SYDNEY GRAMMAR SCHOOL

2021
ANNUAL EXAMINATION

CHEMISTRY
Form V

STRUCTURE OF PAPER

- Section I: Multiple Choice (16 marks)

  Answer all questions on the Multiple-choice Answer Sheet.

- Section II: Extended Response (77 marks)

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

- NESA-approved calculators may be used

EXAMINATION

Date: Monday 6th September, 12:55pm
Duration: 2 hours
Marks: 93

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	EJS	JLS	TW	NAL	AKBB	CXS	AHLS	MTK

Examiners: EJS, AKBB, MTK, NAL, AHLS

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SECTION I: MULTIPLE CHOICE

Attempt ALL Questions
Use the Multiple-Choice Answer Sheet.

1 What is the correct electron configuration for the ground state of a phosphorus atom?

(A) $3s^2\ 3p^3$

(B) $1s^2\ 2s^2\ 2p^3$

(C) $1s^2\ 2s^2\ 2p^6\ 3s^1\ 3p^4$

(D) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$

2 $HClO_4$ reacts with P_4O_{10} as shown in the unbalanced equation below.

$$\mathbf{W}\ HClO_4(l) + \mathbf{X}\ P_4O_{10}(s) \rightarrow \mathbf{Y}\ Cl_2O_7(l) + \mathbf{Z}\ H_3PO_4(s)$$

Which of the following gives the correct values for the coefficients **W**, **X**, **Y** and **Z**?

	W	**X**	**Y**	**Z**
(A)	12	1	6	4
(B)	12	2	6	4
(C)	6	2	4	8
(D)	6	1	2	3

3 Which property generally increases down a group but decreases from left to right across a period?

(A) atomic radius

(B) electronegativity

(C) first ionisation energy

(D) valency

4 Which of the following is correct regarding the molecule ammonia (NH_3)?

	Molecular geometry	**Are polar bonds present?**	**Is it a polar molecule?**
(A)	trigonal planar	yes	no
(B)	trigonal planar	no	yes
(C)	trigonal pyramidal	yes	yes
(D)	trigonal pyramidal	no	yes

5 What intermolecular forces exist between CH_2F_2 molecules?

(A) hydrogen bonds and dispersion forces
(B) dipole-dipole forces and dispersion forces
(C) hydrogen bonds only
(D) dipole-dipole forces only

6 When heated, potassium hydroxide decomposes according to the equation:

$$2\ KOH(s) \rightarrow K_2O(s) + H_2O(l)$$

If 1.50 g of potassium hydroxide undergoes decomposition, what mass of K_2O will be produced?

(A) 0.630 g
(B) 0.750 g
(C) 1.26 g
(D) 1.50 g

7 What is the mass of 10 sodium atoms?

(A) 3.82×10^{-23} g

(B) 3.82×10^{-22} g

(C) 7.22×10^{-25} g

(D) 7.22×10^{-26} g

8 At 25 °C and 100 kPa, a sample of air will behave as an ideal gas. If the pressure remains constant, at what temperature will the sample of air take up twice its original volume?

(A) 12.5 °C

(B) 50 °C

(C) 149 K

(D) 596 K

9 Nitric oxide gas reacts with oxygen gas to form nitrogen dioxide gas as follows:

$$2\ NO(g)\ +\ O_2(g)\ \rightarrow\ 2\ NO_2(g)$$

If 200 mL of nitric oxide undergoes a reaction with 50 mL of oxygen under constant pressure and temperature, what is the total volume of gas present at the end of the reaction?

(A) 50 mL

(B) 100 mL

(C) 150 mL

(D) 200 mL

10 Which solution will produce a precipitate when added to an aqueous solution of barium nitrate?

(A) $Na_2SO_4(aq)$

(B) $NaCl(aq)$

(C) $Mg(CH_3COO)_2(aq)$

(D) $MgBr_2(aq)$

11 Which of the following changes will **decrease** the rate of reaction between granules zinc and sulfuric acid?

(A) increasing the amount of zinc

(B) cooling the sulfuric acid

(C) grinding the zinc into a powder

(D) increasing the concentration of the sulfuric acid

12 The rate of reaction between two gases can be increased by adding a catalyst and by increasing the temperature.

Which of the following are always correct regarding increasing the temperature and the addition of a catalyst?

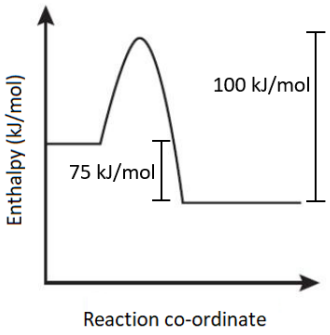
	Increasing the temperature	**Adding a catalyst**
(A)	activation energy increases	collision frequency increases
(B)	activation energy increases	percentage of successful collisions decrease
(C)	frequency of collisions increase	percentage of successful collisions decrease
(D)	frequency of collisions increase	activation energy decreases

13 100 J of heat is added to 10.0 g samples of each of the substances below. Which substance will have the greatest temperature increase?

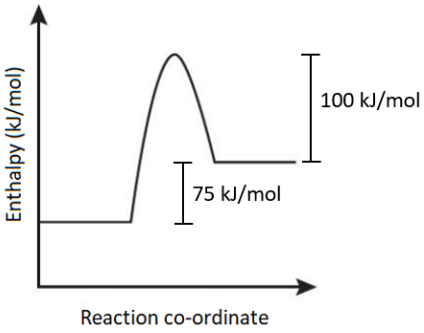
	Substance	**Specific heat capacity ($J\ g^{-1}\ K^{-1}$)**
(A)	gold	0.129
(B)	mercury	0.138
(C)	copper	0.385
(D)	water	4.18

14 Which energy profile diagram shows the forward reaction for a process that has $\Delta H = -75$ kJ mol^{-1} and an activation energy of 100 kJ mol^{-1}?

