PART 1 (60 marks = 30% of paper)

Answer ALL questions in Part 1 on the separate Multiple Choice Answer Sheet provided. Each question in this part is worth 2 marks.

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1. When butane is used as a fuel in cigarette lighters it reacts with oxygen to produce CO_2 and H_2O. Compared with the total chemical energy of the combustion products, the total chemical energy of the reactants is:

   A. higher, and the process is exothermic.

   B. higher, and the process is endothermic.

   C. lower, and the process is exothermic.

   D. lower, and the process is endothermic.

2. Which one of the following represents a process in which the sign of its heat of reaction (ΔH) is different from the others?

   A. Water vapour condensing of the outside of a glass.

   B. $2\ Br \rightarrow Br_2$

   C. $Na^{2+} \rightarrow Na^{3+} + e^-$

   D. $Mg^{2+} + 2\ e^- \rightarrow Mg$

3. In a reversible chemical reaction at constant temperature, the addition of a catalyst:

   A. decreases the time required for the equilibrium to be reached.

   B. increases the rate of the forward reaction but has no effect on the rate of the reverse reaction.

   C. decreases the heat of the reaction, ΔH.

   D. increases the energy of the transition state.

4. The equation for the formation of hydrogen iodide is:

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2\,HI_{(g)} \qquad \Delta H = +\,51.8\ kJ$$

Which of the following changes would cause the rate of formation of HI to increase?

I Increasing the concentration of H_2

II Increasing the concentration of HI

III Increasing the temperature

IV Increasing the volume of the system without changing the amount of substance present

A. I, III and IV

B. II only

C. I, II and III only

D. II and III only

5. The equilibrium constant, K, of the reaction:

$$N_{2(g)} + O_{2(g)} \rightleftarrows 2\,NO_{(g)}$$

is 66.5 at 360°C and 50.7 at 440°C. Which statement is true?

A. The forward reaction is exothermic.

B. If the volume of the container is halved, the $[O_2]$ is unaffected.

C. If the pressure of the system is increased at constant volume by the addition of argon gas there will be a shift to the right.

D. The K value would be greater than 66.5 if more $N_{2(g)}$ were added at 633K.

6. When iron and steam are heated in a closed container, a dynamic equilibrium is established.

$$3\ Fe_{(s)} + 4\ H_2O_{(g)} \rightleftarrows Fe_3O_{4(s)} + 4\ H_{2(g)} \qquad \Delta H = +123\ kJ$$

Which of the following conditions would increase the mass of Fe_3O_4 in the equilibrium mixture?

I Adding more steam

II Adding more hydrogen

III Raising the temperature

IV Adding more iron

A. I only

B. III and IV only

C. I and III only

D. I, II and IV only

7. Germanium, $Ge_{(s)}$ has a very high melting point, little or no electrical conductivity and the melting point of its chloride, $GeCl_4$ is –54°C. From these data it follows that Ge is:

A. an ionic solid.

B. a covalent molecular solid.

C. a covalent network solid.

D. a metallic solid.

8. Which of the following has the lowest boiling point?

A. HCl

B. HI

C. HF

D. HBr

9. Which of the following molecules is not planar?

   A. methanal
   B. ethyne
   C. benzene
   D. propene

10. When butane is chlorinated, the number of dichlorobutane isomers possible is:

   A. 7
   B. 6
   C. 5
   D. 4

11. How many moles of oxygen are required for the complete combustion of 0.5 mole of ethene?

   A. 0.5
   B. 1.5
   C. 1.0
   D. 2.0

12. Which of the following reactions would not give a visible reaction?

   A. Dilute hydrochloric acid is added to a solution of sodium chromate
   B. Ethanal is reacted with acidified potassium permanganate
   C. Potassium is added to 2-propanol
   D. Acidified potassium dichromate is added to propanone

13. In the presence of concentrated sulphuric acid, which two chemicals would produce this compound: $CH_3CH_2CH(Cl)COOCH_2CH_3$?

A. 3-chlorobutanoic acid and ethanol

B. 2-chloro-1-butanol and ethanoic acid

C. 2-chlorobutanoic acid and ethanol

D. 3- chloro-1-butanol and ethanoic acid

14. When compound X with molecular formula $C_6H_{12}O_2$ is hydrolysed in the presence of hydrochloric acid, two compounds M and T are produced. M upon reaction with excess acidified potassium permanganate produces more of compound T. From these data it follows that X is:

A. 1-propylpropanoate

B. 2-propylpropanoate

C. ethylbutanoate

D. 1-butylethanoate

15. A piece of an addition polymer has the structure ——$(CH(CH_3)\text{-}CCl_2)_n$——. The starting monomer for this polymer must have been:

A. 1,1-dichloro 2-methylethene

B. 2,2-dichloropropene

C. 1,1-dichloropropene

D. 2,2-dichloro-1-methylethene

16. Which of the following reactions would not produce hydrogen gas?

A. zinc + sodium hydroxide solution

B. sodium + ethanoic acid

C. aluminium + concentrated nitric acid

D. rubidium + water

17. You are required to identify a blue solid. You put a little into each of three test-tubes and add 5 mL of distilled water.

