SYDNEY GRAMMAR SCHOOL

2022
ANNUAL EXAMINATION

CHEMISTRY
Form V

STRUCTURE OF PAPER

Section I: Multiple Choice (15 marks)

Answer all questions on the Multiple-choice Answer Sheet.

Section II: Extended Response (65 marks)

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

NESA-approved calculators may be used

EXAMINATION

Date: Wednesday 31st August, 8:40 am

Duration: 2 hours

Marks: 80

CHECKLIST

Each boy should have the following:

1 Examination Paper

1 Multiple Choice Answer Sheet

1 Data and Formula Sheet

Master In Charge CXS

EXAM INSTRUCTIONS

Remove the centre staple and hand in all parts of the paper, in order, in one bundle.

CLASS NUMBER	1	2	3	4	5	6	7	8
Class	5CY201	5CY202	5CY203	5CY204	5CY205	5CY206	5CY207	5CY208
Masters Initials	AKBB	TW	MTK	CXS	EJS	CXS	AHLS	JLS

WRITE YOUR **CANDIDATE NUMBER** IN THE SPACE PROVIDED AT THE TOP OF EACH SEPARATE SECTION.

Examiners: CXS, EJS, JLS, AHLS

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SECTION I: MULTIPLE CHOICE

Attempt ALL Questions
Use the Multiple-Choice Answer Sheet.

1 Sodium undergoes rapid corrosion. Which of the following will increase the rate of the corrosion of sodium?

(A) Storing it in oil

(B) Storing in the fridge

(C) Increasing the surface area of the sodium

(D) Storing it in a nitrogen atmosphere

The following table gives information about the protons and neutrons found in four atoms. Use this information to answer questions 2 to 4.

	protons	neutrons
W	10	10
X	11	12
Y	12	11
Z	11	11

2 Which pair are isotopes?

(A) X and Z

(B) X and Y

(C) Y and Z

(D) W and Z

3 Which atom/s are likely to form cations?

(A) X only

(B) X and Y only

(C) Y and Z only

(D) X, Y and Z

4 Which atoms are **most** likely to be unstable and undergo radioactive decay?

(A) X and Z

(B) X and Y

(C) Y and Z

(D) W and Z

5 A transition metal ion X^{3+} has the electronic configuration [Ar]$3d^4$. What is the atomic number of element X?

(A) 22

(B) 24

(C) 25

(D) 27

6 Which of the following contains the lowest concentration of sodium ions?

(A) 0.20 M $Na_3C_6H_5O_7$

(B) 0.35 M Na_2CO_3

(C) 0.50 M NaCl

(D) 0.65 M NaBr

7 The volume of a gas measured at 27°C and 100 kPa is 20.0 L. What final temperature would be required to increase the volume to 40.0 L at 100 kPa?

(A) 54°C

(B) 300°C

(C) 327°C

(D) 600°C

8 Two elements X and Y have the following successive ionisation energies

	Ionisation energy ($kJmol^{-1}$)						
	1st	2nd	3rd	4th	5th	6th	7th
X	1011	1900	2910	4960	6270	21300	25400
Y	737	1250	7730	10500	13600	18000	21700

Which is the most likely formula for the compound that forms between X and Y?

(A) X_3Y_2

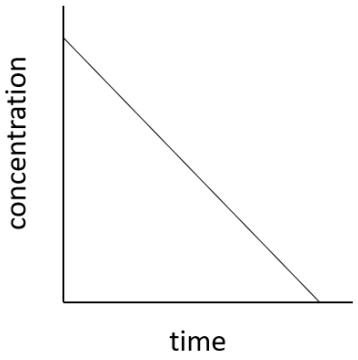
(B) X_3Y

(C) Y_2X

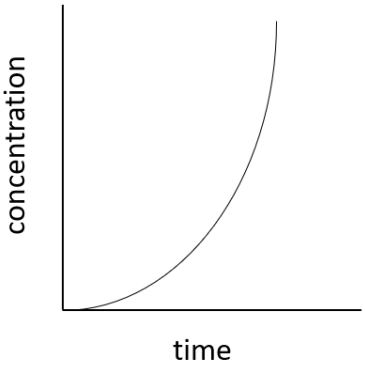
(D) Y_3X_2

9 Which graph best represents the change in concentration of products over time for a reaction as it goes to completion?

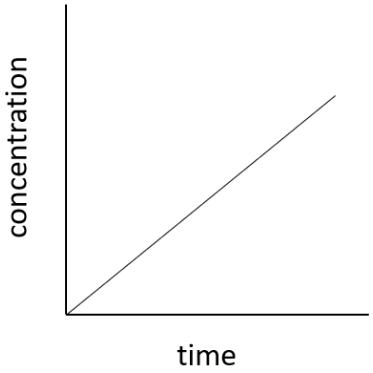
(A)



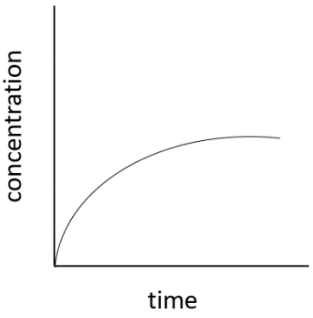
(B)



(C)



(D)



10 Which of the following molecules contains polar bonds but is **not** a polar molecule?

(A) NH_3

(B) SO_2

(C) CCl_4

(D) PCl_3

11 Which of the following contains molecules that exhibit dispersion forces only?

(A) Carbon dioxide, chlorine gas, methane

(B) Fluorine gas, methane, water

(C) Ammonia, carbon dioxide, hydrochloric acid

(D) Carbon monoxide, hydrogen disulfide, silicon dioxide

12 What would happen to the pressure of a given mass of gas when its absolute temperature and volume are both doubled?

(A) Increase by a factor of 2

(B) Decrease by a factor of 2

(C) Stay the same

(D) Cannot tell from the information provided.

13 How many hydrogen atoms are present in 10.0 g of ammonium sulfate?

(A) 4.56×10^{22}

(B) 9.11×10^{22}

(C) 1.82×10^{23}

(D) 3.65×10^{23}

14 3.0 g of magnesium was added to excess 1.10 mol L^{-1} hydrochloric acid.

What is the mass of the gas produced?

(A) 0.12 g

(B) 0.25 g

(C) 2.22 g

(D) 5.43 g

15 A brand of fertiliser states that its phosphate content is 23% by mass.

A boy wanted to check if this statement was true. He completely dissolved 2.5 g of the fertiliser in water and then reacted it with excess $Al(NO_3)_3$.