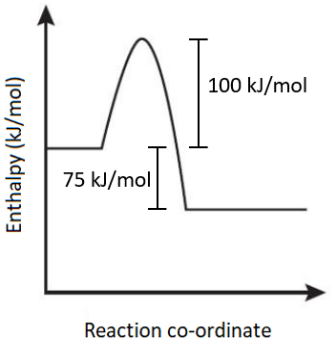
(A)



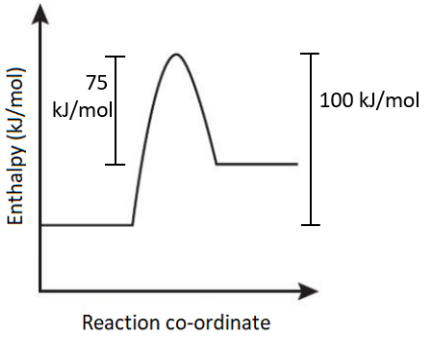
(B)



(C)



(D)



15 Which of the following is most likely to have $\Delta_r S > 0$?

(A) $Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$

(B) $2\ Br(g) \rightarrow Br_2(g)$

(C) $2\ H_2O_2(l) \rightarrow 2\ H_2O(l) + O_2(g)$

(D) $C_2H_4(g) + H_2O(l) \rightarrow C_2H_6O(l)$

16 Which of the following is correct regarding the combustion of calcium to produce calcium oxide?

The reaction:

(A) is spontaneous at all temperatures.

(B) is not spontaneous at any temperature.

(C) is spontaneous at high temperatures.

(D) is spontaneous at low temperatures.

SECTION II: Attempt ALL Questions

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

Candidate Number

Question 17 (4 marks)

Marks

Complete the table by filling in the name or formula. States are not required.

Name	Formula
	$(NH_4)_2CO_3$
	P_2O_5
iron(III) chloride	
sulfuric acid	

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Question 18 (4 marks)

Write balanced chemical equations for the following reactions.

(a) combustion of solid aluminium to produce aluminium oxide

..... **2**

(b) solid magnesium is added to an aqueous solution of copper(II) chloride

..... **2**

SECTION II: Attempt ALL Questions

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

Question 19 (4 marks) **Marks**

Complete the table below by drawing the Lewis diagram and giving the name of the molecular shape.

	Lewis diagram	**Name of molecular shape**
dichlorine monoxide		
methane		

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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 can of soft drink had the following information on the label.

Average quantity	Per serving
Energy	675 kJ
Protein	0.0 g
Fat, total	0.0 g
- saturated	0.0 g
carbohydrates	40.0 g
- sugar	40.0 g
sodium	38 mg

(a) The serving size of this soft drink is 375 mL. Calculate the concentration of sugar %(w/v) in the soft drink.

..... **1**

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(b) The sugar in the soft drink is sucrose ($C_{12}H_{22}O_{11}$). Calculate the concentration (in mol L^{-1}) of sucrose in the soft drink.

..... **3**

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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 (4 marks) **Marks**

A compound contained only carbon, hydrogen, and oxygen. It was found to be 40.0% carbon and 53.3% oxygen by mass.

(a) Determine the empirical formula of the compound.

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(b) The compound has molecular mass of 180.2 g mol^{-1}. Determine the molecular formula for the compound.

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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 (4 marks) **Marks**

Calculate the density (in g mL^{-1}) of the gas tungsten hexafluoride at 45.0 °C and 100.0 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.

Candidate Number

Question 23 (3 marks) **Marks**

Carbon-14 is an unstable isotope of carbon that is produced by cosmic rays in the upper atmosphere.

(a) Outline why this isotope is unstable.

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(b) Write the equation for the expected radioactive decay of carbon-14.

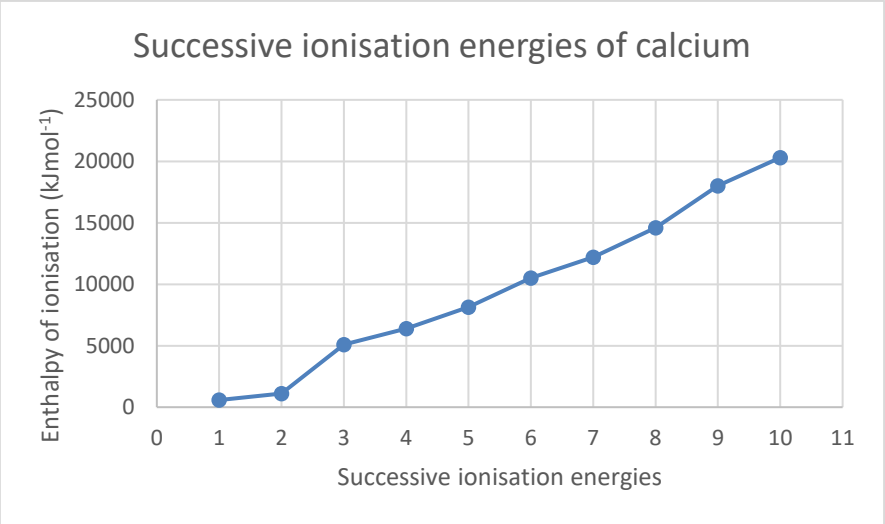
..... **2**

SECTION II: Attempt ALL Questions

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

Question 24 (4 marks) **Marks**

The graph below shows the first 10 successive ionisation energies of calcium.



(a) Give the complete electron configuration of calcium (using spdf notation).

