	50.0	1.4
120.0	50.0	1.4
140.0	50.0	1.5
160.0	50.0	1.4

(a) Construct a line graph to show the relationship between the mass of lead chloride precipitate formed vs volume of sodium chloride solution used. **4**

CONSTRUCT GRAPH OVER PAGE

Marks



(1) scale

(1) axis titles and units

(1) points correctly plotted

(1) line of best fit (horizontal line allowed no higher than 1.44. The value at 140 mL should have been taken as an outlier).

Note: boys who selected an inappropriate scale that went up by 0.15 on the y axis nearly always lost the marks for incorrect plotting of their points.

(b) Calculate the concentration of the sodium chloride solution in mol L^{-1}. 4

(1) For selecting a value where NaCl is limiting (less than 94 mL on the model graph). This value must have been **on the line**. Boys frequently did not select a point on the line, or were unable to read their scales.

$$n PbCl_2 = \frac{1.4\ (mass\ value\ on\ the\ line)}{278.1} = 0.0050342\ mol\ (1)$$

$$nNaCl = 2nPbCl_2 = 0.0100683\ mol\ (1)$$

$$[NaCl] = \frac{n}{V} = \frac{0.0100683}{0.094\ (must\ be\ consistent\ with\ the\ mass\ selected)} = 0.107\ mol/L\ (1)$$

SECTION II: Attempt ALL Questions CRIB-CXS (11)

Candidate number: _____

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 28 (3 marks) **Marks**

Strips of three metals, A, B and C were placed into solutions of the metal ions A^+, B^{2+} and C^{2+}. The observations made are listed in the table below.

Metal	In a solution of:		
	A^+ (aq)	B^{2+} (aq)	C^{2+} (aq)
A (s)	No reaction	Crystals formed	Crystals formed
B (s)	No reaction	No reaction	Crystals formed
C (s)	No reaction	No reaction	No reaction

(a) Use the results in the table to determine which of the above is:

(i) The strongest oxidising agent

$C^{2+}_{(aq)}$ **1**

(ii) The strongest reducing agent

$A_{(s)}$ **1**

(b) Write a net ionic equation for the electrochemical reaction between two substances from the table which produce the highest voltage. *(Include all states)*

$2A_{(s)} + C^{2+}_{(aq)} \rightarrow 2A^+_{(aq)} + C_{(s)}$ **1**

Equation balanced with states for this mark (will allow one missed (aq))

SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 29 (8 marks) **Marks**

An electrochemical cell is designed using an aluminium rod placed in a solution of aluminium ions, Al^{3+}, and a nickel rod placed in a solution of nickel ions, Ni^{2+}.
The two half cells are connected by a salt-bridge and a voltmeter is placed in the external circuit.

(a) Write the half-equation for the reaction occurring in each half-cell.

Oxidation: $Al_{(s)} \rightarrow Al^{3+}_{(aq)} + 3e^-$ Both correct for mark **1**

Reduction: $Ni^{2+}_{(aq)} + 2e^- \rightarrow Ni_{(s)}$ STATES NOT MARKED

(b) Write the net ionic equation for the reaction.