What is the expected mass of precipitate that would be formed?

(A) 0.16 g

(B) 0.74 g

(C) 1.07 g

(D) 3.21 g

SECTION II: 65 marks

Attempt ALL Questions
Write your answer in the space provided.

CANDIDATE NUMBER

Question 16 (2 marks) **Marks**

Give the full electron configuration for the following:

(i) K **1**

(ii) Ca^{2+} **1**

Question 17 (2 marks)

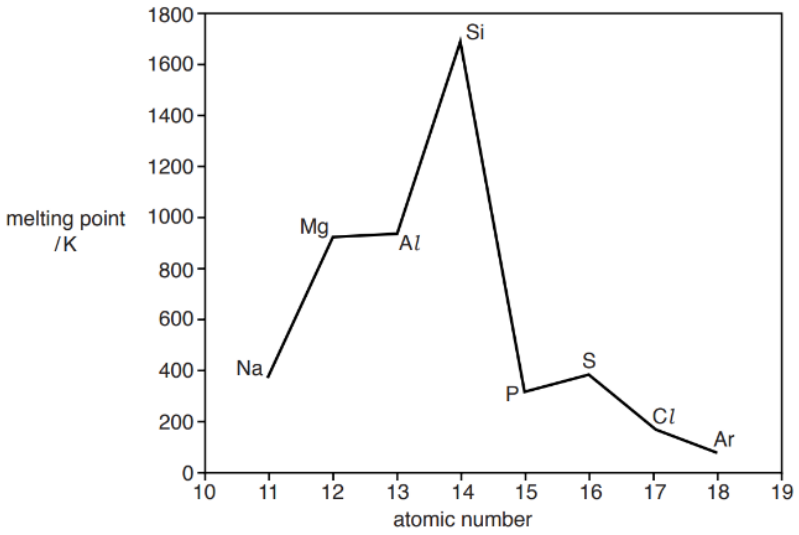
Write a balanced chemical equation for each of the following chemical reactions;

(i) Potassium metal reacting with chlorine gas. **1**

(ii) Sodium hydrogen carbonate reacting with nitric acid. **1**

Question 18 (4 marks) **Marks**

The graph shows the melting points of elements in period 3 of the Periodic table.



(a) Explain why magnesium has a higher melting point than sodium. **2**

(b) Explain why argon has a lower melting point than chlorine. **2**

Question 19 (5 marks) **Marks**

During an experiment, 3.80 g of solid sodium hydroxide was added to 150.0 g of water with an initial temperature of 23.5°C. After the solid completely dissolved, the final temperature of the solution was 28.0°C.

(a) Calculate the molar enthalpy of solution for sodium hydroxide (in kJ mol^{-1}). **4**

(b) The theoretical molar enthalpy of solution is -44.5 kJ mol^{-1}. Provide a reason for the difference between the theoretical and experimental values. **1**

Question 20 (5 marks) **Marks**

(a) Aqueous XO_4^{3-} ions form a precipitate with aqueous silver ions, Ag^+. Write a balanced equation for the reaction, including state symbols. **1**

(b) When 41.17 mL of a solution of aqueous silver ions with a concentration of 0.2040 mol L^{-1} is added to a solution of excess XO_4^{3-} ions, 1.172 g of the precipitate is formed.

(i) Calculate the amount (in moles) of Ag^+ ions used in the reaction. **1**

(ii) Calculate the amount (in moles) of precipitate formed. **1**

(iii) Calculate the molar mass of the precipitate. **1**

(iv) Determine the relative atomic mass of X and identify the element. **1**

CANDIDATE NUMBER

Question 21 (6 marks) **Marks**

Below are some properties of aluminium fluoride and aluminium bromide.

	Melting point (°C)	Conductivity in liquid state
AlF_3	1265	High
$AlBr_3$	98	low

(i) Classify each compound as ionic or covalent molecular. Justify and explain your answer using information from the table. **4**

(ii) Explain, referring to relative electronegativities, the differences in bonding seen for these two aluminium halides. **2**

Question 22 (5 marks) **Marks**

Methanol, $CH_3OH(g)$ can be produced by the reaction between carbon dioxide and hydrogen.

$$CO_2(g) + 3\ H_2(g) \rightarrow CH_3OH(g) + H_2O(g)$$

The table below gives the enthalpy of formation and entropy data for the substances involved in the reaction.

	$CO_2(g)$	$H_2(g)$	$CH_3OH(g)$	$H_2O(g)$
$\Delta_f H$ / kJ mol^{-1}	-394	0	-201	-242
S / J K^{-1} mol^{-1}	214	131	238	189

(i) Calculate the Gibbs free-energy change, ΔG, in kJ mol^{-1}, for this reaction at 298 K to show that this reaction will not be spontaneous at this temperature. **4**

(ii) Show that the reaction becomes spontaneous at 272 K. **1**

Question 23 (5 marks) **Marks**

(i) List the following covalent molecular substances in order of increasing boiling point (lowest first). **1**

C_2H_6 CH_3OH CH_3F

(ii) Explain the order of boiling points in (i). **4**

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CANDIDATE NUMBER

Question 24 (8 marks) **Marks**

Hydrazine, N_2H_4, is an inorganic compound found in some rocket fuel.

(a) Hydrazine is described as having a *covalent molecular* structure.

(i) Describe what is meant by the terms *covalent* and *molecular* in this context. **2**

