CHEMISTRY

Please place your student identification label in this box

Student Number: In figures

In words

_____

_____

Time allowed for this paper

Reading time before commencing work: Ten minutes
Working time for paper: Three hours

Materials required/recommended for this paper

To be provided by the supervisor
This Question/Answer Booklet
Separate Multiple Choice Answer Sheet
Chemistry Data Sheet (inside front cover of this Question/Answer Booklet)

To be provided by the candidate
Standard items: Pens, pencils, eraser or correction fluid, ruler, highlighter
Special items: A 2B, B or HB pencil for the separate Multiple Choice Answer Sheet and
                  calculators satisfying the conditions set by the Curriculum Council for this
                  subject.

Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that
you do not have any unauthorised notes or other items of a non-personal nature in the examination
room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any
further.

Structure of this paper

Part	Number of questions available	Number of questions to be attempted	Suggested working time	Marks available	
1 Multiple choice	30	30	55	60	(30%)
2 Short answers	13	13	60	70	(35%)
3 Calculations	5	5	45	50	(25%)
4 Extended answers	1	1	20	20	(10%)
			Total marks	200	(100%)

Instructions to candidates

1. The rules for the conduct of Tertiary Entrance Examinations are detailed in the booklet *TEE Handbook*. Sitting this examination implies that you agree to abide by these rules.

2. Answer the questions according to the following instructions:

   Part 1   Answer **all** questions, using a 2B, B or HB pencil, on the separate Multiple Choice Answer Sheet. Do **not** use a ball point or ink pen.

   If you consider that two or more of the alternative responses are correct, choose the one you think is best. If you think you know an answer, mark it even if you are not certain you are correct. Marks will not be deducted for incorrect answers.

   Feel free to write or do working on the question paper; many students who score high marks in the Multiple Choice Section do this.

   Parts 2, 3 and 4   Write your answers in the spaces provided in this Question/Answer Booklet. A blue or black ball point or ink pen should be used.

   Questions containing specific instructions to show working should be answered with a complete, logical, clear sequence of reasoning showing how the final answer was arrived at; correct answers for such questions which do not show working will not be awarded full marks.

3. The examiners recommend that you spend your reading time mainly reading the instructions to candidates and Parts 2, 3 and 4.

4. **Chemical equations**
   For full marks, chemical equations should refer only to those species consumed in the reaction and the new species produced. These species may be **ions** [for example $Ag^+(aq)$], **molecules** [for example $NH_3(g)$, $NH_3(aq)$, $CH_3COOH(l)$, $CH_3COOH(aq)$] or **solids** [for example $BaSO_4(s)$, $Cu(s)$, $Na_2CO_3(s)$].

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PART 1   (60 marks)

Answer ALL questions in Part 1 on the separate Multiple Choice Answer Sheet provided, using a 2B, B or HB pencil. Each question in this part is worth 2 marks.

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1.   An element Y has the electron configuration $1s^2 2s^2 2p^5$ and forms a compound XY_2 with element X. Which one of the following could be the electron configuration of X?

(a) $1s^2 2s^2$

(b) $1s^2 2s^2 2p^1$

(c) $1s^2 2s^2 2p^2$

(d) $1s^2 2s^2 2p^6 3s^1$

2.   Which one of the following species has a different number of electrons from all the others?

(a) $A\ell^{3+}$

(b) Ar

(c) Ca^{2+}

(d) $C\ell^-$

3.   As atomic number increases across a period, which one of the following generally **decreases**?

(a)   atomic mass

(b)   number of valence electrons

(c)   first ionisation energy

(d)   atomic radius

4.   Which one of the following compounds contains **only** ionic bonds?

(a) CH_3OH

(b)   HCl

(c)   NaH

(d) $NaNO_3$

5.   Which one of the properties of ammonia is **not** related to the hydrogen bonding between the molecules?

   (a)   freezing point

   (b)   molar mass

   (c)   solubility in water

   (d)   vapour pressure

6.   Which of the following 1.00 mol L^{-1} aqueous solutions will conduct electricity?

            I   hydrogen chloride
            II   ethanol
            III   ammonia
            IV   sodium nitrate

   (a)   IV only

   (b)   I and IV only

   (c)   I, II and IV only

   (d)   I, III and IV only

7.   Which one of the following may have 19 protons, 21 neutrons and 19 electrons?

   (a)   Ar

   (b)   K

   (c) K^+

   (d)   Sc

8.   Which best describes the bonding between Mg and $C\ell$?

   (a)   The atoms readily form ions which are attracted to each other.

   (b)   Polyatomic ions exhibit covalent bonding between the atoms within the ion.

   (c)   Mg and $C\ell$ form covalent bonds by sharing of electron pairs.

   (d)   There is a lattice of positive ions in a sea of delocalised electrons.

