SYDNEY GRAMMAR SCHOOL

2018
ANNUAL EXAMINATION

CHEMISTRY
Form V

STRUCTURE OF PAPER

- Section I: Multiple Choice (12 marks)

  Answer all questions on the Multiple-choice Answer Sheet.

- Section II: Extended Response (72 marks)

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

- Board approved calculators may be used

EXAMINATION

Date: Friday 7th September
Duration: 2 hours
Marks: 84

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 **NAME** AND **CLASS 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	CXS	CRMR	ZI/MTK	TW	AKBB	BED	DBD

Examiners: TW, AKBB, BED, CXS.

This page left blank

SECTION I: MULTIPLE CHOICE

Attempt ALL Questions
Use the Multiple-Choice Answer Sheet.

1 Which of the following substances contains atoms bonded together by covalent bonds only?

(A) MgO

(B) SiO_2

(C) NH_4NO_3

(D) NaCl

2 Which of the following pairs of electron configurations correspond to a pair of atoms that would be expected to form a covalent bond?

(A) $1s^2\ 2s^2\ 2p^5$ and $1s^2\ 2s^2\ 2p^4$

(B) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ and $1s^2$

(C) $1s^2\ 2s^2\ 2p^6\ 3s^1$ and $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

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

3 Which of the following substances would be **least** polar?

(A) CCl_4

(B) $CFCl_3$

(C) HCl

(D) Cl_2O

4 A 450 mL sample of 1.50 M sodium acetate solution was evaporated to achieve a final concentration of 2.25 M. What is the final volume of the solution?

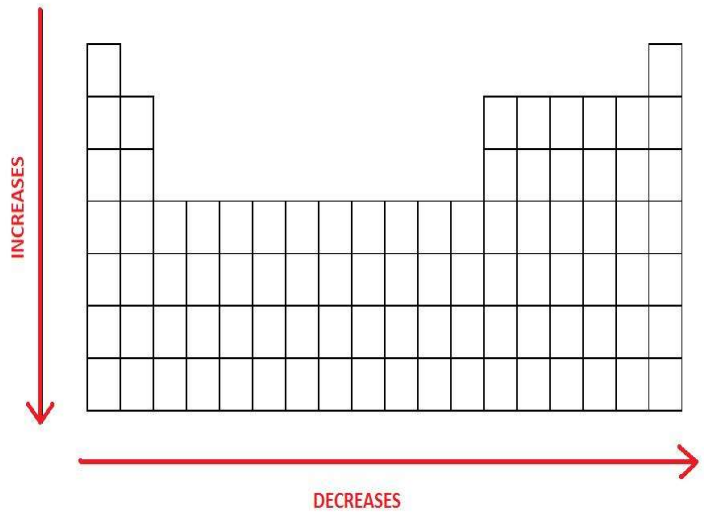
(A) 150 mL

(B) 200 mL

(C) 300 mL

(D) 400 mL

5 The diagram shows a change in a property of atoms down a group and across a period of the Periodic Table.



The property whose change is shown in the diagram could be

(A) first ionisation energy.

(B) relative atomic mass.

(C) electronegativity.

(D) atomic radius.

6 Which of the following correctly identifies a process that occurs at an electrode?

(A) Reduction at the anode.

(B) Electron loss at the cathode.

(C) Electron gain at the anode.

(D) Oxidation at the anode.

7 In which of the following situations is the manganese-containing species oxidised?

(A) $2MnO_4^-(aq) + 16H^+(aq) + 10Cl^-(aq) \rightarrow 2Mn^{2+}(aq) + 8H_2O(l) + 5Cl_2(g)$

(B) $2Mn^{2+}(aq) + 4OH^-(aq) + O_2(g) \longrightarrow 2MnO_2(s) + 2H_2O(l)$

(C) $MnO_4^{2-}(aq) + H_2(g) \rightarrow MnO_2(s) + 2OH^-(aq)$

(D) $MnO_2(s) + 2C(s) \rightarrow 2CO(g) + Mn(s)$

8 A balloon filled with 1.00 L of air at 29.0 °C was cooled to 15.0 °C. Assuming that the pressure remains constant, what is the final volume of the balloon?

(A) 0.349 L

(B) 0.517 L

(C) 0.954 L

(D) 1.049 L

9 How many nitrogen atoms are in 1.34 mol of copper(II) nitrate?

(A) 2.25×10^{23} atoms

(B) 4.49×10^{23} atoms

(C) 8.07×10^{23} atoms

(D) 1.61×10^{24} atoms

10 Nitrogen and hydrogen gas react to form ammonia (NH_3). If 3.0 L of nitrogen is added to excess hydrogen at 100 kPa and 293 K, what volume of ammonia will be produced, assuming that all of the nitrogen is consumed?

(A) 1.5 L

(B) 3.0 L

(C) 6.0 L

(D) 9.0 L

11 When 9.86 J of energy is transferred as heat to a sample of aluminium metal, the temperature of the sample increases from 23.2 °C to 30.5 °C. The specific heat capacity of aluminium is 0.90 J K^{-1} g^{-1}. What is the mass of the aluminium metal sample?

(A) 0.67 g

(B) 0.82 g

(C) 1.2 g

(D) 1.5 g

12 Given that the standard enthalpy of formation for $Cu^{2+}(aq)$ is +64.4 kJ mol^{-1} and that of $Zn^{2+}(aq)$ is −152.4 kJ mol^{-1}, what is the standard enthalpy of reaction for the following reaction?