(ii) Draw a Lewis dot diagram/structure for hydrazine. **2**

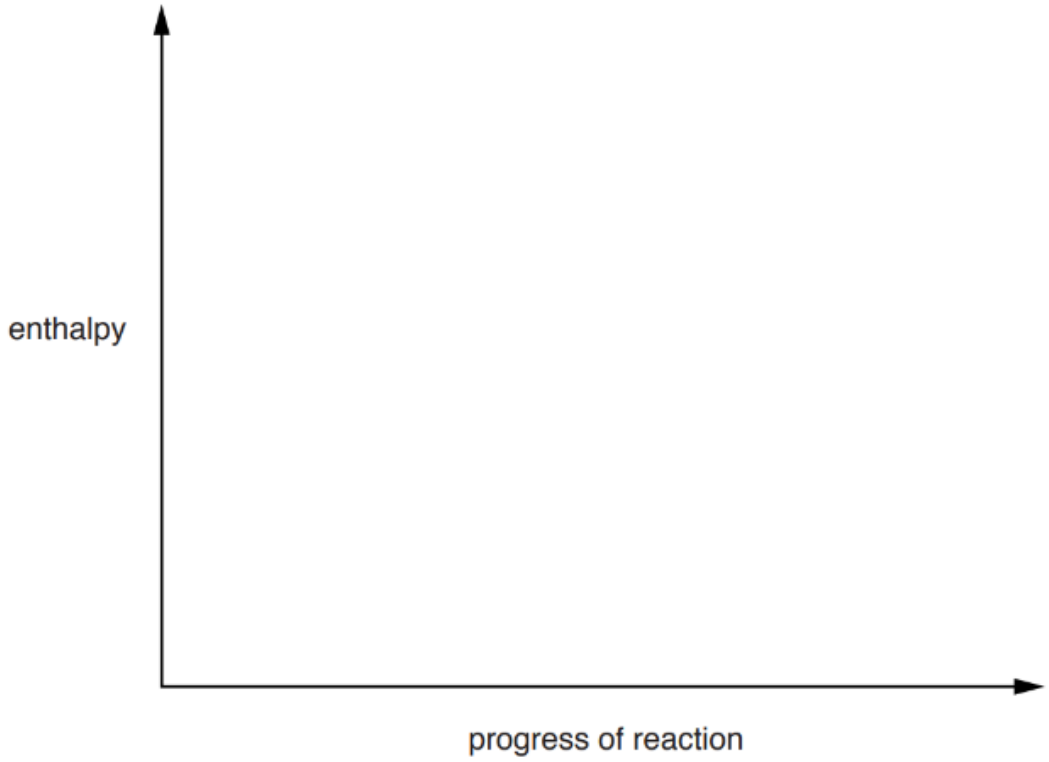
(iii) Identify the electron pair geometry around one of the nitrogen atoms. **1**

(b) Gaseous hydrazine undergoes combustion to produce nitrogen gas and water. The standard enthalpy of combustion, $\Delta_c H^{\ominus}$, for this process is -623 kJ mol^{-1}. **Marks**

(i) Write a balanced chemical reaction for this process **1**

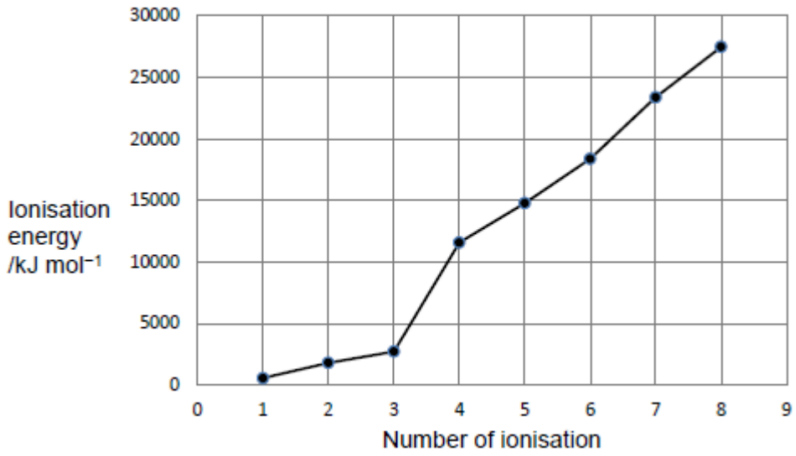
_____

(ii) Draw an energy profile diagram for this reaction, including labels for $\Delta H^{\ominus}$, and activation energy, E_a **2**



Question 25 (3 marks)

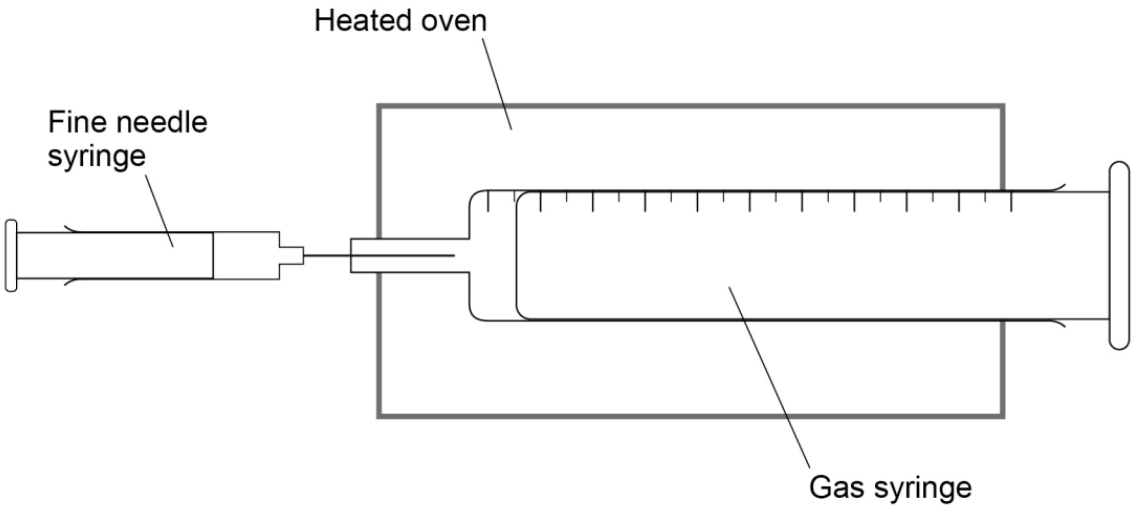
The successive ionisation energies for element X are shown in the graph below.



Explain the shape of the graph and suggest an element that this graph could represent.

Question 26 (3 marks)

A student performs an experiment to determine the formula mass of compound **A** using the apparatus shown below. The student injects a liquid sample of compound **A** from a fine needle syringe into a gas syringe in an oven. At the temperature of the oven, liquid **A** vaporises.



The table shows the student's results.

Mass of fine needle syringe before injecting	11.295 g
Mass of fine needle syringe after injecting	10.835 g
Volume of gas syringe before injecting	0.0 mL
Volume of gas syringe after injecting	178.0 mL
Pressure of gas in gas syringe	100 kPa
Temperature	120°C

Calculate the formula mass of compound **A** to 3 significant figures.