9. What is the pH of a 5.0 x 10^{-3} mol L^{-1} solution of barium hydroxide?

    (a) 2

    (b) 2.3

    (c) 11.7

    (d) 12

10. The water in a seriously neglected swimming pool is tested and found to have a pH of 3. By what factor must the hydrogen ion concentration be changed to increase the water pH to 6?

    (a) decrease the hydrogen ion concentration by 1000 times;

    (b) double the hydrogen ion concentration;

    (c) halve the hydrogen ion concentration;

    (d) increase the hydrogen ion concentration by 1000 times.

11. The concentration of Mg^{2+} in sea water is approximately 0.05 mol L^{-1}. Which one of the following ions could not be present at a significant concentration?

    (a) $C\ell^{-}$

    (b) CO_3^{2-}

    (c) K^{+}

    (d) SO_4^{2-}

12. Sulfuric acid is a stronger acid than acetic (ethanoic) acid. Which one of the following statements best explains this?

    (a) Concentrated sulfuric acid has a concentration of 18 mol L^{-1}, while concentrated acetic acid has a concentration of 17 mol L^{-1}.

    (b) Sulfuric acid has two hydrogen atoms available for ionisation per molecule, while acetic acid has only one hydrogen atom available for ionisation per molecule.

    (c) Sulfuric acid ionises to a greater extent than acetic acid.

    (d) Sulfuric acid is more soluble in water than acetic acid.

13.   Which one of the following correctly identifies the acidity, basicity or neutrality of each of the given solutions?

|	Sodium hydrogensulfate	Potassium phosphate	Ammonium chloride	Magnesium nitrate
(a)	Acidic	Acidic	Acidic	Basic
(b)	Neutral	Basic	Neutral	Acidic
(c)	Acidic	Basic	Acidic	Neutral
(d)	Basic	Neutral	Basic	Neutral

14.   Household vinegar can be produced by adding 250 mL of glacial (nearly pure) acetic (ethanoic) acid to 10 L of pure water. Which one of the following best describes the glacial acetic acid?

(a)   a dilute solution of a strong acid;

(b)   a concentrated solution of a weak acid;

(c)   a dilute solution of a weak acid;

(d)   a concentrated solution of a strong acid.

15.   In which one of the following does manganese have an oxidation state of +6?

(a) Mn_2O_3

(b) MnO_2

(c) MnO_4^{2-}

(d) MnO_4^-

16.   What is the change in the oxidation number of bromine in the following reaction?

$2BrO_3^-(aq) + 10I^-(aq) + 12H^+(aq) \rightarrow 5I_2(aq) + Br_2(aq) + 6H_2O(\ell)$
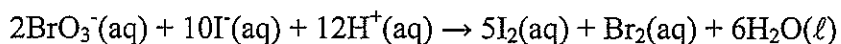
(a)   +7 to 0

(b)   +7 to -1

(c)   +5 to 0

(d)   +5 to -1

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17. In which one of the following pairs do the underlined elements have the same oxidation number?
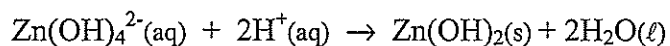
    (a) $\underline{Cr}_2O_7^{2-}$ and $\underline{Cr}O_4^{2-}$

    (b) $\underline{H}F$ and $Mg\underline{H}_2$

    (c) $H_2\underline{O}$ and $H_2\underline{O}_2$

    (d) $\underline{N}O_2$ and $H\underline{N}O_3$

18. Consider the elements $A\ell$, Cr, F, Fe, N, and Zn.

    Which of the elements exhibit variable oxidation states in their compounds?

    (a) all six of the elements;

    (b) $A\ell$, Cr, Fe, and Zn;

    (c) $A\ell$, Cr, Fe, N, and Zn;

    (d) Cr, Fe, and N.

19. Zincate ions react with hydrochloric acid as follows.

    $$Zn(OH)_4^{2-}(aq) + 2H^+(aq) \rightarrow Zn(OH)_2(s) + 2H_2O(\ell)$$
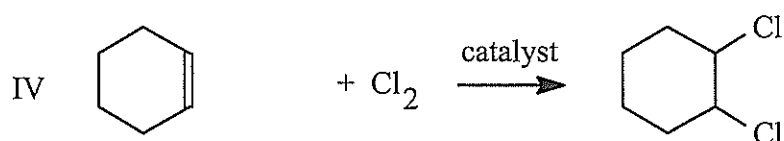
    Which one of the following statements is correct?

    (a) $Zn(OH)_4^{2-}(aq)$ is reduced.

    (b) $Zn(OH)_4^{2-}(aq)$ forms a complex ion.

    (c) $Zn(OH)_4^{2-}(aq)$ acts as an acid.

    (d) $Zn(OH)_4^{2-}(aq)$ acts as a base.