$2Al_{(s)} + 3Ni^{2+}_{(aq)} \rightarrow 2Al^{3+}_{(aq)} + 3Ni_{(s)}$ **1**

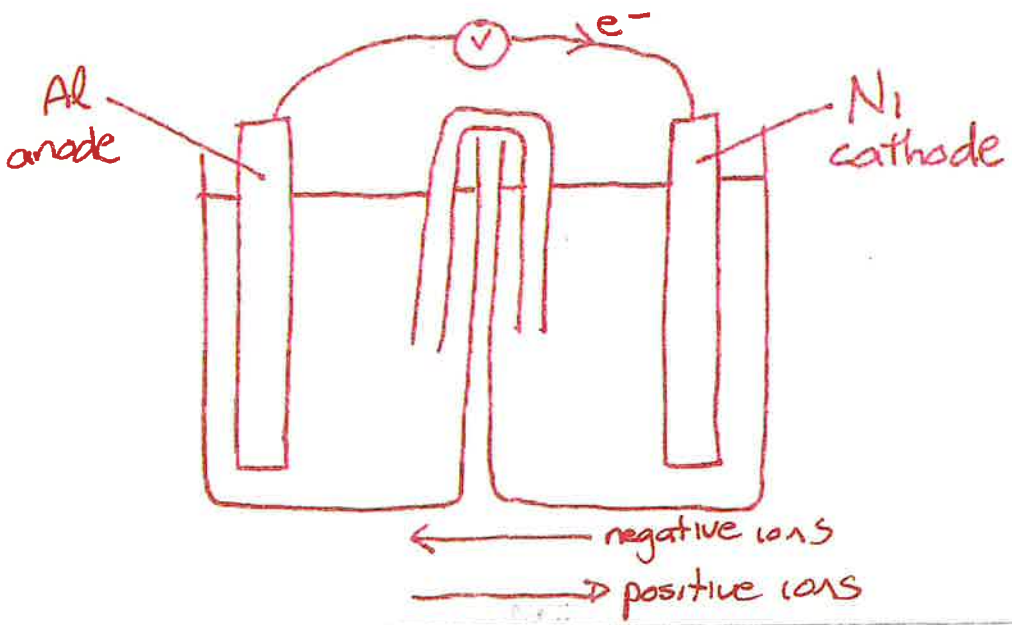
STATES NOT REQUIRED

(c) Draw a diagram to represent the cell, and label:

(i) The direction of electron flow — 1 mark

(ii) The metals and anode and cathode — 1 mark

(iii) The direction of flow of positive and negative ions — 1 mark



3

SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Marks

(d) Over a period of time the nickel electrode changes in mass by 1.86 g. Is this an *increase* or a *decrease* in mass?

increase **1**

(e) Calculate the change in mass of the aluminium electrode over the same period of time.

$n(Ni)$ forming $= 1.86 / 58.69 = 0.03169$ mol **2**

$n(Al)$ reacting $= 0.03169 \times \frac{2}{3}$

$= 0.02113$ mol

$m(Al) = 0.02113 \times 26.98$

$= 0.570$ g ——— 2 marks

(MINUS 1 mark per error)

SECTION II: Attempt ALL Questions

Candidate number:

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 30 (5 marks) **Marks**

A pupil found an unknown potassium salt whose label had faded and wanted to use the molar enthalpy change of solution to figure out which potassium salt it was. The pupil found the molar enthalpy changes for the following potassium salts:

Potassium salt	$\Delta_{sol}H$ kJ mol^{-1}	Molar Mass g mol^{-1}
Potassium iodide	20.3	166.00
Potassium chloride	17.2	74.55
Potassium hydroxide	-57.1	56.11
Potassium sulfate	34.9	174.27
Potassium carbonate	-30.9	138.21

a) 1.50 g of the potassium salt was added to 70.0 g of water which had an initial temperature of 19.8 °C, the maximum temperature reached by the solution was 25.0 °C. Calculate the enthalpy change of solution (in kJ g^{-1}) for the salt and using the information provided suggest which potassium salt it is.

(1) for finding q (J/1.5g)
(1) for finding ΔH in kJ g^{-1}
(1) Calculations for KOH
(1) Suggesting KOH

$q = 70 \times 4.18 \times 5.2 = 1521.52$ J

$\Delta H = \frac{-1521.52}{1.5} = -1.014$ kJ/g

KOH: $\Delta H = \frac{-57.1}{56.11} = -1.018$ kJ/g

K_2CO_3: $\Delta H = \frac{-30.9}{138.21} = -0.22$

KOH & K_2CO_3 only 2 that are exothermic

4

b) Give one reason the molar enthalpy of the solution measured does not match the standard molar enthalpy of solution?

- heat lost to the measured surrounds/environment

Any sensible reason - not pure substance used.