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(b) Explain the shape of the graph.

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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 (6 marks) **Marks**

Some data for sodium, chlorine, and sodium chloride are shown below.

	Melting point (°C)	Boiling point (°C)	Electrical conductivity of solid	Electrical conductivity of liquid
sodium	97.8	883	high	high
chlorine	-102	-34.0	low	low
sodium chloride	801	1470	low	high

Explain these different properties in terms of the structure and bonding of these three substances.

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SECTION II: Attempt ALL Questions

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

Candidate Number

Question 26 (8 marks) **Marks**

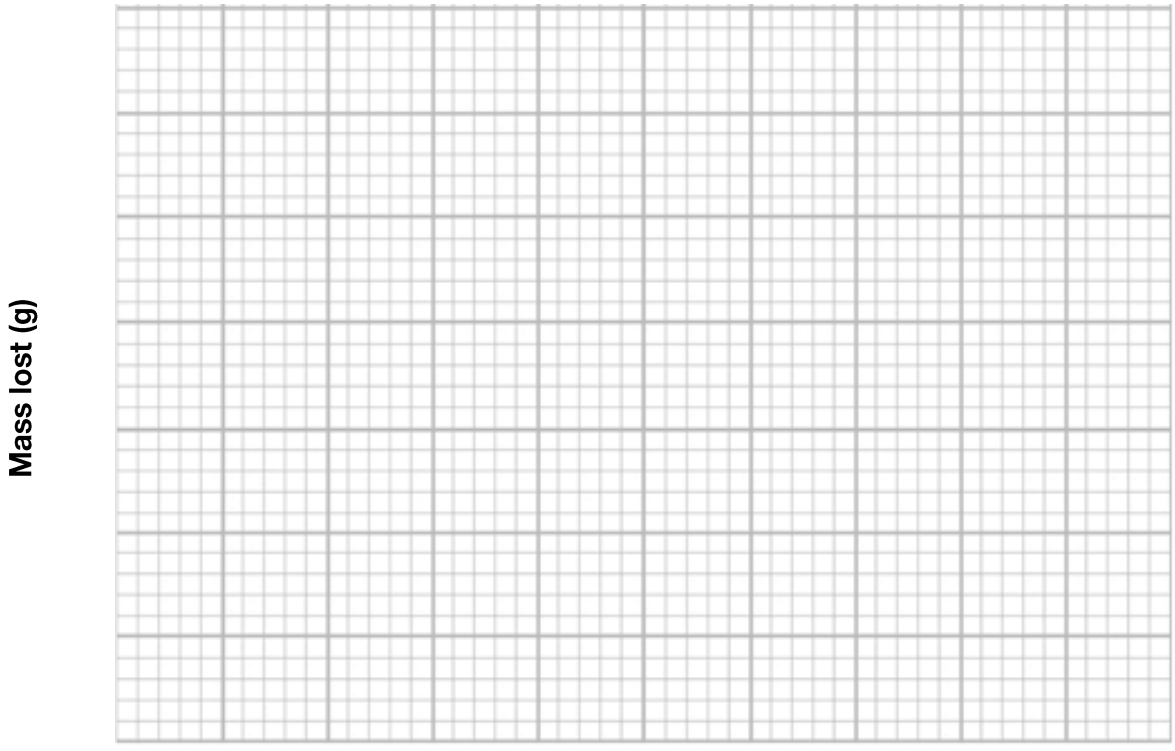
Ammonium chloride reacts with sodium nitrite to produce aqueous sodium chloride, water and nitrogen gas as shown.

$$NH_4Cl(aq) + NaNO_2(aq) \rightarrow NaCl(aq) + 2\ H_2O(l) + N_2(g)$$

In an experiment, 150.0 mL of 1.50 M ammonium chloride solution was added to 200.0 mL of 1.00 M sodium nitrite solution. The reaction was monitored for 80 seconds, and the mass lost from the reaction vessel was recorded below.

Time (s)	0	10	20	30	40	50	60	70	80
Mass lost (g)	0	2.3	3.6	4.4	5.0	5.4	5.6	5.6	5.6

a) Graph these results on the axes below.



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Question continued on next page

Question continued **Marks**

b) Explain the overall shape of the graph seen in (a). **3**

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(c) In a second experiment, the concentration of the ammonium chloride used was **decreased**, so that 150.0 mL of 1.00 M ammonium chloride solution was added to 200.0 mL of 1.00 M sodium nitrite solution and the mass lost was monitored.

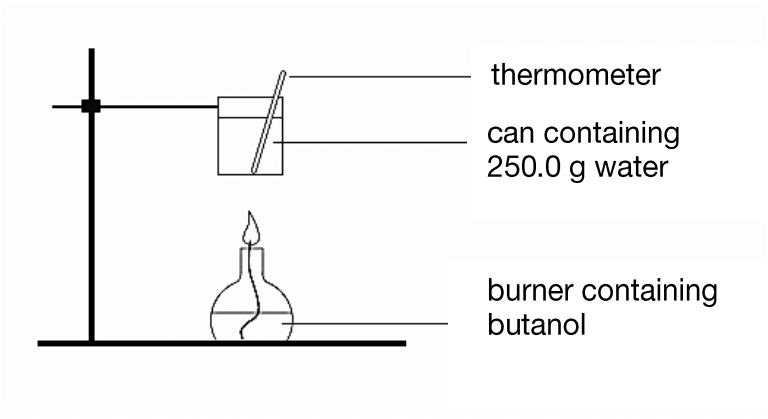
On the axes in (a), sketch the expected result of this second experiment. **2**

SECTION II: Attempt ALL Questions

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

Question 27 (5 marks) **Marks**

250.0 g of water was heated in a calorimeter (as shown below) to measure the heat of combustion of butanol ($C_4H_{10}O$). The initial temperature of the water was 22.0 °C, the final temperature was 41.0 °C, and the mass of butanol burnt was 1.050 g.