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20. A mixed solution containing **both 1 mol L^{-1} $ZnSO_4$ and 1 mol L^{-1} $CuSO_4$** was electrolysed in an electrolytic cell using inert electrodes.

Which one of the following statements is correct?

(a) Copper is produced at the cathode and zinc is produced at the anode.

(b) Copper is produced at the cathode and oxygen gas is produced at the anode.

(c) Hydrogen gas is produced at the cathode and oxygen gas is produced at the anode.

(d) Zinc is produced at the cathode and oxygen gas is produced at the anode.

21. Which of the following are examples of addition reactions?

I $\quad$ $+ Cl_2$ $\xrightarrow{\text{catalyst}}$ $+ HCl$

II $\quad$ $+ Cl_2$ $\xrightarrow{\text{catalyst}}$ $+ H_2$

III $\quad$ $+ Cl_2$ $\xrightarrow{\text{catalyst}}$

IV $\quad$ $+ Cl_2$ $\xrightarrow{\text{catalyst}}$
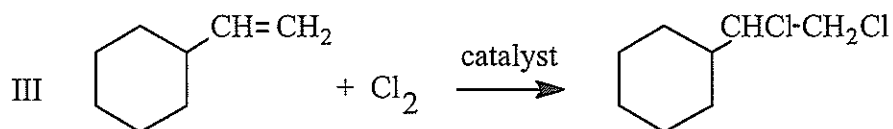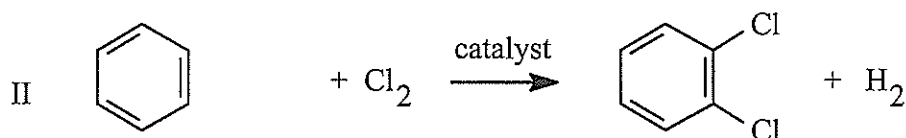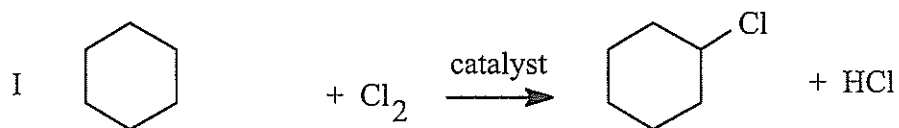
(a) III and IV only

(b) III only

(c) I and IV only

(d) All of I, II, III and IV

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22. 0.100 mol of a compound has a mass of 9.00 g. Its empirical formula is CHO_2. What is the molecular formula of the compound?

    (a) CHO_2

    (b) $C_2H_2O_4$

    (c) $C_3H_3O_6$

    (d) $C_4H_4O_8$

23. When silver sulfide is added to water, the following equilibrium is established.

    $Ag_2S(s) \rightleftharpoons 2Ag^+(aq) + S^{2-}(aq)$
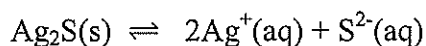
    The value of the equilibrium constant for this reaction is very small. What does this suggest?

    (a) Adding more silver sulfide will increase the amount of ions in solution.

    (b) Silver sulfide reacts extensively with water.

    (c) Silver sulfide has a very low solubility.

    (d) This reaction is endothermic.

24. When $CoCl_2$ is dissolved in dilute hydrochloric acid, the following equilibrium is established.

    $$Co(H_2O)_6^{2+}(aq) \quad + \quad 4C\ell^-(aq) \quad \rightleftharpoons \quad CoC\ell_4^{2-}(aq) \quad + \quad 6H_2O(\ell)$$
    $$\text{red} \qquad\qquad\qquad\qquad\qquad\qquad \text{deep blue}$$
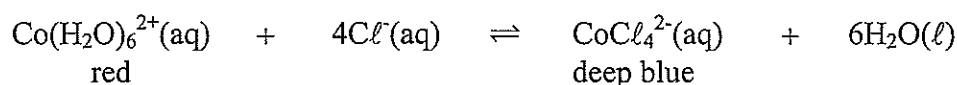
    The solution appears purple in colour as a result of the mixture of the blue and red colours. Which one of the following changes will cause the solution to become more blue in colour?

    (a) A catalyst is added.

    (b) A few drops of concentrated HCl is added.

    (c) A few millilitres of $AgNO_3$ solution is added.

    (d) The solution is diluted by the addition of water.

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25. If solid calcium carbonate is heated in a sealed container, the following equilibrium is established.

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g) \quad \Delta H = +178 \text{ kJ/mol}$$
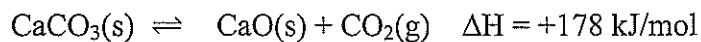
For this system, which one of the following statements about the equilibrium constant K is correct?

(a) K will increase if the pressure of the system is decreased.

(b) K will decrease if the partial pressure of the CO_2 is reduced.