1

* See Appendix 2 for sample Answers

SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 31 (2 marks) **Marks**

Given the following information:

$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ $\Delta H = -116$ kJ mol^{-1} $\times -1.5$

$2N_2(g) + 5O_2(g) + 2H_2O(l) \rightarrow 4HNO_3(aq)$ $\Delta H = -256$ kJ mol^{-1} $\times 0.5$

$N_2(g) + O_2(g) \rightarrow 2NO(g)$ $\Delta H = +183$ kJ mol^{-1} $\times -1$

Calculate the enthalpy change for the reaction below:

$3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(aq) + NO(g)$

~~$3NO_2(g) + 1.5O_2(g) \rightarrow 3NO_2(g)$ $\Delta H = +1$~~ **2**

$3NO_{2(g)} \rightarrow 3NO_{(g)} + 1.5O_{2(g)}$ $\Delta H = -1.5 \times +116$
$= 174$

$N_{2(g)} + 2.5O_{2(g)} + H_2O \rightarrow 2HNO_3$ $\Delta H = 0.5 \times -256$
$= -128$

$2NO_{(g)} \rightarrow N_{2(g)} + O_{2(g)}$ $\Delta H = -1 \times 183$
$= -183$

$\therefore \Delta H = 174 + (-128) + (-183)$
$= -137$ kJ mol^{-1}

(2) marks no mistakes

(1) mark 1-2 mistakes.

0 mark more than 2 mistakes.

SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Question 32 (8 marks) **Marks**

Enthalpy changes depend on the number and type of bonds broken and formed.

Use the average bond enthalpies in the table to answer the following question.

Bond	Bond Energy (kJ/ mol^{-1})	Bond	Bond Energy (kJ mol^{-1})
O=O	498	C–C	347
C=O	732	C–H	413
C–O	336	O–H	464
C ≡ O	1077	H-H	432

(a) Hydrogen gas can be formed industrially by the reaction of natural gas with steam.

$$CH_4\,(g) + H_2O\,(g) \rightarrow 3H_2\,(g) + CO\,(g)$$

Determine the enthalpy change, ΔH, for the reaction, in kJ mol^{-1}, using average bond enthalpies.

$\Delta H = \Sigma$ reactant - Σ product.

$= (4 \times 413 + 2 \times 464) - (3 \times 432 + 1077)$

$= +207$ kJ mol^{-1}

① multiplying ① react - product.

Note: many boys did not know CO was C≡O many also multiple H_2 by 6 i.e. 6×432

2

(b) The table lists the standard enthalpies of formation, $\Delta_f H$ (kJ mol^{-1}) for some of the species in the reaction above.

	$CH_4(g)$	$H_2O(g)$	$CO(g)$
$\Delta_f H$ (kJ mol^{-1})	-74.0	-242	-111

(i) Outline why no value is listed for $H_2(g)$.

As hydrogen is already in its elemental form

1

SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Marks

(ii) Determine the value of $\Delta_r H$, in kJ mol^{-1}, for the reaction using the values in the table.

$\Delta H = \Sigma$ products $-$ Σ reactants **1**

$= -111 - (-74 - 242)$

$= +205$ kJ mol^{-1}

(iii) Outline why the value of enthalpy of reaction calculated from bond energies is less accurate.

As it is the average energy to break one mole of a given bond type **1**

(c) The table lists standard entropy, S°, values in J K^{-1}.

	$CH_4(g)$	$H_2O(g)$	$CO(g)$	$H_2(g)$
S° / J K^{-1} mol^{-1}	+186	+189	+198	+131

Calculate the standard entropy change, $\Delta S°$, in J K^{-1}

$\Delta S = (3 \times 131 + 198) - (186 + 189)$ **1**

$= 591 - 375$

$= 216$ J K^{-1} mol^{-1}

(d) Calculate the standard Gibbs energy change, $\Delta G°$, in kJ, for the reaction at 298 K using your answer to (b)(ii).