$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$$

(A) −216.8 kJ mol^{-1}

(B) −88.0 kJ mol^{-1}

(C) +88.0 kJ mol^{-1}

(D) +216.8 kJ mol^{-1}

SECTION II: Attempt ALL Questions

Name: _____ Class: _____

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

Question 13 (4 marks) **Marks**

The radioisotope, potassium-40 decays to form a beta particle and calcium-40.

(a) Write a balanced nuclear equation for this reaction.

..... **1**

.....

(b) Contrast two features of a beta particle with those of an alpha particle.

..... **2**

.....

.....

.....

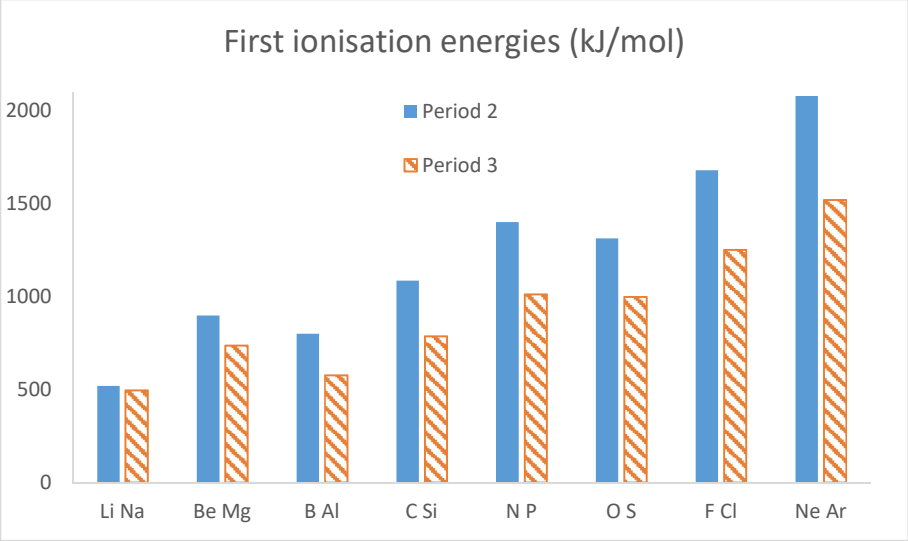
(c) Give the electronic structure of an atom of potassium in spdf orbital notation.

..... **1**

.....

Question 14 (5 marks) **Marks**

The table below shows the first ionisation energies of the Period 2 and Period 3 elements, measured in kJ mol^{-1}.



(a) Explain the general trend in first ionisation energy across Period 2. **3**

.....

.....

.....

.....

.....

.....

(b) Explain why the elements of Period 3 have smaller first ionisation energies than the corresponding elements of Period 2. **2**

.....

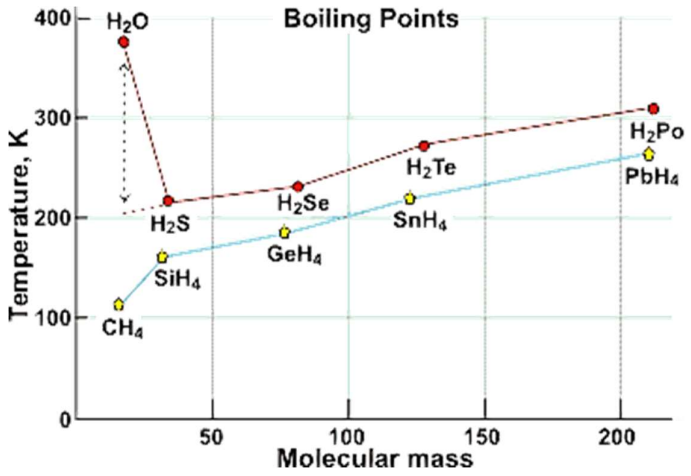
.....

.....

.....

Question 15 (7 marks) **Marks**

The graphs below show the relative boiling points of hydrides of elements in Groups 4 and 6 of the Periodic Table.



(a) Draw a Lewis structure or electron dot formula to represent a molecule of hydrogen sulfide, (H_2S). **1**

(b) Explain why H_2S is polar whereas SiH_4 is not. **2**

.....

.....

.....

.....

.....

.....

Question continued on next page.

Question continued. **Marks**

(c) Explain the trend in the boiling points of the Group 6 hydrides from H_2S to H_2Po.

..... **2**

.....

.....

.....

.....

.....

(d) Explain why the boiling point of water is significantly higher than would be expected from the trend for the other Group 6 hydrides.

..... **2**

.....

.....

.....

.....

.....

SECTION II: Attempt ALL Questions

Name: _____ Class: _____

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

Question 16 (2 marks) **Marks**

Briefly explain how a process employed by Aboriginal or Torres Strait Islander peoples detoxifies poisonous food items.

..... **2**

.....

.....

.....

Question 17 (3 marks)

Consider the following balanced chemical equation:

$Sn(s) + Pb(NO_3)_2(aq) \rightarrow Pb(s) + Sn(NO_3)_2(aq)$

(a) Does the reaction in the equation above proceed spontaneously? Justify your answer.

..... **1**

.....

(b) Identify the spectator ion in the equation in part (a).

..... **1**

.....

(c) Identify the reducing agent (reductant), for the equation in part (a).

..... **1**

.....

Question 18 (6 marks) **Marks**

A student conducts an investigation to determine the voltage of a galvanic cell made from half-cells containing magnesium and silver, and their respective ions.

(a) Draw a labelled diagram of the experimental set-up. Indicate on your diagram the direction of electron flow and the direction of cation movement.

4

(b) Calculate the standard cell potential for this galvanic cell.

..... **1**

.....