(c) K will increase if the temperature of the system is increased.

(d) K will remain constant, regardless of any changes made to the system.

26. Consider the following potential energy diagram for a chemical reaction.

Reaction Coordinate
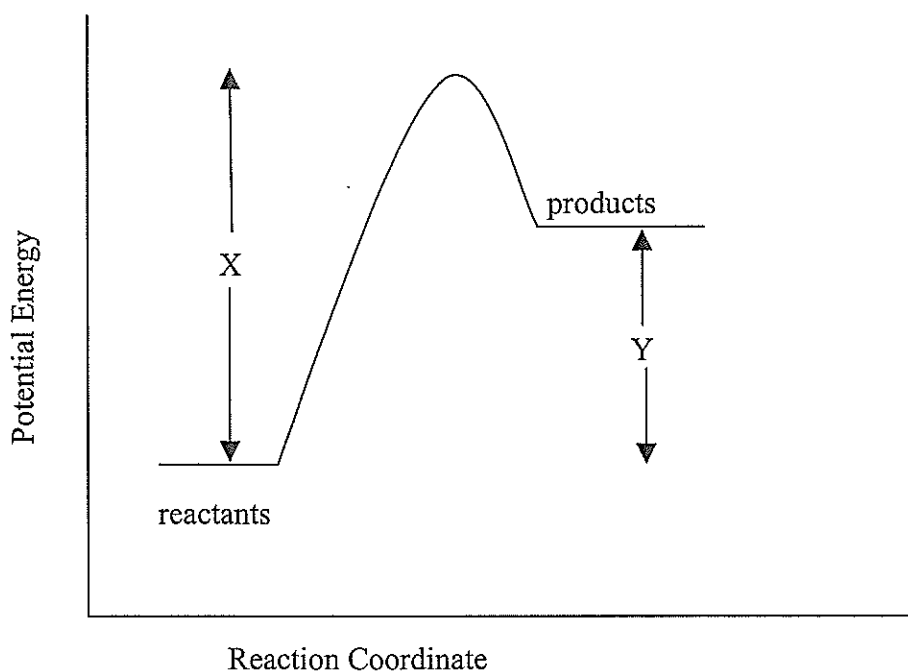
Which one of the following statements about this reaction is **incorrect**?

(a) The reaction mixture will become hotter as the reaction proceeds.

(b) The activation energy for the reverse reaction is X – Y.

(c) The ΔH for the reverse reaction is –Y.

(d) The forward reaction rate is likely to be slower than the reverse reaction rate.

27. The following equilibrium is used in the production of alumina via the Bayer Process.

$$A\ell(OH)_3(s) + OH^-(aq) \rightleftharpoons A\ell(OH)_4^-(aq)$$
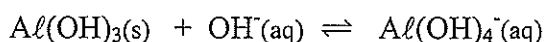
Which one of the following will move the equilibrium in the forward direction to produce more aluminate ion $A\ell(OH)_4^-(aq)$?

(a) addition of cryolite;

(b) addition of $A\ell(OH)_3(s)$ seed crystal;

(c) passing a large electric current through the solution using carbon electrodes;

(d) addition of caustic soda (sodium hydroxide).

28. 1.0 mol of an unknown metal reacts with excess hydrochloric acid to produce 1.5 mol of hydrogen gas. What is the charge on the metal ion?

(a) +1

(b) +2

(c) +3

(d) +4

29. In a sample of ground water, iron in the form of Fe^{2+} was found to have a concentration of 9.00×10^{-3} mol L^{-1}. Assuming the density of the water sample is 1.00 g mL^{-1}, what is the concentration of Fe^{2+} expressed in ppm?

(a) 0.502 ppm

(b) 9.00 ppm

(c) 50.2 ppm

(d) 502 ppm

30. Which of the following fertilisers has the greatest percentage of nitrogen by mass?

(a) $(NH_4)_2SO_4$

(b) NH_2CONH_2

(c) NH_4NO_3

(d) $(NH_4)_2CO_3$

END OF PART 1

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PART 2 (70 marks)

Answer ALL questions in Part 2 in the spaces provided below.

1. Write equations for any reactions that occur in the following procedures. If no reaction occurs write 'no reaction'.

In each case, describe **in full** what you would observe, including any
- colours
- odours
- precipitates (give the colour)
- gases evolved (give the colour or describe as colourless).

If no change is observed, you must state this as the observation.

(a) Butane gas is burnt in air.

Equation _____

Observation _____

_____

[3 marks]

(b) Zinc metal is added to copper nitrate solution.

Equation _____

Observation _____

_____

[3 marks]

(c) Manganese dioxide is added to hydrogen peroxide.

Equation _____

Observation _____

_____

[3 marks]

(d) Sodium metal is added to water.