$\Delta G = \Delta H - T\Delta S$ **1**

$= 205 - 298 \times \frac{216}{1000}$

$= 140.6$ kJ mol^{-1}

Note many boys either did not convert ΔS into kJ as or they converted ΔH into J the ~~ΔH~~ presented ΔG as kJ.

SECTION II: Attempt ALL Questions

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

Marks

(e) Determine the temperature, in K, above which the reaction becomes spontaneous. **1**

$\Delta G = \Delta H - T\Delta S$

$0 = \Delta H - T\Delta S$

$T = \frac{\Delta H}{\Delta S}$

$= \frac{205}{0.216}$

$= 949.07\,K$

= Temperature at which it becomes spontaneous

> or = 949.07K.

Question 33 OVER PAGE

SECTION II: Attempt ALL Questions

Candidate number:

Answer the questions in the spaces provided.
Show all relevant working in questions involving calculations.

① Any correct step/calculation
② 2x correct steps, calcs or IDs.
③ ID two of A-D WITH some justification
④ ID 3-4 of A-D WITH some justification
⑤ ID 4 of A-D with complete justification.

Question 33 (5 marks) **Marks**

Binary compound A can be synthesised by heating elements B and C.

2.158 g of A reacts rapidly with excess water to form 1.406 g of a solid (containing 46.75% B by mass) and 1.158 L (measured at 302.7 K and 101.7 kPa) of the toxic gas D, which contains 94.09% C by mass. D can also be formed from the reaction of aluminium sulfide with water; aluminium hydroxide is the only other product of this reaction.

The molar masses of B, C and D differ by less than 6 g mol^{-1}.

Identify substances A to D, showing all relevant working.

D contains S. Given that D contains 94.09% C by mass, 5
either C is S or $MM(D) \geq \frac{32.07}{\left(\frac{5.91}{100}\right)} = 542\ g\ mol^{-1}$ → no known element.
$MM(D) = \frac{32.07}{\left(\frac{94.09}{100}\right)} = 34.08\ g\ mol^{-1}$ ⇒ C is S.
$MM(D-S) = 2.01\ g\ mol^{-1}$ ⇒ 2x H ∴ D is H_2S.
$m(B\ in\ 2.158\ g\ A) = 1.406\ g \times \frac{46.75}{100} = 0.6573\ g$.
$m(C\ in\ 2.158\ g\ A) = 2.158 - 0.6573\ g = 1.501\ g$
$n(C\ in\ 2.158\ g\ A) = \frac{1.501\ g}{32.07\ g\ mol^{-1}} = 0.04679\ mol$.
Equivalent weight (B) $= \frac{0.6573\ g}{0.04679\ mol} = 14.05\ g\ mol^{-1}$.
But we know B must be within 6 $g\ mol^{-1}$ of C & D, so
$MM(B) = 2 \times 14.05 = 28.09\ g\ mol^{-1}$ ⇒ Si, and there must be 2x S per Si.

END OF EXAMINATION

∴ A is SiS_2, B is Si, C is S, D is H_2S.

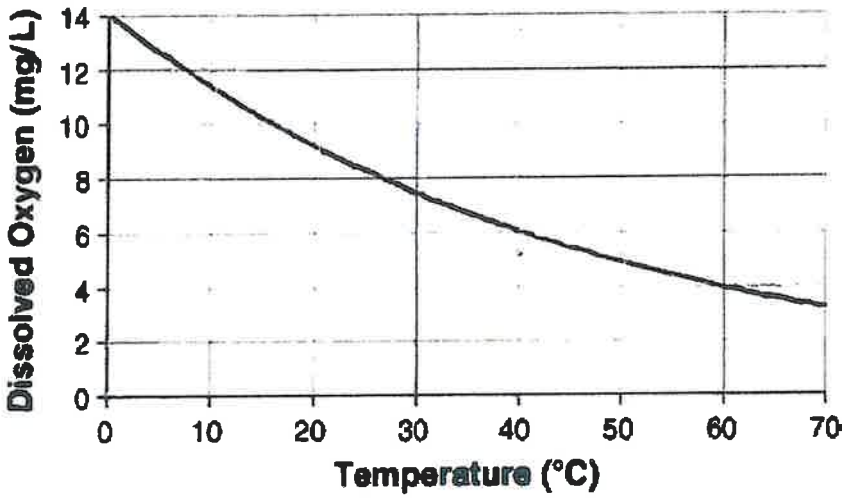
Marking guidelines above.