(a) Write a balanced chemical equation for the complete combustion of butanol.

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(b) Calculate the enthalpy of combustion measured for butanol (in kJ mol^{-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.

Question 28 (6 marks) **Marks**

An equation for the production of ammonia is shown below, together with some standard entropy data.

$$\tfrac{1}{2}\ N_2(g) + \tfrac{3}{2}\ H_2(g) \rightarrow NH_3(g) \qquad \Delta H = -46.2\ kJ\ mol^{-1}$$

	$N_2(g)$	$H_2(g)$	$NH_3(g)$
$S°$ ($J\ K^{-1}\ mol^{-1}$)	192	131	193

(a) Predict whether entropy would increase or decrease for this reaction, justifying your response. **1**

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(b) Calculate a value for the entropy change, $\Delta_f S$, for the formation of 1 mole of ammonia (in $J\ K^{-1}\ mol^{-1}$). **2**

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(c) Calculate the temperature (in K) at which the value of Gibbs Energy, $\Delta_f G$, will be equal to 0 for the formation of 1 mole of ammonia. **3**

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SECTION II: Attempt ALL Questions

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

Candidate Number

Question 29 (8 marks) **Marks**

A student wanted to identify an unknown ionic compound with the formula $XCl_2 \bullet yH_2O$.

First, they heated 8.000 g of the hydrated compound over a Bunsen flame until a constant mass of 4.760 g was reached.

(a) Calculate the amount (in mol) of water contained in 8.000 g of the hydrated compound.

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Next, they dissolved the remaining 4.760 g in 50 mL water and added excess aqueous sodium carbonate. They filtered and dried the precipitate, and found it had a mass of 4.433 g.

(b) Write a balanced chemical equation for this reaction (use X to represent the cation).

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(c) Use this information to identify the metal X and the formula of the hydrated compound.

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Metal X	Formula of hydrated compound

SECTION II: Attempt ALL Questions

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

Question 30 (6 marks) **Marks**

Water can be decomposed into its elements using electrolysis. Given the following information on average bond energies:

Bond	Average bond enthalpy (kJ mol^{-1})
O-O	144
O=O	498
O-H	463
H-H	436

(a) Calculate the energy (in kJ) required to decompose 100.0 g of water.

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(b) Would you expect boiling 100 g of water to use more or less energy than the value calculated in part (a)? Justify your choice.

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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 (7 marks) **Marks**

Compound **X** is an ionic compound that can be used as a fertiliser. It is commonly produced from calcium carbonate by the three-step reaction sequence shown.

Step 1: 10.00 g of calcium carbonate is heated strongly to produce metal oxide **A** and a colourless gas **B**.

Step 2: All of the metal oxide **A** produced in Step 1 reacts with 3.600 g of carbon to produce two products; **C** and 2.477 L of gaseous **D** (measured at 25 °C and 100 kPa). **C** is 37.47% carbon by mass.

Step 3: All of **C** produced in Step 2 then reacts with 2.477 L of gaseous element **E** (measured at 25 °C and 100 kPa) to produce 8.004 g compound **X** and 1.200 g element **F**. Compound **X** is 14.99% carbon by mass.

(a) Write a balanced chemical equation for Step 1, clearly identifying **A** and **B**.

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(b) Identify **C**-**F** and compound **X**, showing all relevant calculations and logic.

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C	D	E	F	Compound X

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

2021
FORM V ANNUAL EXAMINATION

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 ●		9.	A ○	B ○	C ○	D ●	
2.	A ●	B ○	C ○	D ○		10.	A ●	B ○	C ○	D ○	
3.	A ●	B ○	C ○	D ○		11.	A ○	B ●	C ○	D ○	
4.	A ○	B ○	C ●	D ○		12.	A ○	B ○	C ○	D ●	
5.	A ○	B ●	C ○	D ○		13.	A ●	B ○	C ○	D ○	
6.	A ○	B ○	C ●	D ○		14.	A ○	B ○	C ●	D ○	
7.	A ○	B ●	C ○	D ○		15.	A ○	B ○	C ●	D ○	
8.	A ○	B ○	C ○	D ●		16.	A ○	B ○	C ○	D ●	

SECTION II: Attempt ALL Questions

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

Candidate Number

Question 17 (4 marks)

Marks

Complete the table by filling in the name or formula. States are not required.

Name	Formula
ammonium carbonate	$(NH_4)_2CO_3$
diphosphorus pentoxide	P_2O_5
iron(III) chloride	$FeCl_3$
sulfuric acid	H_2SO_4

4

Question 18 (4 marks)

Write balanced chemical equations for the following reactions.

(a) combustion of solid aluminium to produce aluminium oxide

$4Al(s) + 3O_2(g) \rightarrow 2Al_2O_3(s)$ **2**

OR $2Al(s) + \frac{3}{2}O_2(g) \rightarrow Al_2O_3(s)$

(b) solid magnesium is added to an aqueous solution of copper(II) chloride

$Mg(s) + CuCl_2(aq) \rightarrow MgCl_2(aq) + Cu(s)$ **2**

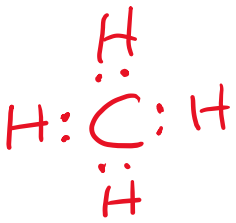
for each:
① mark for correct formulae of substances
① mark for correct balancing based on formulae

SECTION II: Attempt ALL Questions

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

Question 19 (4 marks) **Marks**

Complete the table below by drawing the Lewis diagram and giving the name of the molecular shape.