Equation _____

Observation _____

_____

[3 marks]

SEE NEXT PAGE

2.   For each species listed in the table below, draw the structural formula, representing all valence shell electron pairs either as **:** or as **-** .

[for example, $H : \ddot{\underset{..}{O}} : H$ $H - \ddot{\underset{..}{O}} - H$ $H - \underset{\_}{O} - H$ water or
or   and so   on]

Species	Electron-dot diagram	Shape (name or sketch)
Silane (Silicon tetrahydride) SiH_4		
Phosphorus trichloride $PC\ell_3$		
Carbonate ion $CO_3{}^{2-}$		

[9 marks]

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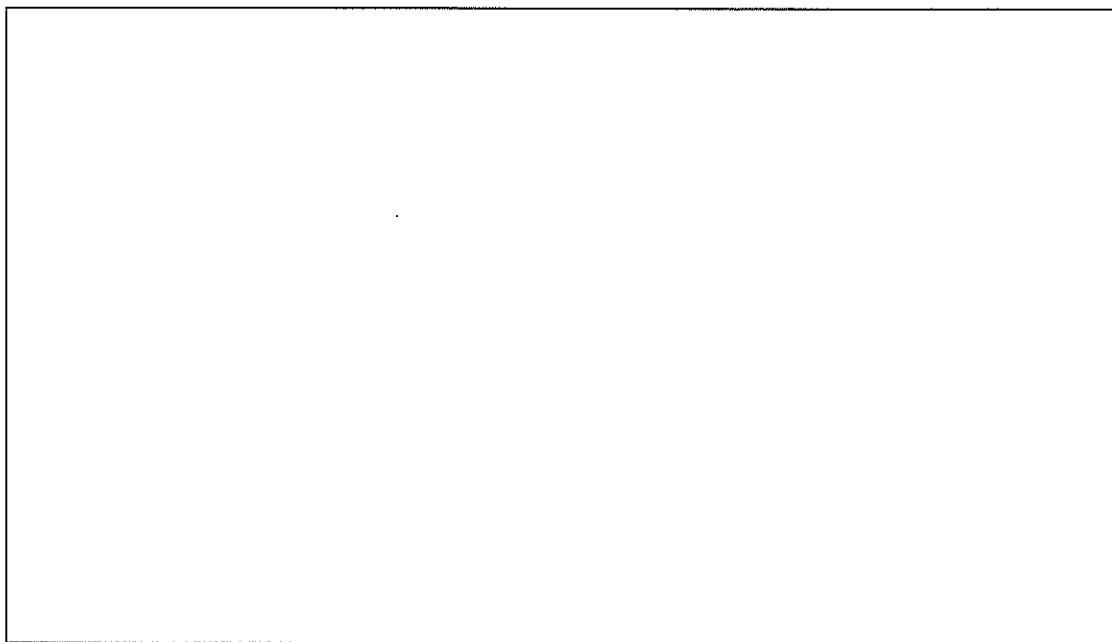
3. For each of the following substances, provide a common use and the property that is responsible for that use.

Substance	Use	Property
Aluminium		
Diamond		
Zinc		
Stainless steel		
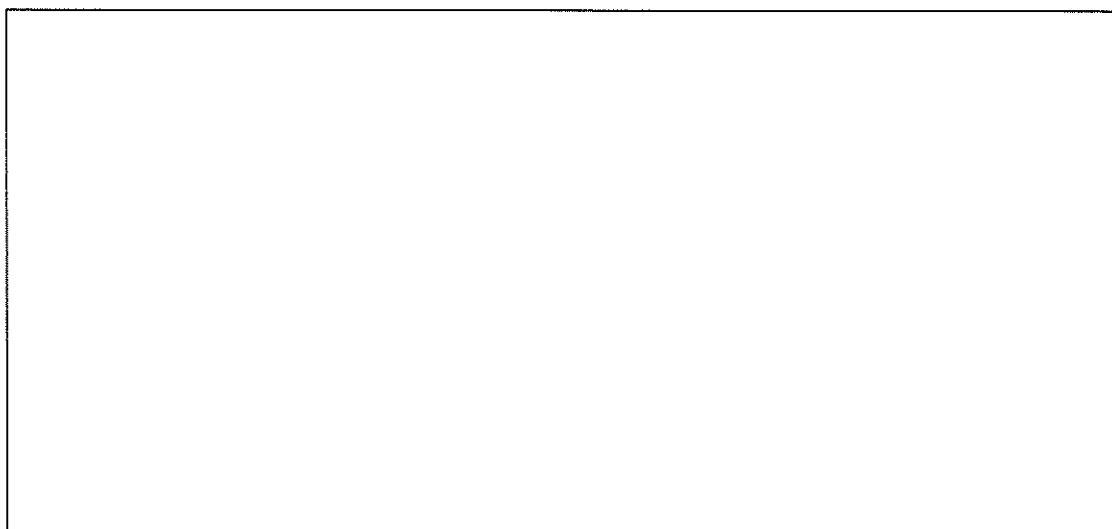
[8 marks]

4.   A desalination plant uses reverse osmosis filters to remove salt from sea water. Periodically the desalinated water is tested to determine the effectiveness of the filters. The test uses a conductivity meter to measure the ability of the water solution to conduct electricity. Explain why a high conductivity would indicate that the filter was not working properly.