Question 27 (4 marks)

An Airbus A320 plane, in need of maintenance, is located in a hangar at Sydney airport. As part of the maintenance, its two engines are run at the same time in the idle power position for 15 minutes. Due to a malfunction, instead of producing carbon dioxide, all engines are producing carbon monoxide according to the following incomplete combustion chemical equation:

$$C_{12}H_{26}(l) + \frac{25}{2}O_2(g) \rightarrow 12CO(g) + 13H_2O(l)$$

The NSW Government has determined that exposure to carbon monoxide levels above 25.0 μg L^{-1} is dangerous.

A total of 200.0 kg of $C_{12}H_{26}$ was combusted in the hangar. The volume of the hanger is 2.00×10^{10} L.

Determine if the level of carbon monoxide produced in the hangar would be dangerous. Use relevant calculations to support your answer.

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CANDIDATE NUMBER

Question 28 (5 marks) **Marks**

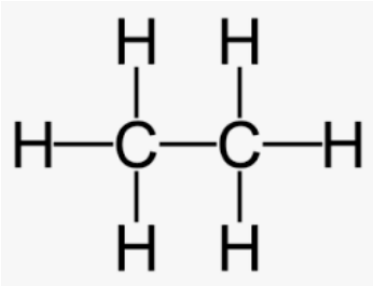
Crocetin consists of the elements carbon, hydrogen and oxygen.

(i) Determine the empirical formula of crocetin, if 1.00 g of crocetin forms 2.68 g of carbon dioxide and 0.657 g of water when it undergoes complete combustion. **4**

(ii) Determine the molecular formula of crocetin given that 0.300 mole of crocetin has a mass of 98.5 g. **1**

Question 29 (4 marks)

Ethane, $C_2H_6(g)$, can be represented by the following structural diagram.



The enthalpy of formation of ethane, $\Delta_f H$, can be represented by the equation:

$$2\ C(s) + 3\ H_2(g) \rightarrow C_2H_6(g)$$

Given the following data, calculate the enthalpy of formation of ethane.

$C(s) \rightarrow C(g)$	$\Delta H = 715\ kJ\ mol^{-1}$
Bond enthalpy (C-C)	$\Delta H = 348\ kJ\ mol^{-1}$
Bond enthalpy (C-H)	$\Delta H = 413\ kJ\ mol^{-1}$
Bond enthalpy (H-H)	$\Delta H = 436\ kJ\ mol^{-1}$

Question 30 (4 marks)

An equimolar mixture of two alkali metals with a combined mass of 59.87 g was burned in oxygen. The volume of oxygen used at 25°C and 100 kPa was 6.842 L. Identify the two metals, showing all working.

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Chemistry

FORMULAE SHEET

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

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

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

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.

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

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

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

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

2022 CRIB

ANNUAL EXAMINATION

CHEMISTRY

Form V

STRUCTURE OF PAPER

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Answer all questions on the Multiple-choice Answer Sheet.

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Marks: 80

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Masters Initials	AKBB	TW	MTK	CXS	EJS	CXS	AHLS	JLS

WRITE YOUR **CANDIDATE NUMBER** IN THE SPACE PROVIDED AT THE TOP OF EACH SEPARATE SECTION.

Examiners: CXS, EJS, JLS, AHLS

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SECTION I: MULTIPLE CHOICE

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	protons	neutrons
W	10	10
X	11	12
Y	12	11
Z	11	11

2 Which pair are isotopes?

(A) X and Z
(B) X and Y
(C) Y and Z
(D) W and Z

3 Which atom/s are likely to form cations?

(A) X only
(B) X and Y only
(C) Y and Z only
(D) X, Y and Z

4 Which atoms are **most** likely to be unstable and undergo radioactive decay?

(A) X and Z
(B) X and Y
(C) Y and Z
(D) W and Z

* Both accepted although (c) is the correct answer

5 A transition metal ion X^{3+} has the electronic configuration $[Ar]3d^4$. What is the atomic number of element X?

(A) 22

(B) 24

(C) 25

(D) 27

6 Which of the following contains the lowest concentration of sodium ions?

(A) 0.20 M $Na_3C_6H_5O_7$

(B) 0.35 M Na_2CO_3

(C) 0.50 M NaCl

(D) 0.65 M NaBr

7 The volume of a gas measured at 27°C and 100 kPa is 20.0 L. What final temperature would be required to increase the volume to 40.0 L at 100 kPa?

(A) 54°C

(B) 300°C

(C) 327°C

(D) 600°C

8 Two elements X and Y have the following successive ionisation energies

	Ionisation energy ($kJmol^{-1}$)						
	1st	2nd	3rd	4th	5th	6th	7th
X	1011	1900	2910	4960	6270	21300	25400
Y	737	1250	7730	10500	13600	18000	21700

Which is the most likely formula for the compound that forms between X and Y?

(A) X_3Y_2

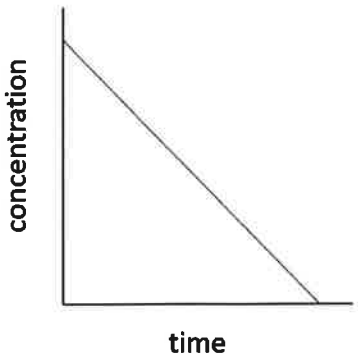
(B) X_3Y

(C) Y_2X

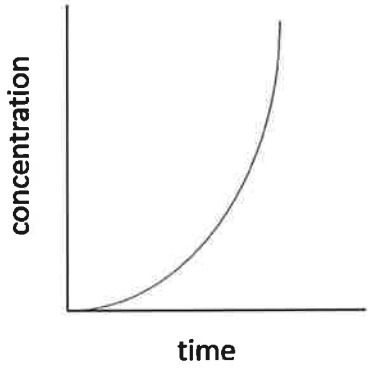
(D) Y_3X_2

9 Which graph best represents the change in concentration of products over time for a reaction as it goes to completion?

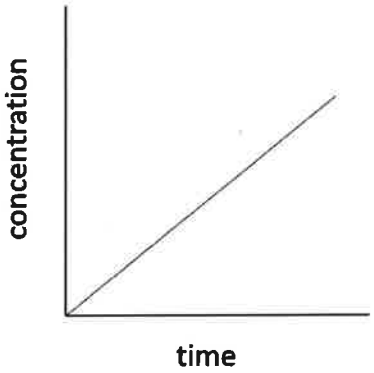
(A)



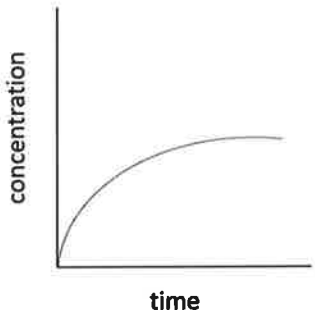
(B)



(C)



(D)



10 Which of the following molecules contains polar bonds but is **not** a polar molecule?

(A) NH_3

(B) SO_2

(C) CCl_4

(D) PCl_3

11 Which of the following contains molecules that exhibit dispersion forces only?

(A) Carbon dioxide, chlorine gas, methane

(B) Fluorine gas, methane, water

(C) Ammonia, carbon dioxide, hydrochloric acid

(D) Carbon monoxide, hydrogen disulfide, silicon dioxide

12 What would happen to the pressure of a given mass of gas when its absolute temperature and volume are both doubled?

(A) Increase by a factor of 2

(B) Decrease by a factor of 2

(C) Stay the same

(D) Cannot tell from the information provided.