(c) The experimental voltage obtained from galvanic cells is often different to that indicated from standard reduction potentials. Suggest a reason why this may be.

..... **1**

.....

Question 19 (5 marks) **Marks**

In a metal displacement reaction following half reactions were observed to occur:

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

$Ag^+ + e^- \rightarrow Ag$

(a) Write a net ionic equation for this reaction, including all states.

..... **2**

.....

(b) A strip of copper was placed into a solution containing silver nitrate. After the reaction was complete the silver was removed from the surface of the copper strip and the copper strip was removed. The resulting suspension, containing solid silver, was filtered.

copper strip before reaction	2.298 g
copper strip after reaction	2.216 g
filter paper before filtration	1.662 g
filter paper after filtration	2.002 g

(i) Calculate the chemical amount (in mol) of silver produced and of copper consumed.

..... **2**

.....

.....

.....

(ii) Calculate the experimental mole ratio of silver to copper and account for any deviation from ideal results.

..... **1**

.....

.....

.....

This page left blank

SECTION II: Attempt ALL Questions

Name: _____ Class: _____

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

Question 20 (4 marks) **Marks**

A compound was found to contain 24.8% carbon, 2.0% hydrogen and 73.2% chlorine.

(a) Determine the empirical formula of this compound.

..... **3**

.....

.....

.....

.....

.....

(b) The molar mass of this compound is 96.9 g mol^{-1}. Determine the molecular formula of this compound.

..... **1**

.....

Question 21 (2 marks)

Chromium has four stable isotopes, whose relative isotopic masses and percentage abundances are shown in the table below.

Isotope	Isotopic mass (u)	Percentage abundance (%)
^{50}Cr	49.946	4.3450
^{52}Cr	51.941	83.789
^{53}Cr	52.941	9.5012
^{54}Cr	53.939	2.3657

Calculate the relative atomic mass of chromium.

..... **2**

.....

.....

.....

.....

.....

Question 22 (5 marks) **Marks**

In an experiment, 2.369 g of aluminium hydroxide reacts with 60.0 mL of 0.714 M sulfuric acid to produce a salt solution and water.

(a) Write a balanced chemical equation for this reaction.

..... **1**

.....

(b) Calculate the chemical amount (in mol) of the salt produced.

..... **4**

.....

.....

.....

.....

.....

Question 23 (4 marks)

A 33.34 g sample of a diatomic gas was stored in a 20.0 L vessel at 150 kPa and 30 °C. What is the identity of this gas?

..... **4**

.....

.....

.....

.....

.....

.....

.....

Question 24 (5 marks) **Marks**

Antacids contain calcium carbonate and are used to neutralise stomach acid. The mass of one antacid tablet was found to be 1.30 g. To determine the amount of calcium carbonate present, this tablet was crushed into a fine powder and excess hydrochloric acid was added to it. After the reaction was complete, there was a decrease in mass of 0.220 g.

(a) Write a balanced equation for the reaction between calcium carbonate and hydrochloric acid.

..... **1**

.....

(b) Calculate the mass (in g) of calcium carbonate present in the antacid tablet.

..... **2**

.....

.....

.....

(c) Calculate the percentage by mass of calcium carbonate in the antacid tablet.

..... **1**

.....

(d) At 100 kPa and 296 K, what volume of gas would have be produced?

..... **1**

.....

.....

SECTION II: Attempt ALL Questions

Name: Class:

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

Question 25 (4 marks) **Marks**

	silicon tetrachloride	silicon dioxide
Melting point (°C)	−68	1713

Explain the melting points of silicon tetrachloride and silicon dioxide in terms of their structure and bonding.

..... **4**

.....

.....

.....

.....

.....

.....

.....

Question 26 (6 marks) **Marks**

5.000 g of silver nitrate is dissolved in 100.0 g of water, initially at 25.0 °C.

(a) If the enthalpy of solution ($\Delta_{sol}H$) for silver nitrate is +22.6 kJ mol^{-1}, what is the final temperature of the solution?

..... **4**

.....

.....

.....

.....

.....

.....

.....

(b) Given that silver nitrate is soluble in water at room temperature, what must be the sign of the entropy of solution ($\Delta_{sol}S$) for silver nitrate? Explain your answer.

..... **2**

.....

.....

.....

.....

.....

Question 27 (2 marks) **Marks**

The reaction of acetylene (C_2H_2) with hydrogen (H_2) can produce either ethylene (C_2H_4) or ethane (C_2H_6):

$C_2H_2(g) + H_2(g) \rightarrow C_2H_4(g)$ $\Delta_r H^{\ominus} = -175.7$ kJ mol^{-1}

$C_2H_2(g) + 2H_2(g) \rightarrow C_2H_6(g)$ $\Delta_r H^{\ominus} = -312.0$ kJ mol^{-1}

Industrially, ethylene and hydrogen are produced from ethane on a massive scale.

What is $\Delta_r H$ for the reaction of ethane (C_2H_6) to form ethylene (C_2H_4) and H_2?

..... **2**

.....

.....

.....

Question 28 (3 marks)

Tetraethyllead [$Pb(C_2H_5)_4$] was formally used as a fuel additive, but its use in automotive petrol has been banned in Australia since 2002. It combusts as follows:

$$[Pb(C_2H_5)_4](l) + \frac{27}{2}O_2(g) \rightarrow PbO(s) + 8CO_2(g) + 10H_2O(l) \quad \Delta H° = -6278\ kJ\ mol^{-1}$$

	standard enthalpy of formation (kJ mol^{-1})
$CO_2(g)$	−393.5
$H_2O(l)$	−285.8
$[Pb(C_2H_5)_4](l)$	+53.0

Given the information in the table above, calculate the standard enthalpy of formation of PbO(s).