[2 marks]

5.   Explain in terms of intermolecular forces why methylated spirits (mainly ethanol) is more effective than water for removing grease from clothing.

[3 marks]

6. The 'Thermite reaction' is a spectacular chemical reaction in which finely powdered aluminium and iron(III) oxide are mixed and ignited. A bright, hot flame is observed and molten iron and aluminium oxide are produced.

    (a) Write the chemical equation for this reaction.

    [1 mark]

    (b) Explain why the aluminium and iron(III) oxide must be finely powdered and thoroughly mixed.

    [2 marks]

    (c) This reaction does not occur at room temperature. One way to start the reaction is to drop a piece of burning magnesium ribbon onto the mixture. Why is it necessary to start the reaction this way?

    [1 mark]

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(d)   Using the following axes, draw a reaction profile diagram for the thermite
        reaction. On your diagram label the activation energy and ΔH.

Potential energy

Reaction pathway   [3 marks]
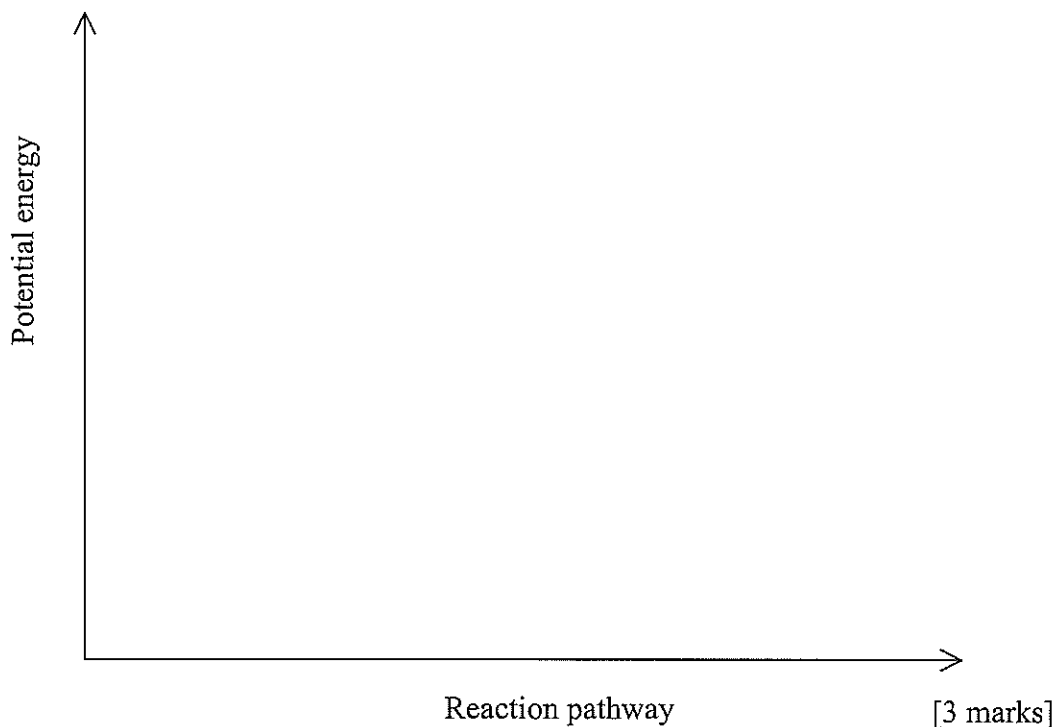
(e)   Is the reaction endothermic or exothermic?

[1 mark]

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7. The reaction between carbon and hydrogen gas to form methane can be represented by the following equation.