APPENDIX 1

Presentation of working

Question:

Oxygen becomes less soluble in water as the temperature of water increases. Use the information on the accompanying graph, where the amount of oxygen dissolved in water at different temperatures is measured (pressure at 100 kPa), to answer the following question.



Calculate the volume of oxygen gas (at 50.0°C) is released when 2.50 L of water saturated with oxygen at 25°C is heated to 50.0°C at 100 kPa?

Sample 1: This working is clear and easy to follow

From 25°C to 50°C, $8.2\,mg\,L^{-1} \rightarrow 4.6\,mg\,L^{-1}$ ✓

$\times 2.5$ $\quad 20.5\,mg \rightarrow 11.5$

$\therefore$ 9 mg lost ✓

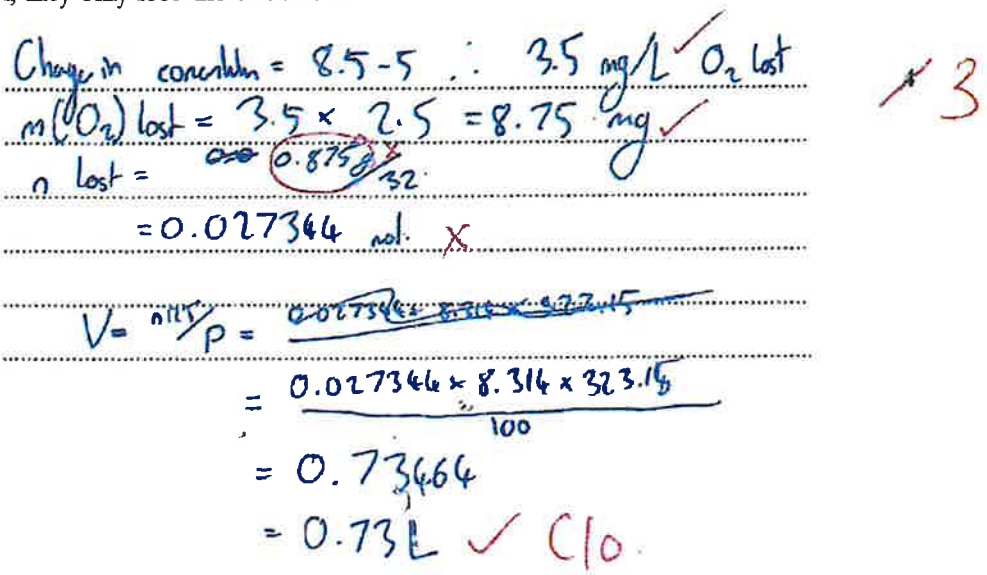
$n(O_2) = \frac{9 \times 10^{-3}}{32.00 \times 2} = 0.0002813$ mol

$PV = nRT$, $V = \frac{nRT}{P} = \frac{0.0002813 \times 8.314 \times (273.15 + 50)}{100}$ ✓