..... **3**

.....

.....

.....

.....

Question 29 (5 marks) **Marks**

Widgiemoolthalite is a rare blue-green mineral first identified in Widgiemooltha, Western Australia, in 1992. It contains three different ions, none of which contains atoms of more than two elements.

When 2.000 g of widgiemoolthalite reacts with excess hydrochloric acid it dissolves completely and releases 0.5354 g of carbon dioxide. Strongly heating 2.000 g of widgiemoolthalite produces water vapour, carbon dioxide and 1.1358 g of nickel(II) oxide as the only products.

Calculate the empirical formula for widgiemoolthalite, expressing your answer in terms of the ions and molecules present.

..... **5**

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

END OF EXAMINATION

Formulae sheet, Data sheet and Periodic Table overleaf

FORMULAE SHEET

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

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

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

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

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.

SECTION I: MULTIPLE CHOICE

Attempt ALL Questions
Use the Multiple-Choice Answer Sheet.

1 Which of the following substances contains atoms bonded together by covalent bonds only?

(A) MgO

(B) SiO_2

(C) NH_4NO_3

(D) NaCl

2 Which of the following pairs of electron configurations correspond to a pair of atoms that would be expected to form a covalent bond?

(A) $1s^2\ 2s^2\ 2p^5$ and $1s^2\ 2s^2\ 2p^4$

(B) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ and $1s^2$

(C) $1s^2\ 2s^2\ 2p^6\ 3s^1$ and $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

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

3 Which of the following substances would be **least** polar?

(A) CCl_4

(B) $CFCl_3$

(C) HCl

(D) Cl_2O

4 A 450 mL sample of 1.50 M sodium acetate solution was evaporated to achieve a final concentration of 2.25 M. What is the final volume of the solution?

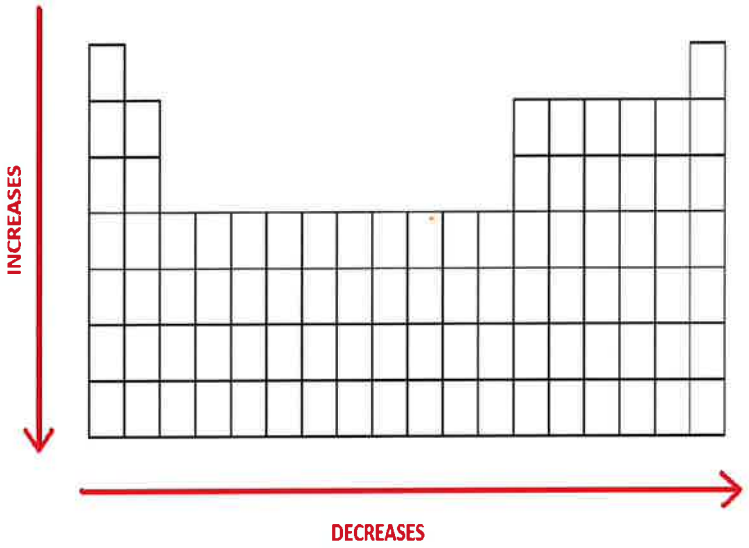
(A) 150 mL

(B) 200 mL

(C) 300 mL

(D) 400 mL

5 The diagram shows a change in a property of atoms down a group and across a period of the Periodic Table.



The property whose change is shown in the diagram could be

(A) first ionisation energy.

(B) relative atomic mass.

(C) electronegativity.

(D) atomic radius.

6 Which of the following correctly identifies a process that occurs at an electrode?

(A) Reduction at the anode.

(B) Electron loss at the cathode.

(C) Electron gain at the anode.

(D) Oxidation at the anode.

7 In which of the following situations is the manganese-containing species oxidised?

(A) $2MnO_4^-(aq) + 16H^+(aq) + 10Cl^-(aq) \rightarrow 2Mn^{2+}(aq) + 8H_2O(l) + 5Cl_2(g)$

(B) $2Mn^{2+}(aq) + 4OH^-(aq) + O_2(g) \longrightarrow 2MnO_2(s) + 2H_2O(l)$

(C) $MnO_4^{2-}(aq) + H_2(g) \rightarrow MnO_2(s) + 2OH^-(aq)$

(D) $MnO_2(s) + 2C(s) \rightarrow 2CO(g) + Mn(s)$

8 A balloon filled with 1.00 L of air at 29.0 °C was cooled to 15.0 °C. Assuming that the pressure remains constant, what is the final volume of the balloon?

(A) 0.349 L

(B) 0.517 L

(C) 0.954 L

(D) 1.049 L

9 How many nitrogen atoms are in 1.34 mol of copper(II) nitrate?

(A) 2.25×10^{23} atoms

(B) 4.49×10^{23} atoms

(C) 8.07×10^{23} atoms

(D) 1.61×10^{24} atoms

10 Nitrogen and hydrogen gas react to form ammonia (NH_3). If 3.0 L of nitrogen is added to excess hydrogen at 100 kPa and 293 K, what volume of ammonia will be produced, assuming that all of the nitrogen is consumed?

(A) 1.5 L

(B) 3.0 L

(C) 6.0 L

(D) 9.0 L

11 When 9.86 J of energy is transferred as heat to a sample of aluminium metal, the temperature of the sample increases from 23.2 °C to 30.5 °C. The specific heat capacity of aluminium is 0.90 J K^{-1} g^{-1}. What is the mass of the aluminium metal sample?