$$C(s) + 2H_2(g) \rightleftharpoons CH_4(g) + 75 \text{ kJ}$$
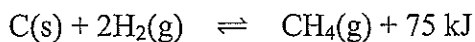
The concentrations of hydrogen and methane were plotted over time and the following graph produced.
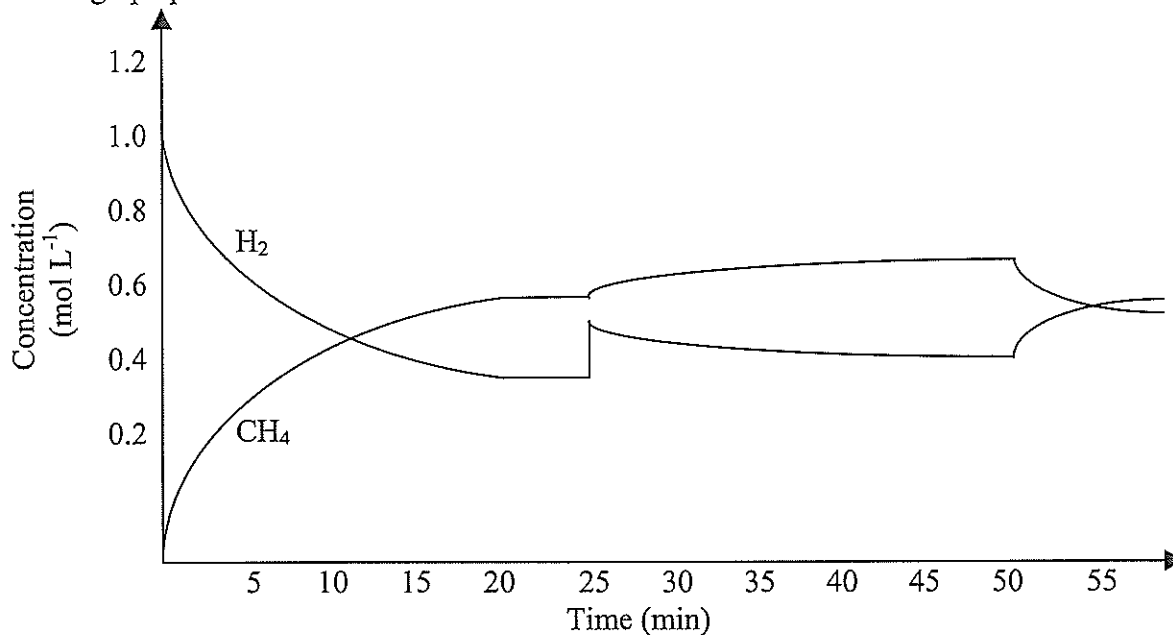
(a) About what time was equilibrium first established?

[1 mark]

(b) Suggest what could have caused the change at the 25 minute mark.

[1 mark]

(c) Suggest what change to the system occurred at the 50 minute mark.

[1 mark]

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(d)   What would be the effect on the equilibrium if more $C(s)$ was added to the system?

[1 mark]

(e)   Explain, using Le Chatelier's Principle, what would be the effect of halving the volume of the reaction container.

[2 marks]

8.   Buckyballs (Buckminsterfullerene molecules) are a molecular form of carbon with the formula C_{60}. Will buckyballs conduct electricity? Justify your answer.

[2 marks]

9. A student conducted an experiment and wrote down the following set of observations.

   A pungent, colourless solution was added drop-wise to a pale blue solution. A pale blue precipitate was formed. On further addition of the colourless solution, the precipitate dissolved and a dark blue solution was formed.

   Write equations to represent the two sets of observations.

   [4 marks]

10. Two isomers of $C_5H_{12}O$ have the following structures.

    A

    B
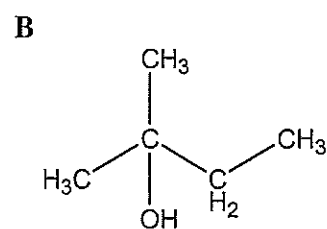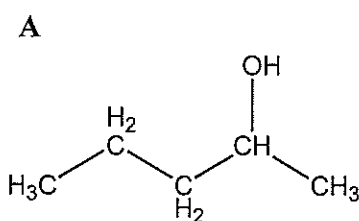
    Both are colourless liquids. Describe a chemical test that could be used to distinguish between the two compounds.

Test	Observations

    [3 marks]

11. Sodium oxalate is used as a primary standard in redox titrations, while potassium permanganate is not. Explain why this is so.

[2 marks]

12. A chemist adds acetic acid (ethanoic acid) to separate beakers containing sodium metal, ethanol and sulfuric acid, and acidified potassium permanganate. Complete the following table.

Reactants	Observations
Acetic acid + sodium metal	
Acetic acid + ethanol and sulfuric acid	
Acetic acid + acidified potassium permanganate	

Write a balanced equation for any reactions that occur.

[5 marks]

SEE NEXT PAGE

13. Complete the following table.

IUPAC Name	Structural Formula
5-chloro-3-methylpentanal	
	$CH_3CH_2CH_2COOH$
	$CH_3CHCH_2CH_3$ $\mid$ OH
4-chloro-2-pentanone	
propanamine	
	$CH_3CHCH_2C = O$ with OH on the third carbon and $CHCH_3$ / $C\ell$ branch

[6 marks]

END OF PART 2

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PART 3 (50 marks)

Answer ALL questions in Part 3. The calculations are to be set out in detail in this Question/Answer Booklet. Marks will be allocated for correct equations and clear setting out, even if you cannot complete the problem. When questions are divided into sections, clearly distinguish each section using (a), (b) and so on. Express your final numerical answers to three (3) significant figures where appropriate, and provide units where applicable. Information which may be necessary for solving the problems is located on the separate Chemistry Data Sheet. Show clear reasoning: if you don't, you will not receive full marks.