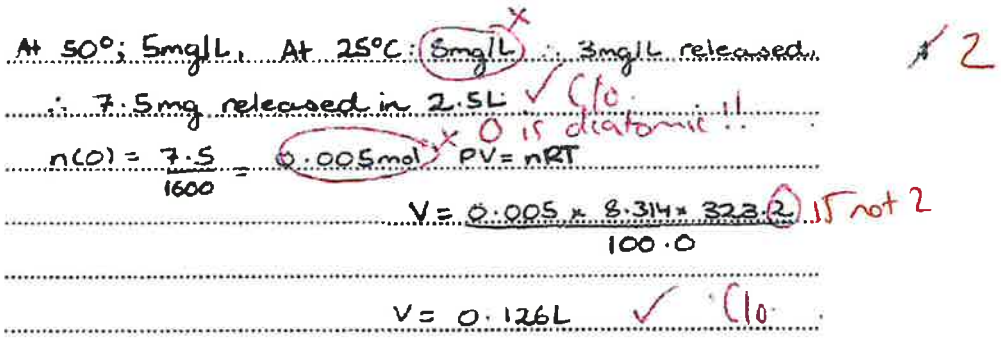
$= 0.007556$ L (dissolved) of O_2 (g) ✓

4

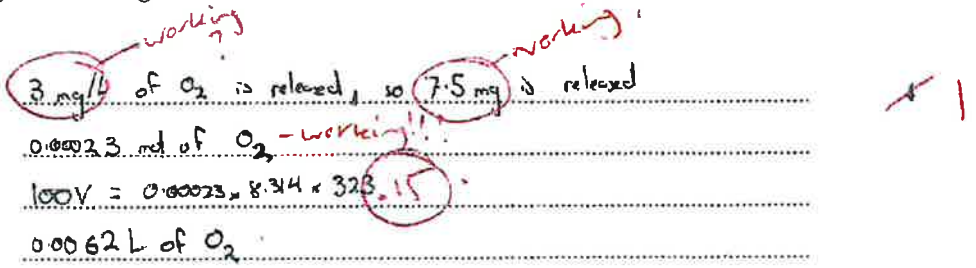
Sample 2: This student has the incorrect answer, so the marker searches for the mistake/s. This student has not converted mg to g correctly. As the error is clearly visible and the following step is correct, they only lose the one mark.



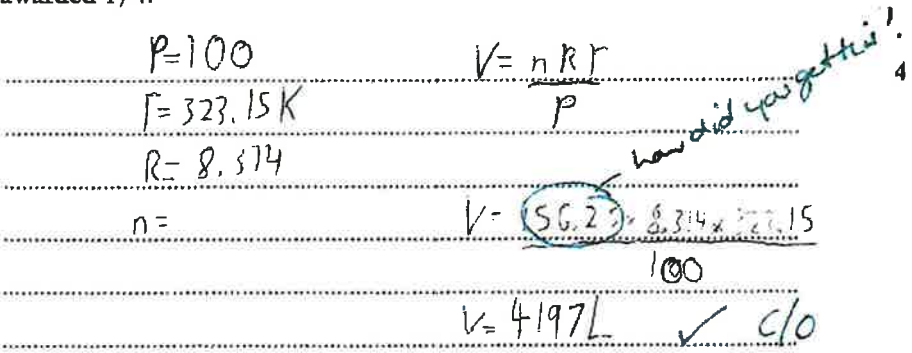
Sample 3: This student has made two independent errors. They read the value from the graph incorrectly, and calculated the moles of oxygen as if it were monoatomic. As their working is clear, they were able to be awarded two marks.



Sample 4: **Many** students provide working similar to the sample below. Intermediate values are provided, however, the working showing how they got that value is excluded (which is the most important part). In the sample below, the student read the values from the graph incorrectly (-1) and only determined the concentration at one temperature (-1). They then provided the moles of oxygen; however, it is unclear to the marker how they got this (-1). They received one mark for showing the working for PV = nRT.



Sample 5: **Many** students provide working similar to the sample below, with only some steps shown. In the sample below, the student correctly calculate n using PV = nRT, however, they did not show how they obtained the incorrect number of moles. The may have only made a single mistake, however, as there were three steps (and marks) required to calculate moles, they could only be awarded 1/4.