	Lewis diagram	Name of molecular shape
dichlorine monoxide		**Bent**
methane		**Tetrahedral**

4

* Dots and/or crosses and/or line representing bonding pair accepted
* Must include lone pairs for OCl_2

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 can of soft drink had the following information on the label.

Average quantity	Per serving
Energy	675 kJ
Protein	0.0 g
Fat, total	0.0 g
- saturated	0.0 g
carbohydrates	40.0 g
- sugar	40.0 g
sodium	38 mg

(a) The serving size of this soft drink is 375 mL. Calculate the concentration of sugar %(w/v) in the soft drink. **1**

$= \frac{40\,g}{375\,mL} \times 100 = 10.67\%\,(w/v)$

$= 10.7\%\,(w/v)$

(b) The sugar in the soft drink is sucrose ($C_{12}H_{22}O_{11}$). Calculate the concentration (in mol L^{-1}) of sucrose in the soft drink. **3**

$n(C_{12}H_{22}O_{11}) = \frac{m}{MM}$ $MM = 342.296\,g\,mol^{-1}$

$= \frac{40}{342.296}$

$= 0.116857924\,1\,mol$ (1)

$c = \frac{n}{V} = \frac{0.116857924\,1\,mol}{0.375\,L}$

$= 0.311621131\,mol\,L^{-1}$ (1)

$= 0.312\,mol\,L^{-1}$ (3 sig figs) (1) for correct sig figs

SECTION II: Attempt ALL Questions

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

Question 21 (4 marks) **Marks**

A compound contained only carbon, hydrogen, and oxygen. It was found to be 40.0% carbon and 53.3% oxygen by mass.

(a) Determine the empirical formula of the compound. **3**

	C	O	H
% mass	40	53.3	6.7 (1)
÷ MM	12.01	16	1.008 (1)
moles	3.33	3.33	6.65
ratio	1	1	2

CH_2O (1)

(b) The compound has molecular mass of 180.2 g mol^{-1}. Determine the molecular formula for the compound. **1**

$C_6H_{12}O_6$

SECTION II: Attempt ALL Questions

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

Question 22 (4 marks) **Marks**

WF_6

Calculate the density (in g mL^{-1}) of the gas tungsten hexafluoride at 45.0 °C and 100.0 kPa.

$PV = nRT$ **4**

$\frac{n}{V} = \frac{P}{RT}$

$\frac{n}{V} = \frac{100kPa}{8.314 L \cdot kPa\, mol^{-1} K^{-1} \times 318.15K}$ (1) or 318K

$\frac{n}{V} = 0.037805769\ mol\,L^{-1}$ (1)

$\frac{n}{V} \times MM = \frac{m}{V}$ $MM = 183.9 + 6 \times 19$

$= 297.9\ g\,mol^{-1}$

$\frac{m}{V} = 0.037805769\ mol\,L^{-1} \times 297.9\ g\,mol^{-1}$

$= 11.262333796\ g\,L^{-1}$ (1) $\div 1000$

density $= 0.011262333796\ g\,mL^{-1}$ (1) or convert to mL^{-1} earlier

$= 0.0113\ g\,mL^{-1}$

Question 23 (3 marks) **Marks**

Carbon-14 is an unstable isotope of carbon that is produced by cosmic rays in the upper atmosphere.

(a) Outline why this isotope is unstable.

For smaller elements the most stable ratio of protons to neutrons is 1:1. Carbon -14 has 6 protons and 7 neutrons and is consequently unstable

Too many neutrons relative to the number of protons

There is not a 1:1 ratio of protons to neutrons **1**

(b) Write the equation for the radioactive decay of carbon-14.

.....

1 mark for identifying Beta decay

1 mark for correctly balanced equation **2**

Question 24 (4 marks) **Marks**

(a) Give the complete electron configuration of calcium.

$1S^2, 2S^2, 2P^6, 3S^2, 3P^6, 4S^2$ **1**

(b) Explain the shape of the of the graph.

Marks	Answer must include
3	Definition of ionisation energy as well as clear and unambiguous explanation of general increase in successive ionisation energies AND jump between 2nd and 3rd energies.
2	As above with ambiguities/details missing OR only 2 out of the three concepts explained clearly.
1	Any correct statement about ionisation energy or basic explanation of trend shown.

Sample answer

The first ionisation energy is a measure of the amount of energy required to remove an electron from a neutral atom of an element OR state that it requires energy to remove an electron. - **This was badly done or not at all!**

Successive ionisation energies will be increasingly great as it becomes increasingly difficult to remove electrons from increasingly positively charged species

There is a large increase between the 2nd and 3rd ionisation energies as calcium contains 2 electrons in its outer shell. The 3rd ionisation energy therefore represents removal of an electron from an inner shell. As there are now less inner shells these electrons which are less shielded and therefore more tightly held, thus requiring considerably more energy to remove.

- *(There seems to be a lot of confusion amongst the boys about the definition of Effective Nuclear Charge. The effective nuclear charge is the net positive charge experienced by valence electrons. It can be approximated by the equation: $Z_{eff} = Z - S$, where Z is the atomic number and S is the number of shielding electrons. Many boys tried to argue that successive ionisation energies increase due to electron shielding decreasing and/or the effective nuclear charge increasing. Whilst this may be true when removing electrons from a new inner shell it is not true as a general principle of successive ionisation energies)*

3

Question 25 (6 marks) **Marks**

Some data for sodium, chlorine, and sodium chloride are shown below.

	Melting point (°C)	**Boiling point (°C)**	**Electrical conductivity of solid**	**Electrical conductivity of liquid**
Sodium	97.8	883	high	high
Chlorine	-102	-34.0	low	low
Sodium chloride	801	1470	low	high

Explain these different properties in terms of the structure and bonding of these three substances.