(A) 0.67 g

(B) 0.82 g

(C) 1.2 g

(D) 1.5 g

12 Given that the standard enthalpy of formation for $Cu^{2+}(aq)$ is +64.4 kJ mol^{-1} and that of $Zn^{2+}(aq)$ is −152.4 kJ mol^{-1}, what is the standard enthalpy of reaction for the following reaction?

$$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$$

(A) −216.8 kJ mol^{-1}

(B) −88.0 kJ mol^{-1}

(C) +88.0 kJ mol^{-1}

(D) +216.8 kJ mol^{-1}

SECTION II: Attempt ALL Questions CRIB

Name: _____ Class: _____

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

Question 13 (4 marks) **Marks**

The radioisotope, potassium-40 decays to form a beta particle and calcium-40.

(a) Write a balanced nuclear equation for this reaction. 1

$^{40}_{19}K \longrightarrow {}^{0}_{-1}e + {}^{40}_{20}Ca$ (One mark for no errors)

(b) Contrast two features of a beta particle with those of an alpha particle.

Beta	−1 charge	0 mass	less ionising	More penetrati
Alpha	+2 charge	mass of 4	More ionisin	less penetrati

(1) (1)

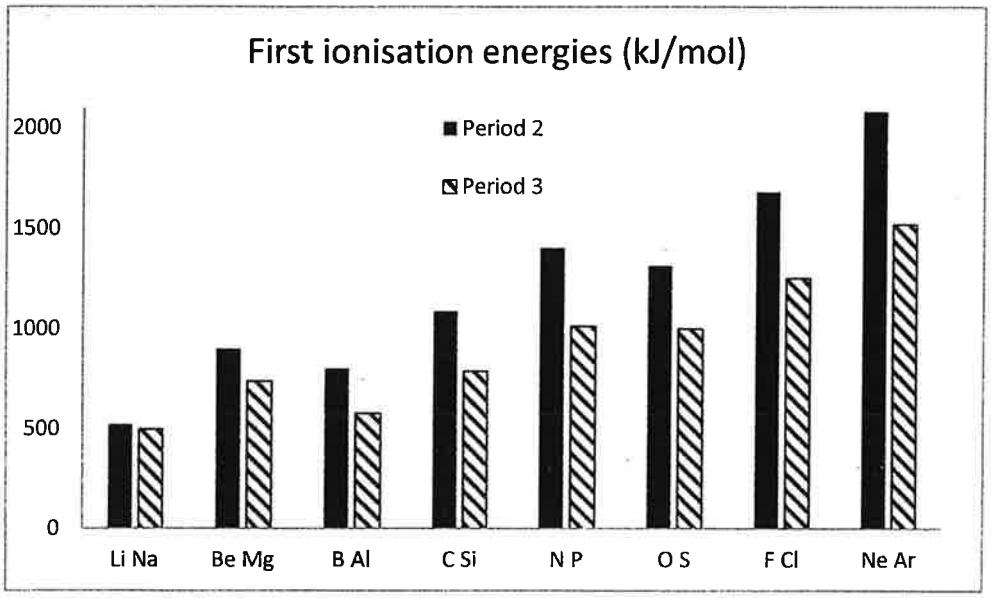
(* 1 mark for beta is $^{0}_{-1}e$ & alpha is $^{4}_{2}He$)

(c) Give the electronic structure of an atom of potassium in spdf orbital notation. 1

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

Question 14 (5 marks) **Marks**

The table below shows the first ionisation energies of the Period 2 and Period 3 elements, measured in kJ mol^{-1}.



(a) Explain the general trend in first ionisation energy across Period 2. **3**

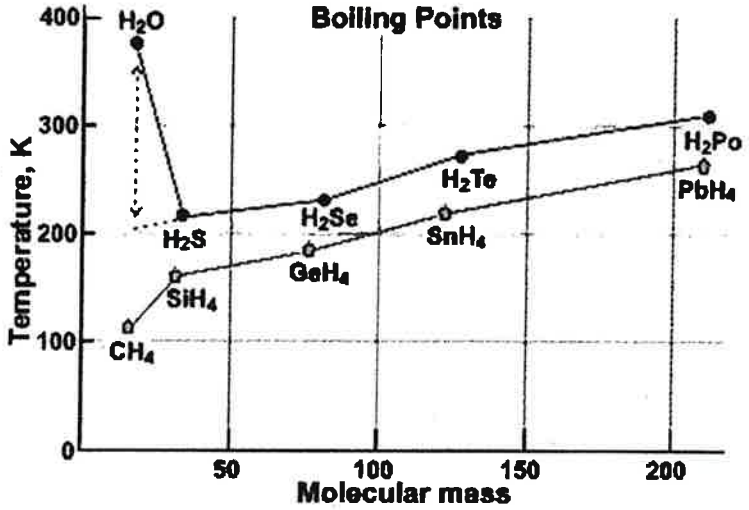
Increasing across period
because: 1. Greater nuclear charge — (1)
2. Electrons removed from same shell (1)
3. ∴ More energy is required to remove electron (1)

(b) Explain why the elements of Period 3 have smaller first ionisation energies than the corresponding elements of Period 2.

Period 3: valence electrons are further from the nucleus (1/2)
OR have an extra shell of electrons shielding
= the attractive nuclear force
∴ Less energy is required to remove one electron (1)

Question 15 (7 marks) **Marks**

The graphs below show the relative boiling points of hydrides of elements in Groups 4 and 6 of the Periodic Table.



(a) Draw a Lewis structure or electron dot formula to represent a molecule of hydrogen sulfide, (H_2S).