APPENDIX 2

Question 30 (5 marks) **Marks**

A pupil found an unknown potassium salt whose label had faded and wanted to use the molar enthalpy change of solution to figure out which potassium salt it was. The pupil found the molar enthalpy changes for the following potassium salts:

Potassium salt	$\Delta_{sol}H$ kJ mol^{-1}	Molar Mass g mol^{-1}
Potassium iodide	20.3	166.00
Potassium chloride	17.2	74.55
Potassium hydroxide	-57.1	56.11
Potassium sulfate	34.9	174.27
Potassium carbonate	-30.9	138.21

a) 1.50 g of the potassium salt was added to 70.0 g of water which had an initial temperature of 19.8 °C, the maximum temperature reached by the solution was 25.0 °C. Calculate the enthalpy change of solution (in kJ g^{-1}) for the salt and using the information provided suggest which potassium salt it is.

$\Delta T_{H_2O} = 25.0°C - 19.8°C = 5.2K$

$q_{H_2O} = mc\Delta T = 70.0_g \times 4.18 J_g^{-1} K^{-1} \times 5.2K$

$= 1.5 kJ$

$\Delta_{sol}H = \frac{-q_{H_2O}}{m(KOH)} = \frac{-1.5kJ}{1.5 g} = -1.0 kJ_g^{-1}$

$kJ_g^{-1} = kJ\,mol^{-1} \div g\,mol^{-1}$

Since $\Delta_{sol}H$ is negative, it must be KOH or K_2CO_3, and since $|\Delta_{sol}H| = 1$ mol for KOH, this will give the most $-1.0 kJ_g^{-1}$ ... hence the potassium salt is KOH.

(4)

b) Give one reason the molar enthalpy of the solution measured does not match the standard molar enthalpy of solution?

Heat may have been lost to the environment during the reaction, which would suggest that the reaction is less endothermic than it really is.

(1)

5

Question 30 (5 marks)

20.3 kJ/mol → kJ/g Marks

A pupil found an unknown potassium salt whose label had faded and wanted to use the molar enthalpy change of solution to figure out which potassium salt it was. The pupil found the molar enthalpy changes for the following potassium salts:

kJ/gK

J ÷1000 / Kg K ÷1000

Potassium salt	$\Delta_{sol}H$ kJ mol^{-1}	Molar Mass g mol^{-1}
Potassium iodide	20.3	166.00
Potassium chloride	17.2	74.55
Potassium hydroxide	-57.1	56.11
Potassium sulfate	34.9	174.27
Potassium carbonate	-30.9	138.21

a) 1.50 g of the potassium salt was added to 70.0 g of water which had an initial temperature of 19.8 °C, the maximum temperature reached by the solution was 25.0 °C. Calculate the enthalpy change of solution (in kJ g^{-1}) for the salt and using the information provided suggest which potassium salt it is.

$70 \times (25 - 19.8) \times 4.18 \times 10^{-3}$ (4)

$= 1.52152$ kJ

$1.52152 \div 1.5 = -1.01435$ kJ/g exothermic

$KOH \rightarrow -57.1 / 56.11 = -1.017$ kJ/g

$K_2CO_3 \rightarrow -30.9 / 138.21 = -0.22357$ kJ/g

most likely Potassium ~~sulfate~~ hydroxide

b) Give one reason the molar enthalpy of the solution measured does not match the standard molar enthalpy of solution?

Heat loss to surroundings (1)

5

Question 18 (3 marks) **Marks**

Hydrogen sulfide and carbon dioxide are molecules with different shapes and different properties Their boiling points are identified below:

Compound	Hydrogen sulfide (H_2S)	Carbon dioxide (CO_2)
Boiling point (°C)	-60°C	-78.5°C

By referring to molecular shape and intermolecular forces, explain the difference in the boiling points between hydrogen sulfide and carbon dioxide.