13 How many hydrogen atoms are present in 10.0 g of ammonium sulfate?

(A) 4.56×10^{22}

(B) 9.11×10^{22}

(C) 1.82×10^{23}

(D) 3.65×10^{23}

14 3.0 g of magnesium was added to excess 1.10 mol L^{-1} hydrochloric acid.

What is the mass of the gas produced?

(A) 0.12 g

(B) 0.25 g

(C) 2.22 g

(D) 5.43 g

15 A brand of fertiliser states that its phosphate content is 23% by mass.

A boy wanted to check if this statement was true. He completely dissolved 2.5 g of the fertiliser in water and then reacted it with excess $Al(NO_3)_3$.

What is the expected mass of precipitate that would be formed?

(A) 0.16 g

(B) 0.74 g

(C) 1.07 g

(D) 3.21 g

SECTION II: 65 marks

Attempt ALL Questions
Write your answer in the space provided.

CRLB (CXS)

CANDIDATE NUMBER

Question 16 (2 marks) **Marks**

Give the full electron configuration for the following:

(i) K **1**

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

(ii) Ca^{2+} **1**

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

Question 17 (2 marks)

Write a balanced chemical equation for each of the following chemical reactions;

(i) Potassium metal reacting with chlorine gas. **1**

$2\,K(s) + Cl_2(g) \rightarrow 2\,KCl(s)$

• states required for the mark

(ii) Sodium hydrogen carbonate reacting with nitric acid. **1**

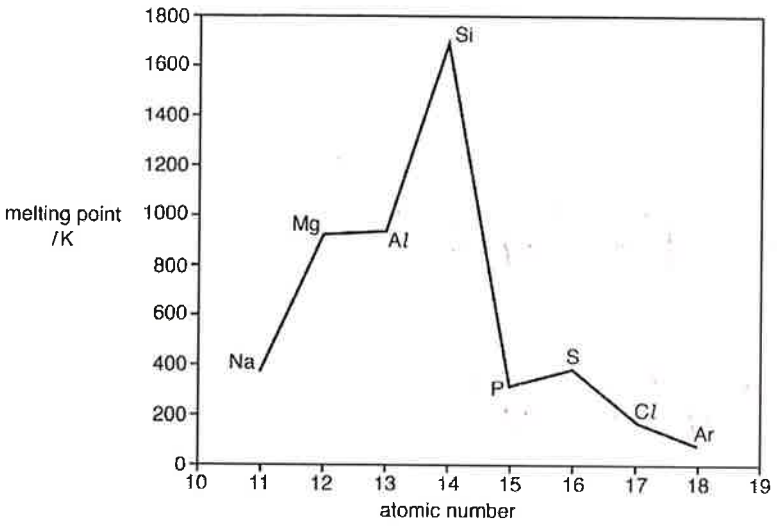
$NaHCO_3(s) + HNO_3(aq) \rightarrow NaNO_3 + H_2O(l) + CO_2(g)$

(s) or (aq) — (aq)

• states required for the mark.

Question 18 (4 marks) **Marks**

The graph shows the melting points of elements in period 3 of the Periodic table.



(a) Explain why magnesium has a higher melting point than sodium. **2**

- Mg has stronger metallic bonds (or more energy is required to break the bonds within Mg ....1 mark
- because - either - Mg radius is smaller ....1 mark
  - Mg has a higher positive charge
  - Mg has more delocalised electrons

(b) Explain why argon has a lower melting point than chlorine. **2**

- Ar has weaker intermolecular forces (or dispersion forces if the force is named) ..1 mark
- This is because argon has fewer electrons than Cl_2 and therefore weaker temporary dipoles (weaker dispersion forces) ...1 mark

Question 19 (5 marks) **Marks**

During an experiment, 3.80 g of solid sodium hydroxide was added to 150.0 g of water with an initial temperature of 23.5°C. After the solid completely dissolved, the final temperature of the solution was 28.0°C.

(a) Calculate the molar enthalpy of solution for sodium hydroxide (in kJ mol^{-1}). **4**

$n(NaOH) = 3.80/39.998 = 0.0950$ mol (1 Mark)

$q = m\,c\,\Delta T$

$= 150.0 \times 4.18 \times 4.5$

$= 2822$ J (1 Mark)

$\Delta H^{\ominus}_{sol} = \frac{-2.822}{0.0950} = -30$ kJ mol^{-1} (1 Mark) (to 2 s.f.)

$= -29.7$ kJ mol^{-1} (to 3 s.f.) (1 Mark)

(b) The theoretical molar enthalpy of solution is -44.5 kJ mol^{-1}. Provide a reason for the difference between the theoretical and experimental values. **1**

Some heat lost to unmeasured surroundings OR assumption that c(solution) = 4.18 J

Question 20 (5 marks) **Marks**

(a) Aqueous XO_4^{3-} ions form a precipitate with aqueous silver ions, Ag^+. Write a balanced equation for the reaction, including state symbols. **1**

$3\,Ag^+(aq) + XO_4^{3-}(aq) \rightarrow Ag_3XO_4(s)$ (+ states must be included)

(b) When 41.17 mL of a solution of aqueous silver ions with a concentration of 0.2040 mol L^{-1} is added to a solution of excess XO_4^{3-} ions, 1.172 g of the precipitate is formed.