H S H OR H–S–H OR H S H

1

(b) Explain why H_2S is polar whereas SiH_4 is not.

2

1 mark – H_2S is bend or not symmetrical
SiH_4 is tetrahedral or symmetrical

1 mark – uneven charge distribution
or words to that effect.

Question continued. **Marks**

(c) Explain the trend in the boiling points of the Group 6 hydrides from H_2S to H_2Po.

Increasing strength of dispersion forces (1) 2

Owing to increasing number of electrons (1)
*didn't give increased size (or mass)

(One mark if increasing boiling point is linked with intermolecular forces increasing strength, even if the wrong forces are identified)

(* If student identified dipole/dipole or H-bonds in addition to dispersion as playing a role then MINUS 1 mark)

(d) Explain why the boiling point of water is significantly higher than would be expected from the trend for the other Group 6 hydrides.

2

Hydrogen bonds between H_2O molecules and these are the strongest intermolecular forces (1)

other Group 6 hydrides have weaker i.f. (1)

SECTION II: Attempt ALL Questions

Name: CRIB Class: MTK.

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

Question 16 (2 marks) **Marks**

Briefly explain how a process employed by Aboriginal or Torres Strait Islander peoples detoxifies poisonous food items.

1 – process eg soak in water (after grinding) for hou½
1 – explanation of detox eg. toxins dissolve / leach / diffuse out / water soluble.

Question 17 (3 marks)

Consider the following balanced chemical equation:

$$Sn(s) + Pb(NO_3)_2(aq) \rightarrow Pb(s) + Sn(NO_3)_2(aq)$$

(a) Does the reaction in the equation above proceed spontaneously? Justify your answer.

1 – yes, E° is +ve. (0.01 V). **1**
OR 1 – yes Sn is more reactive than Pb

(b) Identify the spectator ion in the equation in part (a).

NO_3^- * did not penalise $(NO_3)_2^-$? **1**

(c) Identify the reducing agent (reductant), for the equation in part (a).

Sn(s) **1**

Question 18 (6 marks) **Marks**

A student conducts an investigation to determine the voltage of a galvanic cell made from half-cells containing magnesium and silver, and their respective ions.

(a) Draw a labelled diagram of the experimental set-up. Indicate on your diagram the direction of electron flow and the direction of cation movement. **4**

1 – 2x ½ cells ē salt bridge
1 – labels (solutions / electrodes)
1 – e^- flow (from $Mg_{(s)} \rightarrow Ag_{(s)}$ via external wire
1 – cation flow (across salt bridge / cells from Mg cell → Ag cell)

* ignored lack of (V) or (G)
* 1 mark given if e^- and cations are same, but in wrong direction.
* only 2 max if Mg electrode in Ag^+ / Ag in Mg^{2+}.
* only 2 max if battery added.

(b) Calculate the standard cell potential for this galvanic cell. **1**

$Mg \rightarrow Mg^{2+} + 2e^-$ 2.36 V
$Ag^+ + e^- \rightarrow Ag$ 0.80 V
3.16 V.

* units not penalise
* – 3.16 V not paid

(c) The experimental voltage obtained from galvanic cells is often different to that indicated from standard reduction potentials. Suggest a reason why this may be. **1**

Conditions move away from std quickly.
– any valid reason paid.
* did not pay human error; faulty equipment; incomplete reaction

Question 19 (5 marks) **Marks**

In a metal displacement reaction following half reactions were observed to occur:

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

$Ag^+ + e^- \rightarrow Ag$

(a) Write a net ionic equation for this reaction, including all states.

$Cu_{(s)} + 2Ag^+_{(aq)} \longrightarrow Cu^{2+}_{(aq)} + 2Ag_{(s)}$ **2**

−1 states missing −1 wrong equation eg showing $2e^-$ or NO_3^- ?
−1 balancing wrong

(b) A strip of copper was placed into a solution containing silver nitrate. After the reaction was complete the silver was removed from the surface of the copper strip and the copper strip was removed. The resulting suspension, containing solid silver, was filtered.

copper strip before reaction	2.298 g
copper strip after reaction	2.216 g
filter paper before filtration	1.662 g
filter paper after filtration	2.002 g

(i) Calculate the chemical amount (in mol) of silver produced and of copper consumed.

(1) $n(Ag) = 0.340/107.9 = 3.15 \times 10^{-3}$ mol. **2**

(1) $n(Cu) = 0.082/63.55 = 1.29 \times 10^{-3}$ mol

(ii) Calculate the experimental mole ratio of silver to copper and account for any deviation from ideal results.

$n(Ag)/n(Cu) = 2.44:1$ ~~of~~ ideal ~~of~~ 2:1 * not marked **1**

(1) As there is too much silver, the sample must not be dry

* did not pay impurities without clarification nor any answer meaning too little silver.

SECTION II: Attempt ALL Questions

Name: _____ Class: _____

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

Question 20 (4 marks) **Marks**

A compound was found to contain 24.8% carbon, 2.0% hydrogen and 73.2% chlorine.

(a) Determine the empirical formula of this compound.

$n(C) = 24.8/12.01$ $n(H) = 2/1.008$ $n(Cl) = 73.2/35.45$

$= 2.065$ $= 1.984$ $= 2.065$ (1)

$\div 1.984$

1.04 : 1 : 1.04 (1)

$\therefore$ CHCl (1)

(b) The molar mass of this compound is 96.9 g mol^{-1}. Determine the molecular formula of this compound.

96.9 $96.9/48.47 = 2$ $\therefore C_2H_2Cl_2$ 1

* E.C = carry on error.