- ID both molecular shapes
- ID at least the major IMF CO_2 disp, H_2S dipole
- Relate the greater IMF of H_2S to a greater boiling point

Question 19 (5 marks) **Marks**

a) Naturally occurring boron exists as two isotopes, boron-10 and boron-11. Use the data in the table below to determine the percentage abundance of boron-10 in a natural sample of boron. *Show all working.*

Isotope	Relative isotopic mass
Boron-10	10.0129
Boron-11	11.0093

1 working: 10.81= (x)10.0129 + (1-x)11.093

1 correct answer

x= 20.00%

Some students had carry through errors or the numbers in their working or the answer provided was not the solution when the equation was solved.

b) Boron-12 is a radioisotope that can be produced via neutron (n) bombardment of boron-11. It then decays via negative beta decay.

Write two nuclear equations showing the synthesis and radioactive decay of boron-12.

1 mark for each equation

$^{11}_{5}B + {}^{1}_{0}n \rightarrow {}^{12}_{5}B$ (synthesis)

$^{12}_{5}B \rightarrow {}^{12}_{6}C + {}^{0}_{-1}e$ (decay)

c) Is the decay product of boron – 12 stable or unstable. Give a reason for your answer.

stable (1:1 proton ratio)

ECF awarded if a reasonable answer is provided but the decay product was different to C12

Question 20 (4 marks) **Marks**

a) Describe the trend in ionisation energy down a group on the periodic table.

decreases

b) Explain why the atomic radius generally decreases across a period on the periodic table.

- Identify an increase in positive charge of the nucleus as you move from left to right across a period.
- Electrons are added to the same shell as you move along a period.
- Electrostatic attraction increases causing the outer electrons to move closer to the nucleus. Decreasing atomic radius.

As you move across the period, the number of positively charge protons in the nucleus increases. The number of electrons also increases, but across a period they are added into the same shell so the electron shielding effect does not significantly impact the attraction of the valence electrons to the nucleus. As a result of greater nuclear charge and no significant impact of the electron shielding, the electrostatic force between the nucleus and the valence electrons increases across a period and hence nucleus pulls the outer electrons closer to the nucleus. This reduces the atomic radius as you move from left to right across the period.

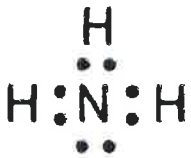
Question 21 (7 marks) **Marks**

a) Ammonia, NH_3, is a small covalently bonded polar molecule. Explain, in terms of electronegativity, why it forms as a covalent molecule rather than an ionic compound.

Identify that N and H must have a low enough difference in electronegativity.

As a result of low difference in electronegativity, the electrons are shared between atoms in the covalent bond.

b) Draw the Lewis electron dot diagram for ammonia and identify its molecular shape



Give dots and/or crosses or a line representing bonding pair of electrons

SHAPE

Trigonal pyramidal 2

c) Ammonia is a molecule that has hydrogen bonding. With the aid of a diagram, labelling the position of the hydrogen bond, explain the term *hydrogen bond* using ammonia as an example.

Each point was assigned 1 mark each:

- ID internal N-H bond is very polar due to their difference in electronegativity.
- Interaction of the N on one molecule with the H on another.
- Correct diagram (clearly labelling the h-bond)

The significant difference in electronegativity in N and H make the covalent N-H bond in ammonia highly polar. N has a significant **partial** negative charge and H has a significant **partial** positive charge. The partial positive charge of the hydrogen on one ammonia molecule causes to the partially negative charge of the nitrogen on a **neighbouring molecule** at the lone pair.
Many students did not clearly specify which N and which H were being referenced when going from describing the internal bond to describing the location of the h bond from one molecule to the next. Many students did not label the h bond as the questions prescribes.

Question 22 (3 marks) **Marks**

Write a balanced chemical equation for the reaction between the following chemicals.

Include all states.

(i) sodium sulfate and barium nitrate

..... **3**

(ii) magnesium oxide and nitric acid

.....

(1 for each correct equation, 1 for completely correct states for both)

$Na_2SO_4(aq) + Ba(NO_3)_2(aq) \rightarrow BaSO_4(s) + 2NaNO_3(aq)$

$MgO(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + H_2O(l)$