(i) Calculate the amount (in moles) of Ag^+ ions used in the reaction. **1**

$n(Ag^+) = 0.04117 \times 0.2040$

$= 8.401$ mmol

$= 0.008401$ mol

(ii) Calculate the amount (in moles) of precipitate formed. **1**

$n(Ag_3XO_4) = \frac{8.410}{3} = 2.800$ mmol

$= 0.002800$ mol

(iii) Calculate the molar mass of the precipitate. **1**

$MM(Ag_3XO_4) = 1.172 / 0.002800$

$= 418.5$ g mol^{-1}

(iv) Determine the relative atomic mass of X and identify the element. **1**

$M_r(X) = 418.5 - (3 \times 107.9) - (4 \times 16)$

$= 30.83$ g mol^{-1}

X is phosphorus

CRIB (AHLS)

CANDIDATE NUMBER

Question 21 (6 marks) **Marks**

Below are some properties of aluminium fluoride and aluminium bromide.

	Melting point (°C)	Conductivity in liquid state
AlF_3	1265	High
$AlBr_3$	98	low

(i) Classify each compound as ionic or covalent molecular. Justify and explain your answer using information from the table. **4**

AlF_3 is ionic

$AlBr_3$ is covalent molecular } (1)

Notation:
C – correct classification
S – strong ionic bonds
M – mobile ions
W – weak IMF

AlF_3

– High MP due to strong ionic bonds or ionic lattice that need a lot of energy to break/separate ions (1)

– Conducts in liquid state as lattice breaks up so ions are free to move to carry charge (1)

Note: * Many boys wrote electrons are mobile → incorrect
* ions carry charge accepted

$AlBr_3$

– Low MP due to weak intermolecular forces that easily break (1)

– Poor conductivity as molecules not charged * not marked

Note: * Loss of mole for contradicting statement
↳ eg. the intermolecular force of ionic bonds

(ii) Explain, referring to relative electronegativities, the differences in bonding seen for these two aluminium halides. **2**

– Big difference between Al & F compared to Al & Br * Comparison (1)

– F attracts electrons from Al to form ions, (1)
whereas Br tendency is to share with Al

Question 22 (5 marks) **Marks**

Methanol, $CH_3OH(g)$ can be produced by the reaction between carbon dioxide and hydrogen.

$$CO_2(g) + 3\ H_2(g) \rightarrow CH_3OH(g) + H_2O(g)$$

The table below gives the enthalpy of formation and entropy data for the substances involved in the reaction.

	$CO_2(g)$	$H_2(g)$	$CH_3OH(g)$	$H_2O(g)$
$\Delta_f H$ / kJ mol^{-1}	-394	0	-201	-242
S / J K^{-1} mol^{-1}	214	131	238	189

(i) Calculate the Gibbs free-energy change, ΔG, in kJ mol^{-1}, for this reaction at 298 K to show that this reaction will not be spontaneous at this temperature. **4**

$\Delta H = (-201 - 242) - (-394)$

$= -49\text{kJ mol}^{-1}$ (1)

$\Delta S = (238 + 189) - (214 + 3 \times 131)$

$= -182\text{J K}^{-1}\text{mol}^{-1}$ (1)

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

$= -49 - 298 \times [-0.180]$ (1) Conversion to kJ K^{-1} mol^{-1}

$= 4.64\text{kJ mol}^{-1}$ (1)

(ii) Show that the reaction becomes spontaneous at 272 K. **1**

Let $\Delta G = 0$

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

$= \frac{-49}{-0.180}$

$= 272\text{K}$

OR

$\Delta G = -49 - 272 \times -0.180$

$= -0.04\text{kJ mol}^{-1}$

$\therefore$ spontaneous

Question 23 (5 marks) **Marks**

(i) List the following covalent molecular substances in order of increasing boiling point (lowest first). **1**

C_2H_6 CH_3OH CH_3F

$C_2H_6 < CH_3F < CH_3OH$

* Many boys had CH_3F as the highest BP

(ii) Explain the order of boiling points in (i). **4**

- C_2H_6 is lowest BP as it only exhibits dispersion forces (1)
- CH_3F is middle as it exhibits dipole-dipole (1) since it is a polar molecule.
- CH_3OH is highest BP as it contains hydrogen bonding (1) since O is covalently bonded to H
- Ordering: Hydrogen bonding is stronger than dipole-dipole, and both are stronger than dispersion forces (1)

Notation: DF → C_2H_6 dispersion forces
DD → CH_3F dipole-dipole
HB → CH_3OH hydrogen bonding
O → correct reasoning for ordering

Note: * Carry on error provided for ordering if boys had incorrect IMF for the substances or wrong order in Part (i)
↳ Had to be reasonable to be accepted
e.g. CH_3F is higher than CH_3OH, even though both contain hydrogen bonding, as F is more electronegative than O, thus the H-bonds are stronger.

* If part (i) incorrect, error was carried forward from part (ii), so a mark could be awarded for part (i) based on the reasoning in (ii)

CRIB – JLS

CANDIDATE NUMBER

Question 24 (8 marks) **Marks**

Hydrazine, N_2H_4, is an inorganic compound found in some rocket fuel.

(a) Hydrazine is described as having a *covalent molecular* structure.

(i) Describe what is meant by the terms *covalent* and *molecular* in this context. **2**

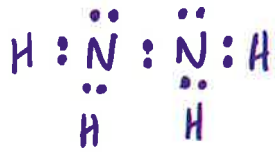
NOTE: Very few boys awarded 2/2 on this question.

Covalent : Shared pair of electrons between two atoms.

Molecular : Discrete particles made up of 2 or more atoms.

ACCEPT : • Discrete structure that does not form a recurring network structure.
• particles held together by weak dispersion forces.

(ii) Draw a Lewis dot diagram/structure for hydrazine. **2**



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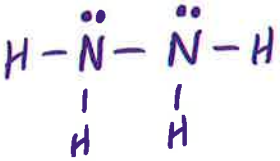
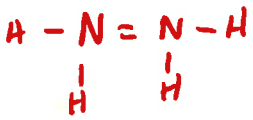


ACCEPT FOR 1 MARK :



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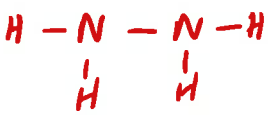


NOTE: No marks for incorrect formula!

(iii) Identify the electron pair geometry around one of the nitrogen atoms. **1**

Tetrahedral

ACCEPT : Any answer that matches answer for part ii

NOTE : Many students gave the molecular geometry instead of the electron pair geometry.