Marks	**Answer must include**
6	Detailed **explanation** of the structure and bonding of all 3 chemical substances and how these affect the MP, BP and electrical conductivity of these substances.
5	Same as above BUT missing **one explanation** of structure or bonding or their effect on **one** of the properties.
4	Able to **explain** structure **AND** bond types of **two** species and **link** each species to **one** relevant property.
3	Able to **explain** structure and bond type of **one** species and link it to **one** specific property **OR** Able to state **either** the structure **OR** bond types of **two** species **AND** link **one** property to each species.
2	Able to link a correct structure (or bond type-dispersion) to **one** of the species **OR** link **one** property to a given structure or bond type.
1	Able to identify **one** relevant structure or bond type **OR** identify a process associated with **one** of the properties.

The following abbreviations have been used to identify missing or inadequately detailed pieces of information from an answer.

S – structure B – bonding MP – melting point BP – boiling point C- conductivity

Na – sodium Cl – chlorine NaCl – sodium chloride

So for instance an answer inadequately detailing a discussion of sodium conductivity would be signified by Na-C

SAMPLE ANSWER on next page

SAMPLE ANSWER

*Chlorine is composed of diatomic molecules with a shared pair of electrons (known as a covalent bond) holding the atoms of the molecule together. The molecules, which are not charged, are attracted to each other by weak intermolecular dispersion forces.

It doesn't take much energy to weaken and ultimately break dispersion forces accounting for the low melting and boiling points of the chlorine molecules. As there are no charged particles involved chlorine does not conduct electricity.

*Sodium is a metal. Metals consist of a lattice of cations awash in a sea of delocalised electrons. The electrons act as a sort of glue or electrostatic attraction to hold the lattice together. This is known as metallic bonding.

This electrostatic glue is not terribly strong and as such metals tend to have midrange MP and BP. The delocalised electrons are free to migrate through the lattice of cations accounting for the electrical conductivity of metals

*Sodium Chloride is an ionic compound composed of alternating cations and anions. The electrostatic attraction between these differently charged ions is known as an ionic bond.

Ionic bonds are quite strong with each ion being held in place by several oppositely charged ions around it. This means that a great deal of energy is required to break these bonds resulting in high MP and BP. As a solid these charged ions are held rigidly in a lattice and are therefore not free to migrate and conduct a charge. When in the liquid state however these ions are free to migrate and in so doing conduct electricity.

Question 26 (9 marks) **Marks**

Ammonium chloride reacts with sodium nitrite to produce aqueous sodium chloride, water and nitrogen gas as shown.

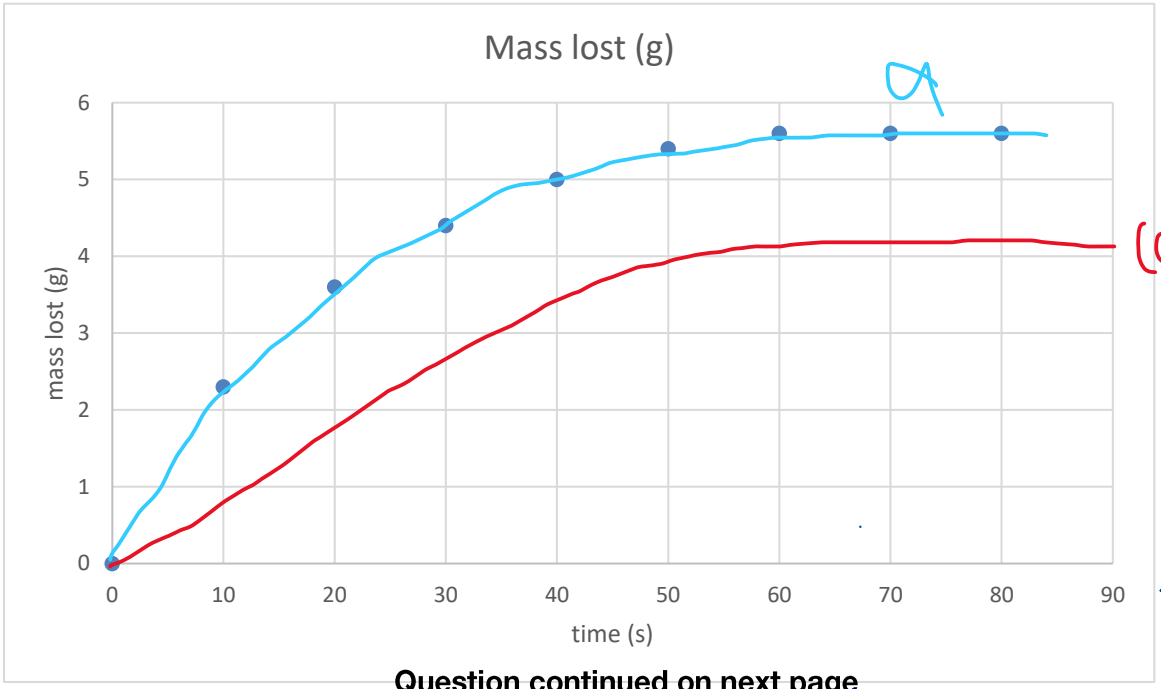
$$NH_4Cl(aq) + NaNO_2(aq) \rightarrow NaCl(aq) + 2\,H_2O(l) + N_2(g)$$

In an experiment, 150.0 mL of 1.50 M ammonium chloride solution was added to 200.0 mL of 1.00 M sodium nitrite solution. The reaction was monitored for 80 seconds, and the mass lost from the reaction vessel was recorded below.