Question 21 (2 marks)

Chromium has four stable isotopes, whose relative isotopic masses and percentage abundances are shown in the table below.

Isotope	Isotopic mass (u)	Percentage abundance (%)
^{50}Cr	49.946	4.3450
^{52}Cr	51.941	83.789
^{53}Cr	52.941	9.5012
^{54}Cr	53.939	2.3657

Calculate the relative atomic mass of chromium.

$\frac{49.946 \times 4.345 + 51.941 \times 83.789 + 52.941 \times 9.5012 + 53.939 \times 2.3657}{100}$ 2

$= 51.997$

(2) - correct answer with significant figures.

(1) - Answer given with incorrect significant figures. Working must be shown for this mark.

* 14 boys lost marks for calculation errors due to:
- incorrect rounding, particularly intermediate rounding
- incorrect transcription of values
- simple calculation errors despite correct working.

CHECK YOUR WORKING

Many more lost marks for incorrect significant figures.

Question 22 (5 marks) **Marks**

In an experiment, 2.369 g of aluminium hydroxide reacts with 60.0 mL of 0.714 M sulfuric acid to produce a salt solution and water.

(a) Write a balanced chemical equation for this reaction.

$2Al(OH)_3 + 3H_2SO_{4(aq)} \longrightarrow Al_2(SO_4)_{3(aq)} + 6H_2O_{(l)}$ 1

* states not marked.

(b) Calculate the chemical amount (in mol) of the salt produced.

$n\ Al(OH)_3 = \frac{2.369}{78.004}$ $n\ H_2SO_4 = 0.06 \times 0.714$ 4

$= 0.03037$ mol AND. $= 0.04284$ (1)

$Al(OH)_3$ requires $0.3037 \times \frac{3}{2} = 0.04556$ mol H_2SO_4

$\therefore$ H_2SO_4 limiting. (1)

$n\ Al_2(SO_4)_3 = [1/3]$ (1) $\times\ 0.04284$

$= 0.0143$ mol (1)

Question 23 (4 marks)

A 33.34 g sample of a diatomic gas was stored in a 20.0 L vessel at 150 kPa and 30 °C. What is the identity of this gas?

$n = \frac{PV}{RT}$ 4

$= \frac{150 \times 20}{8.314 \times (30 + 273.15)}$ (1) (1)

$= 1.1902$ mol

$M(X_2) = m/n$

$= 33.34 / 1.1902$

$= 28.01$ g/mol (1)

$M(X) = 28.01/2$

$= 14.01$ $\therefore$ nitrogen (1)

Question 24 (5 marks) **Marks**

Antacids contain calcium carbonate and are used to neutralise stomach acid. The mass of one antacid tablet was found to be 1.30 g. To determine the amount of calcium carbonate present, this tablet was crushed into a fine powder and excess hydrochloric acid was added to it. After the reaction was complete, there was a decrease in mass of 0.220 g.

(a) Write a balanced equation for the reaction between calcium carbonate and hydrochloric acid. **1**

$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O_{(l)}$

* States not marked

(b) Calculate the mass (in g) of calcium carbonate present in the antacid tablet. **2**

$n(CO_2) = 0.220/44.01$

$= 0.004999$ mol (1)

$n(CaCO_3) = 0.004999$ mol (1:1)

$m(CaCO_3) = n \times 100.09$

$= 0.500$g (1)

(c) Calculate the percentage by mass of calcium carbonate in the antacid tablet. **1**

$0.5/1.3 = 38.5\%$

(d) At 100 kPa and 296 K, what volume of gas would have be produced? **1**

$V = \frac{nRT}{P}$

$= (0.004999 \times 8.314 \times 296) \div 100.$

$= 0.123$L.

Note: the conditions for 24.79L is 25°C & 298.15K which are not the conditions above.

SECTION II: Attempt ALL Questions

Name: _____ Class: _____

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

Question 25 (4 marks) **Marks**

	silicon tetrachloride	silicon dioxide
Melting point (°C)	−68	1713

Explain the melting points of silicon tetrachloride and silicon dioxide in terms of their structure and bonding.

4

① Identify structure & bonding in $SiCl_4$
e.g. discrete molecules with 4 Cl atoms covalently bonded to one Si atom.

① Identify structure & bonding in SiO_2
e.g. covalent network of Si and O atoms covalently bonded in a 3D array/lattice

① Identify what is being broken upon melting
e.g. intermolecular forces between $SiCl_4$ molecules vs covalent bonds between Si and O atoms.

① Relate strengths/energies to melting point data
e.g. covalent bonds require more energy to break than intermolecular forces, hence SiO_2 has a much higher melting point than $SiCl_4$.

Question 26 (6 marks) **Marks**

5.000 g of silver nitrate is dissolved in 100.0 g of water, initially at 25.0 °C.

(a) If the enthalpy of solution ($\Delta_{sol}H$) for silver nitrate is +22.6 kJ mol^{-1}, what is the final temperature of the solution? **4**

① $n(AgNO_3) = \frac{5.000\,g}{107.9+14.01+3\times16.00\ g\,mol^{-1}} = \frac{5.000\,g}{169.91\,g\,mol^{-1}} = 0.02943\,mol.$

① $q = 0.02943\,mol \times 22.6\,kJ\,mol^{-1} = 0.665\,kJ = 665\,J.$

① $\Delta T = \frac{-q_{sys}}{mC} = \frac{665\,J}{100\times4.18} = -1.59\,°C.$

① $\therefore T_{final} = 25.0 - 1.59$
$= 23.4\,°C.$

Signs not marked for q or ΔT, just direction of final temperature (i.e subtract off from 25.0).