ACCEPT: $H_2O(g)$

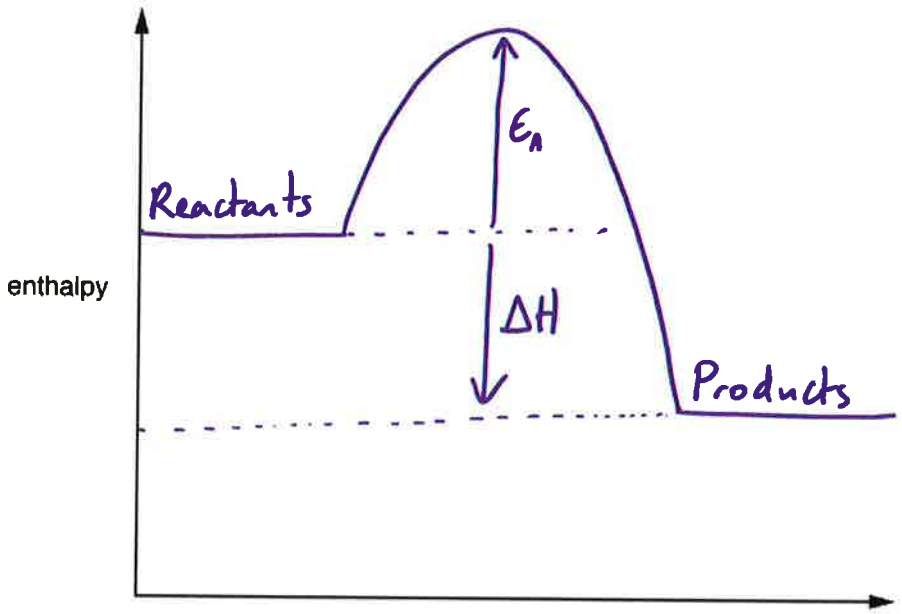
(b) Gaseous hydrazine undergoes combustion to produce nitrogen gas and water. The standard enthalpy of combustion, $\Delta cH^{\ominus}$, for this process is -623 kJ mol^{-1}. **Marks**

NOTE: formulae, states and balancing had to be correct for mark.

(i) Write a balanced chemical reaction for this process **1**

$N_2H_4(g) + O_2(g) \rightarrow N_2(g) + 2H_2O(l)$

(ii) Draw an energy profile diagram for this reaction, including labels for $\Delta H^{\ominus}$, and activation energy, E_a **2**

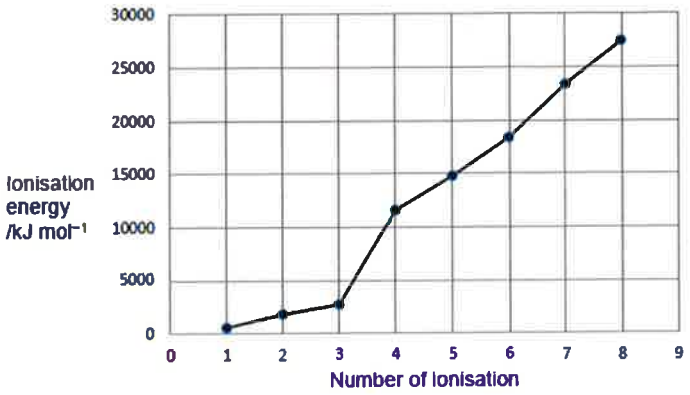


MARK 1: Awarded for correct energy profile for an exothermic reaction
H(reactants) > H(products)

MARK 2: Correct labelling of ΔH and E_A.

Question 25 (3 marks)

The successive ionisation energies for element X are shown in the graph below.



Explain the shape of the graph and suggest an element that this graph could represent.

MARK 1 : Explanation for general increase in IE

IE increases as electron is being removed from increasingly positively charged ion / electrons are being held closer to the nucleus / less shielding / less e^- repulsion.

MARK 2 : Explanation for jump between IE 3 and IE 4

Electron is being removed from orbital / shell closer to the nucleus / electron is experiencing much less shielding

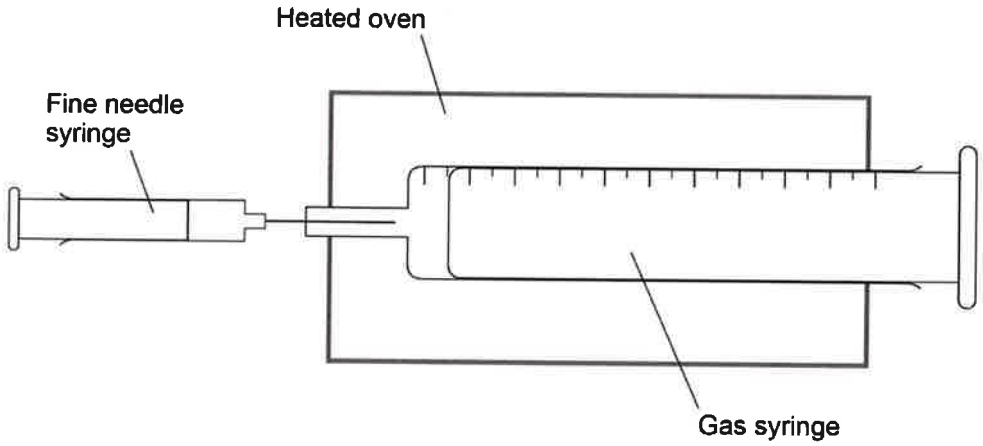
MARK 3 : ID element

Aluminium (or other group 3 element with greater than 8 electrons)

Scandium also accepted.

Question 26 (3 marks)

A student performs an experiment to determine the formula mass of compound **A** using the apparatus shown below. The student injects a liquid sample of compound **A** from a fine needle syringe into a gas syringe in an oven. At the temperature of the oven, liquid **A** vaporises.



The table shows the student's results.

Mass of fine needle syringe before injecting	11.295 g
Mass of fine needle syringe after injecting	10.835 g
Volume of gas syringe before injecting	0.0 mL
Volume of gas syringe after injecting	178.0 mL
Pressure of gas in gas syringe	100 kPa
Temperature	120°C

Calculate the formula mass of compound **A** to 3 significant figures.

$m(A) = 0.46$ g $V(A) = 178.0$ mL

$pV = nRT$ $n = \frac{pV}{RT} = \frac{100 \times 0.178}{8.314 \times 393.15}$

$= 0.005446$ mol

$MM = \frac{m}{n}$ $MM(A) = 84.5$ g mol^{-1}

3 MARKS : correct answer to 3 sig figs
2 MARKS : One calc error or one calc error + sig fig error
1 MARK : m(A) and V(A)

Question 27 (4 marks)

An Airbus A320 plane, in need of maintenance, is located in a hangar at Sydney airport. As part of the maintenance, its two engines are run at the same time in the idle power position for 15 minutes. Due to a malfunction, instead of producing carbon dioxide, all engines are producing carbon monoxide according to the following incomplete combustion chemical equation:

$$C_{12}H_{26}(l) + \frac{25}{2}O_2(g) \rightarrow 12CO(g) + 13H_2O(l)$$

The NSW Government has determined that exposure to carbon monoxide levels above 25.0 μg L^{-1} is dangerous.