Time (s)	0	10	20	30	40	50	60	70	80
Mass lost (g)	0	2.3	3.6	4.4	5.0	5.4	5.6	5.6	5.6

a) **Graph these results on the axes below.**

Some students misinterpreted this as a limiting reagent graph – it is not as the x axis is time therefore RR.



A

(C)

4

3

Question continued on next page

1 mark – appropriate scale (axis labels on the)
1 mark – accurate points
1 mark – appropriate curve of best fit.

Question continued **Marks**

b) **Explain the overall shape of the graph seen in (a).**

Marks	Criteria
3	Identifies that the slope of the graph changes and indicates a reduction in the reaction rate Relates the reduction in the rate of reaction to the decrease in concentration of the reactants as the reaction progresses Identify that the reaction stops.
2	Identifies that the reaction changes its rate due to the shape of the graph. Identifies that the reaction stops
1	Describes something correct about their graph.

Sample answer

1) initially fast reaction rate as (mass loss)/(time) represented by the gradient is steep. This is due to near full concentration of both reactants.

2) As the reaction proceeds the concentration of the reactants decreases, this leads to a slower reaction rate seen in the reduction of the gradient.

3) all of the $NaNO_2$ is used up (limiting reagent) so the reaction has finished and no more mass is lost from the reaction OR reaction is complete. Gradient = 0 reaction rate = 0

IF a straight line is drawn: answers still must have discussed reaction rate/concentration to get 3/3, this was difficult as there was only 2 points on the graph or the discussion was about limiting reagent only.

Many students did not identify **concentration link to reaction rate**, but rather they identified "amount" instead. Strictly speaking concentration is the quantity linked to RR.

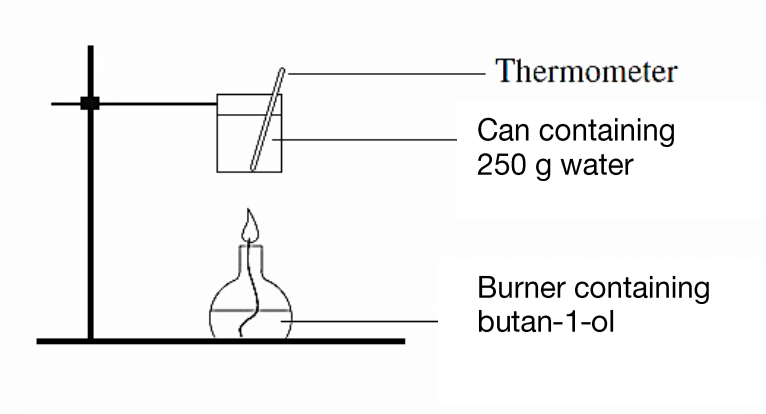
(c) In a second experiment, the concentration of the ammonium chloride used was reduced, so that **150.0 mL of 1.00 M ammonium chloride solution was added to 200.0 mL of 1.00 M sodium nitrite solution and the mass lost was monitored.**

On the axes in (a), sketch the expected result of this second experiment.
2

1 mark each
1) slower reaction rate, smaller gradient to start (lower conc of reactants)
2) end point 4.2 g of mass lost (N_2) due to NH4Cl being limiting reagent
(should have same general shape steep (but less steep than original), then flattening out at 4.2)

Question 27 (5 marks) **Marks**

250.0 g of water was heated in a calorimeter (as shown below) to measure the heat of combustion of butanol ($C_4H_{10}O$). The initial temperature of the water was 22.0 °C, the final temperature was 41.0 °C, and the mass of butanol burnt was 1.050 g.



(a) Write a balanced chemical equation for the complete combustion of butanol.

$C_4H_{10}O(l) + 6\ O_2(g) \rightarrow 4\ CO_2(g) + 5\ H_2O(l)$ **1** no states marked

(b) Calculate the enthalpy of combustion measured for butanol (in kJ mol^{-1}).

1) q = 250 x 4.18 x 19 = 19855J, 19.9kJ (1 mark)

2) moles of butanol: M=74.12, n=1.050/74.12 = 0.01417 (1 mark)

3) ΔH = -19.9/0.01417 = -1404 kj/mol

(2 marks 1 working, **1 correct answer including negative sign)**

ECF available with working.

Many students forgot the negative sign for exothermic enthalpy.

Question 28 (6 marks) **Marks**

An equation for the production of ammonia is shown below, together with some entropy data.

$$\tfrac{1}{2}\ N_2(g) + 3/2\ H_2(g) \rightarrow NH_3(g) \qquad \Delta H = -46.2\ kJ\ mol^{-1}$$

	$N_2(g)$	$H_2(g)$	$NH_3(g)$
S ($J\ K^{-1}\ mol^{-1}$)	192	131	193

(a) Predict whether entropy would increase or decrease for this reaction, justifying your response.

1) Entropy will decrease: 2 mol of gas → 1 mol gas
decrease in **gaseous moles**

many students did not identify that the reason is due to the reduction of gas moles.

(b) Calculate a value for the entropy change, ΔS, for the formation of 1 mole of ammonia.

ΔSr = sumΔSp – sumΔSr

1) ΔSr = 193 – (½ x 192 + 3/2x131) (substitute into correct formula)

2) ΔSr = -99.5J/K/mol (-0.0995 kJ/K/mol) (correct answer)

(ecf available with working)

Some students forgot the multiply by the molar coefficients.

(c) Calculate the temperature at which the value of Gibbs Energy, ΔG, will be equal to 0 for the formation of 1 mole of ammonia.

1) correct equation
ΔG = ΔH – TΔS, ΔG = 0, ΔH = TΔS, **ΔH/ΔS =T**

2) correct substitution (especially dS)
-46.2/-0.0995 = T

3) correct answer = 464K

Ecf with appropriate working.