(b) Given that silver nitrate is soluble in water at room temperature, what must be the sign of the entropy of solution ($\Delta_{sol}S$) for silver nitrate? Explain your answer. **2**

① Given that silver nitrate dissolves in water $\Delta_{sol}G$ must be negative.

① Since $\Delta_{sol}H$ is positive, the only way $\Delta_{sol}G$ can be negative is if $-T\Delta S$ is negative, i.e if $\Delta_{sol}S$ is positive.

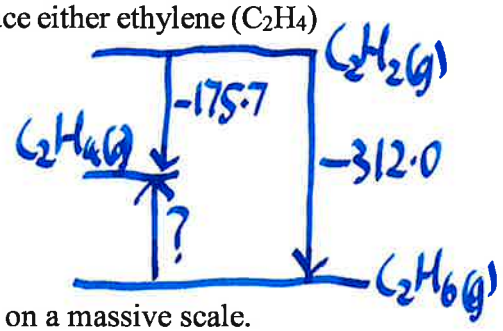
If boys argued that $AgNO_{3(s)} \rightarrow Ag^+_{(aq)} + NO_3^-{}_{(aq)}$ must have a positive $\Delta_{sol}S$ → ① max. This is not actually true in general for all ionic compounds.

Question 27 (2 marks) **Marks**

The reaction of acetylene (C_2H_2) with hydrogen (H_2) can produce either ethylene (C_2H_4) or ethane (C_2H_6):

$C_2H_2(g) + H_2(g) \rightarrow C_2H_4(g)$ $\quad \Delta_r H^\ominus = -175.7$ kJ mol^{-1}

$C_2H_2(g) + 2H_2(g) \rightarrow C_2H_6(g)$ $\quad \Delta_r H^\ominus = -312.0$ kJ mol^{-1}



Industrially, ethylene and hydrogen are produced from ethane on a massive scale.

What is $\Delta_r H$ for the reaction of ethane (C_2H_6) to form ethylene (C_2H_4) and H_2? **2**

$C_2H_6(g) \rightarrow C_2H_2(g) + 2H_2(g) \quad \Delta H = +312.0$ kJ mol^{-1}

$C_2H_2(g) + H_2(g) \rightarrow C_2H_4(g) \quad \Delta H = -175.7$ kJ mol^{-1}

$C_2H_6(g) \rightarrow C_2H_4(g) + H_2(g) \quad \Delta H = +312.0 - 175.7$

$= +136.3$ kJ mol^{-1}

(−1) for any mistake.

Question 28 (3 marks)

Tetraethyllead [$Pb(C_2H_5)_4$] was formally used as a fuel additive, but its use in automotive petrol has been banned in Australia since 2002. It combusts as follows:

$$[Pb(C_2H_5)_4](l) + \frac{27}{2}O_2(g) \rightarrow PbO(s) + 8CO_2(g) + 10H_2O(l) \quad \Delta H° = -6278\ kJ\ mol^{-1}$$

	standard enthalpy of formation (kJ mol^{-1})
$CO_2(g)$	−393.5
$H_2O(l)$	−285.8
$[Pb(C_2H_5)_4](l)$	+53.0

Given the information in the table above, calculate the standard enthalpy of formation of PbO(*s*).

$\Delta H^\ominus = -6278$ kJ mol^{-1} $= \Delta_f H^\ominus(PbO) + 8\times(-393.5) + 10\times(-285.8) - 53.0$ **3**

$\therefore \Delta_f H^\ominus(PbO) = -6278 + 8\times393.5 + 10\times285.8 + 53.0$

$= -219$ kJ mol^{-1}

(−1) per error

Question 29 (5 marks) **Marks**

Widgiemoolthalite is a rare blue-green mineral first identified in Widgiemooltha, Western Australia, in 1992. It contains three different ions, none of which contains atoms of more than two elements.

When 2.000 g of widgiemoolthalite reacts with excess hydrochloric acid it dissolves completely and releases 0.5354 g of carbon dioxide. Strongly heating 2.000 g of widgiemoolthalite produces water vapour, carbon dioxide and 1.1358 g of nickel(II) oxide as the only products.

Calculate the empirical formula for widgiemoolthalite, expressing your answer in terms of the ions and molecules present. **5**

$n(CO_2) = \frac{0.5354}{44.01} = 0.01217$ mol. (1)

$n(NiO) = \frac{1.1358}{58.69+16} = \frac{1.1358}{74.69} = 0.1521$ mol. (1)

$m(H_2O) = 2.000 - 1.1358 - 0.5354 = 0.3288$ g.

$\therefore n(H_2O) = \frac{0.3288\ g}{18.016\ g\ mol^{-1}} = 0.01825$ mol. (1)

$\therefore$ Mole ratio $CO_2 : NiO : H_2O = \frac{0.01217}{0.01217} : \frac{0.1521}{0.01217} : \frac{0.01825}{0.01217}$

$= 1 : 1.25 : 1.5$

or $4 : 5 : 6$. (1)

Since no ion contains atoms of more than two elements, the CO_2 must have come from carbonate ions (CO_3^{2-})

Charge balance: $5 \times Ni^{2+}$: 10+ charge

$4 \times CO_3^{2-}$: 8− charge

This leaves 2− charge, containing H, that gives water upon strong heating $\Rightarrow 2 \times OH^-$

This will give $1 \times H_2O$, which leaves 5 more H_2O molecules.

$\therefore Ni_5(CO_3)_4(OH)_2 \cdot 5H_2O_{(s)}$ (1)

END OF EXAMINATION