A total of 200.0 kg of $C_{12}H_{26}$ was combusted in the hangar. The volume of the hanger is 2.00×10^{10} L.

Determine if the level of carbon monoxide produced in the hangar would be dangerous. Use relevant calculations to support your answer.

STEP 1 $n(C_{12}H_{26}) = \frac{200\,000\ g}{178.328\ g\ mol^{-1}}$ $MM(C_{12}H_{26}) = 170.328\ g\ mol^{-1}$

$= 1174.2\ mol$

STEP 2 $n(CO) = 1174.2 \times 12$

$= 14090\ mol$

STEP 3 $[CO] = \frac{14090\ mol}{2.00 \times 10^{10}\ L}$

$= 7.045 \times 10^{-7}\ mol\ L^{-1}$

STEP 4 $conc(CO) = 7.045 \times 10^{-7} \times 28.01\ g\ mol^{-1}$

$= 1.973 \times 10^{-5}\ g\ L^{-1}$

$= 19.7\ mg\ L^{-1}$

$19.7\ mg\ L^{-1} < 25\ mg\ L^{-1}$ ∴ not dangerous

4 MARKS : All correct
3 MARKS : One incorrect step
2 MARKS : At least two correct steps
1 MARK : One correct step

NOTE : Max 2 marks was awarded if student assumed step 3 gave conc. in g mol^{-1}.

EJS CRIB

CANDIDATE NUMBER

Question 28 (5 marks) **Marks**

Crocetin consists of the elements carbon, hydrogen and oxygen.

(i) Determine the empirical formula of crocetin, if 1.00 g of crocetin forms 2.68 g of carbon dioxide and 0.657 g of water when it undergoes complete combustion. **4**

$n(CO_2) = \frac{2.68}{44.01} = 0.0609 \text{ mol} \therefore n(C) = 0.0609 \text{ mol}$ (1)

$n(H_2O) = \frac{0.657}{18.016} = 0.0365 \text{ mol}$ (1) $\therefore n(H) = 0.0729 \text{ mol}$

$m(O) = 1.00 - m(C) - m(H)$ (1)

$m(O) = 1.00 - (0.0609 \times 12.01) - (0.0729 \times 1.008) = 0.195 \text{ g}$

$n(O) = \frac{0.195}{16.00} = 0.0122 \text{ mol}$

C : 0.0609 ∴ 1 → 5

H : 0.0729 ∴ 1.2 → 6

O : 0.0122 ∴ 0.2 → 1 C_5H_6O (1)

(ii) Determine the molecular formula of crocetin given that 0.300 mole of crocetin has a mass of 98.5 g. **1**

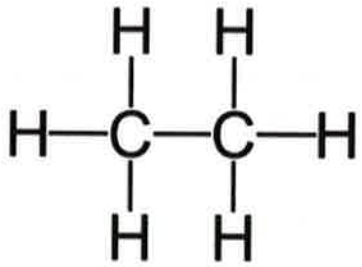
$MM = \frac{m}{n} = \frac{98.5}{0.3} = 328.33$

$MM(C_5H_6O) = 82.098 \therefore C_{20}H_{24}O_4$ (1)

(CE given from (i))

Question 29 (4 marks)

Ethane, $C_2H_6(g)$, can be represented by the following structural diagram.



The enthalpy of formation of ethane, $\Delta_f H$, can be represented by the equation:

$$2\ C(s) + 3\ H_2(g) \rightarrow C_2H_6(g)$$

Given the following data, calculate the enthalpy of formation of ethane.

$C(s) \rightarrow C(g)$	$\Delta H = 715\ kJ\ mol^{-1}$
Bond enthalpy (C-C)	$\Delta H = 348\ kJ\ mol^{-1}$
Bond enthalpy (C-H)	$\Delta H = 413\ kJ\ mol^{-1}$
Bond enthalpy (H-H)	$\Delta H = 436\ kJ\ mol^{-1}$

$2\ C_{(g)} + 3H_{2(g)} \rightarrow C_2H_{6(g)}$

bonds broken: $= 0 + 3 \times 436$ bonds produced: $= 1 \times 348 + 6 \times 413$

$\Delta H = +1308 - 2826 = -1518\ kJ\ mol^{-1}$

$\therefore\ 2\ C_{(g)} + 3H_{2(g)} \rightarrow C_2H_{6(g)}$ $\Delta H = -1518\ kJ\ mol^{-1}$

$2\ C_{(s)} \rightarrow 2\ C_{(g)}$ $\Delta H = +1480\ kJ\ mol^{-1}$

$\therefore\ 2C_{(s)} + 3H_{2(g)} \rightarrow C_2H_{6(g)}$ $\Delta H = -1518 + 1480$

$= -88\ kJ\ mol^{-1}$

marked -1 for each error (easy to get entry mark)

* There were many opportunities to make especially with + & −, and using stoichiometric ratios. *

Question 30 (4 marks)

An equimolar mixture of two alkali metals with a combined mass of 59.87 g was burned in oxygen. The volume of oxygen used at 25°C and 100 kPa was 6.842 L. Identify the two metals, showing all working.

several methods to get correct answer

$n(O_2) = \frac{6.842}{24.79} = 0.2760$ mol (1)

$\therefore$ 0.1380 mol per metal

since alkali metal (1) ratio $n(O_2) : n(X/Y)$

$4X + O_2 \rightarrow 2X_2O$ or $2X + 2Y + O_2 \rightarrow X_2O + Y_2O$

$\therefore n(X) = n(Y) = 0.5520$ mol

$m(X+Y) = 59.87$ (1) use the combined mass

$\therefore mm(X) \times 0.5520 + mm(Y) \times 0.5520 = 59.87$

using periodic table, must be Na & Rb (1)

- most common error was to not consider the stoichiometry of the reaction and to assume $n(O_2) = n(X) = n(Y)$. This gave best answer Cs & Rb and got 2/4 marks.
- many boys did not know what alkali metals were!