1. In the reaction between tin metal and iodine, tin(IV) iodide is formed.

   (a) Write an equation for this reaction.

   If 0.945 g of tin is added to 3.67 g of iodine,

   (b) identify the limiting reagent;

   (c) calculate the mass of tin(IV) iodide formed; and

   (d) calculate the mass of excess reactant remaining after the reaction.

   [9 marks]

2.   Ascorbic acid (vitamin C, $C_6H_8O_6$) can be oxidised at the anode of an electrolytic cell. Over a 6.00 minute period, 1.50 g of ascorbic acid reacted in a cell in which the cathode half cell produced 0.544 g of copper from a copper sulfate electrolyte.

   (a)   Calculate the number of moles of electrons passed through the cells.

                                                                     [2 marks]

   (b)   Calculate how many moles of electrons are lost in the oxidation of one mole of ascorbic acid.

                                                                     [3 marks]

   (c)   Calculate the current that passed through the cells.

                                                                     [2 marks]

   (d)   Write a possible half equation for the oxidation of ascorbic acid.

                                                                     [2 marks]

3. A compound was analysed to determine its empirical formula. The compound contained potassium, nickel, oxalate and water and had the general formula $K_wNi_x(C_2O_4)_y.zH_2O$.

1.834 g of the compound was heated to 150°C to drive off the water. The mass of the compound was determined a number of times during the heating and the following data were obtained.

Time (hours)	Mass (g)
0	1.834
1.0	1.680
1.5	1.649
2.0	1.648

Half of the anhydrous compound (0.824 g) was dissolved in water and H_2S gas bubbled through the solution. 0.238 g of NiS was precipitated.

The remaining half of the compound was oxidized and 0.463 g of carbon dioxide was produced.

From this information, determine the empirical formula of the compound.

[Hint: Treat $C_2O_4^{2-}$ as a single unit.]

[12 marks]

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4. 2.79 g of an impure sample of zinc was added to excess dilute hydrochloric acid solution. All of the hydrogen produced was collected by the downward displacement of water. The volume of the damp hydrogen was 916 mL and was collected at a total pressure of
100.4 kPa and a temperature of 25°C. The vapour pressure of water at 25°C is 2.34 kPa. Assuming that the impurities in the zinc sample do not react with the hydrochloric acid, calculate the percentage purity of the zinc.

[8 marks]

5.   (a)   A hydrochloric acid solution was standardised by titrating 10.00 mL of it against a 0.106 mol L^{-1} sodium hydroxide solution. The following results were obtained.

Volume of Sodium Hydroxide Solution

	TITRATION			
	1	2	3	4
Final volume (mL)	37.56	37.18	38.53	37.27
Initial volume (mL)	0.50	1.22	2.55	1.33
Titre				

Calculate the concentration of the hydrochloric acid solution.

(b)   A sample of magnesium oxide was found to be contaminated with sodium chloride. Magnesium oxide is not very soluble in water but can be dissolved in an excess of the standardised hydrochloric acid.

In order to determine the purity of the magnesium oxide, 3.86 g of the sample was dissolved in 500.0 mL of hydrochloric acid solution and then 50.0 mL of the resulting solution was titrated against the sodium hydroxide solution of known concentration. The average titre was found to be 10.4 mL.

Calculate the percentage of magnesium oxide in the contaminated sample.

[12 marks]

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SEE NEXT PAGE

PART 4 (20 marks)

Where applicable use equations, diagrams and illustrative examples of the chemistry you are describing.

Marks are awarded for the relevant chemical content of your answer and also for coherence and clarity of expression. Your answer should be presented in about $1\frac{1}{2}$ - 2 pages. Begin your essay on the lined page following the end of the question.

Discuss the similarities and differences of the chemistry of **three** of the following industrial processes:

- extraction of aluminium from alumina through the Hall-Heroult process;
- extraction of gold by electrolysis from $[Au(CN)_2]^-$;
- extraction of iron in the blast furnace;
- production of sulfuric acid through the contact process; and
- production of ammonia through the Haber process.

In your answer you should include the following:

- equations;
- diagrams where appropriate; and
- a discussion about why each process is considered the most suitable for the particular product.

(Marks will not be awarded for a discussion of the Bayer process or the cyanide leach process.)

END OF QUESTIONS
Check that you have written your Student Number on the front cover of this booklet

Write your response to Part 4 below.