Some students forgot to convert S to kJ units.

SECTION II: Attempt ALL Questions

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

Candidate Number

Question 29 (8 marks) **Marks**

A student wanted to identify an unknown ionic compound with the formula $XCl_2 \bullet yH_2O$.

First, they heated 8.000 g of the hydrated compound over a Bunsen flame until a constant mass of 4.760 g was reached.

(a) Calculate the amount (in mol) of water contained in 8.000 g of the hydrated compound. **2**

$m(H_2O) = 8.000 - 4.760 = 3.240\ g$ (1)

$n(H_2O) = \frac{3.240}{1.008 \times 2 + 16} = 0.1798\ mol$ (1)

Next, they dissolved the remaining 4.760 g in 50 mL water and added excess aqueous sodium carbonate. They filtered and dried the precipitate, and found it had a mass of 4.433 g.

(b) Write a balanced chemical equation for this reaction (use X to represent the cation). **1**

$XCl_{2(aq)} + Na_2CO_{3(aq)} \rightarrow 2NaCl_{(aq)} + XCO_{3(s)}$

(states not marked)

(c) Use this information to identify the metal X and the formula of the hydrated compound. **5**

$m(XCO_3) = 4.433g$ $\quad m(XCl_2) = 4.760g$

$n(XCO_3) = \frac{4.433}{X + 60.01}$ $\quad n(XCl_2) = \frac{4.760}{X + 70.9}$ ← (1)

(1) → $n(XCO_3) = n(XCl_2) \therefore \frac{4.433}{X + 60.01} = \frac{4.760}{X + 70.9}$

(1) $X = 87.62 \therefore X$ is strontium

$n(SrCl_2) = \frac{4.760}{158.51} = 0.0300\ mol$ (1)

$n(H_2O) = 0.1798 \therefore SrCl_2 : H_2O$

$1 : 6$ (1)

Metal X	Formula of hydrated compound
Sr	$SrCl_2 \cdot 6H_2O$

SECTION II: Attempt ALL Questions

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

* students could still get correct answer using $2H_2O \rightarrow 2H_2 + O_2$

Question 30 (6 marks) **Marks**

Water can be decomposed into its elements using electrolysis. Given the following information on average bond energies: but they needed to recognise this value is for 2 moles H_2O.

Bond	Average bond enthalpy (kJ mol^{-1})
O-O	144
O=O	498
O-H	463
H-H	436

(a) Calculate the energy (in kJ) required to decompose 100.0 g of water.

4

* (1)

$H_2O \rightarrow H_2 + \frac{1}{2}O_2$ (1)

$2 \times OH$ $1 \times H\text{-}H$ $\frac{1}{2} \times O=O$ $\therefore 926 - 685$

2×463 $1 \times 436 + \frac{1}{2} \times 498$ $= 241$ kJ per 1 mole (as in equation)

$= 926$ $= 685$

$n(H_2O) = \frac{100}{18.016} = 5.55$ mol (1)

$\therefore$ energy $= 241$ kJ/mol $\times 5.55$ mol (1)

$= 1340$ kJ (per 100g)

(b) Would you expect boiling 100 g of water to use more or less energy than the value calculated in part (a)? Justify your choice.

2

(1) less

(1) boiling breaks intermolecular forces (hydrogen bonds) which are weaker than covalent bonds broken in (a)

SECTION II: Attempt ALL Questions

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

Question 31 (7 marks) **Marks**

Compound **X** is an ionic compound that can be used as a fertiliser. It is commonly produced from calcium carbonate by the three-step reaction sequence shown.

Step 1: 10.00 g of calcium carbonate is heated strongly to produce metal oxide **A** and a colourless gas **B**.

Step 2: All of the metal oxide **A** produced in Step 1 reacts with 3.600 g of carbon to produce two products; **C** and 2.477 L of gaseous **D** (measured at 25 °C and 100 kPa). **C** is 37.47% carbon by mass.

Step 3: All of **C** produced in Step 2 then reacts with 2.477 L of gaseous element **E** (measured at 25 °C and 100 kPa) to produce 8.004 g compound **X** and 1.200 g element **F**. Compound **X** is 14.99% carbon by mass.

(a) Write a balanced chemical equation for Step 1, clearly identifying **A** and **B**. **2**

$CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$

A B

(b) Identify **C**-**F** and compound **X**, showing all relevant calculations and logic. **5**

5 marks - all correct + valid working

4 marks - 4 correct + valid working

3 marks - at least 2 correct with logical molar calcs

2 marks - at least 1 correct with working

1 mark - any reasonable attempt

C	D	E	F	Compound X
CaC_2	CO	N_2	C	$CaCN_2$

Sample working 31 (b)

$n(\mathbf{A}/CaO) = 0.09991$ mol

$n(C) = 0.2998$ mol

possible gases: CO_2 ← B, CO, O_2

$\therefore CaO + 3C \rightarrow \mathbf{C} + \mathbf{D}$

$n(\mathbf{D}) = \frac{2.477}{24.79} = 0.09991$ mol

since $CaO : \mathbf{D} = 1:1$, must be CO

$\mathbf{C} = CaC_2$ (from balanced equation + matches % data)

$CaC_2 + \mathbf{E} \rightarrow \mathbf{F} + \mathbf{X}$

$m(\mathbf{E}) = (8.004 + 1.200) - m(CaC_2)$

$= 2.7998$ g

$\therefore mM(\mathbf{E}) = 28$ $\therefore \mathbf{E} = N_2$

using equation balancing

$\mathbf{F} = C$ & $\mathbf{X} = CaCN_2$

(matches % data)