- a dilute solution of $NaOH_{(aq)}$ added to the 1st test-tube gives a blue precipitate.
- a dilute solution of $AgNO_{3(aq)}$ added to the 2nd test-tube gives a white precipitate.
- a dilute solution of $BaCl_{2(aq)}$ added to the 3rd test-tube produces no change.

Of the following, the formula for the blue solid is:

A. $CuCl_2$

B. $CuSO_4$

C. $Cu(OH)_2$

D. $Cu(NO_3)_2$

18. $HClO_4$ is a strong acid. Therefore solutions of its ammonium salt, NH_4ClO_4, and its sodium salt, $NaClO_4$, would have which of the following pH values?

A. NH_4ClO_4: less than 7 $NaClO_4$: greater than 7

B. NH_4ClO_4: less than 7 $NaClO_4$: equal to 7

C. NH_4ClO_4: equal to 7 $NaClO_4$: greater than 7

D. NH_4ClO_4: equal to 7 $NaClO_4$: equal to 7

19. A solution of the nitrate of a metal in water is colourless.
- On addition of $NaOH_{(aq)}$, a white precipitate is formed which is soluble in excess $NaOH_{(aq)}$.
- To a second sample of the metal nitrate solution, $NH_{3(aq)}$ is added and again a white precipitate is formed. However, excess $NH_{3(aq)}$ results in no further reaction.

Of the following the metal is:

A. Cr

B. Cu

C. Al

D. Zn

20. In a laboratory experiment an aqueous solution of sulphuric acid is slowly added to an aqueous solution of barium hydroxide. Conductivity measurements are taken continuously during the addition. These show that:

A. conductivity decreases at a uniform rate.

B. conductivity increases at a uniform rate.

C. conductivity decreases at a uniform rate to a minimum, then increases at a uniform rate.

D. conductivity increases at a uniform rate to a maximum, then decreases at a uniform rate.

21. Equal volumes of two solutions are mixed: solution 1 has a pH = 2; and solution 2 has a pH = 4. The pH of the final solution is:

A. 2.30

B. 3.00

C. 6.00

D. 1.99

22. A certain compound X is composed of 3 different elements. When X is totally reacted with oxygen it forms three oxides. Gaseous oxide one turns limewater milky, oxide two has a pH = 7 and a solution of oxide three turns blue litmus paper red.

Which of the following is the most likely composition of compound X?

A.	carbon	sulfur	sodium
B.	hydrogen	carbon	sulfur
C.	hydrogen	carbon	sodium
D.	sulfur	carbon	nitrogen

23. What is the best indicator to use when titrating a solution of ammonia of concentration 0.1 mol L^{-1} with a solution of hydrochloric acid of the same concentration?

A.	phenolphthalein	
B.	phenol red	(pH range 7 to 9)
C.	bromothymol blue	(pH range 6 to 8)
D.	methyl red	(pH range 4 to 6)

24. In the titration of standard $NaOH_{(aq)}$ (in the burette) versus $CH_3COOH_{(aq)}$, a student uses methyl orange as the indicator. Based on this data which of the following statement is true?

A. The end point will be achieved before the equivalence point and the calculated [CH_3COOH] will be higher than the actual value.

B. The end point will be achieved after the equivalence point and the calculated [CH_3COOH] will be higher than the actual value.

C. The end point will be achieved before the equivalence point and the calculated [CH_3COOH] will be lower than the actual value.

D. The end point will be achieved after the equivalence point and the calculated [CH_3COOH] will be lower than the actual value.

25. The change of oxidation state of the vanadium atom when VO^{2+} is converted to VO_2^+ is:

A. +1

B. –1

C. –2

D. +2

26. The unbalanced reaction between acidified potassium permanganate and methanol to produce carbon dioxide is:

$a\,MnO_4^- + b\,CH_3OH + c\,H^+ \rightarrow d\,Mn^{2+} + e\,CO_2 + f\,H_2O$

The values of *a* and *b* are:

A. a = 6 and b = 5

B. a = 5 and b = 6

C. a = 6 and b = 3

D. a = 5 and b = 3

27. The cathode reaction in the hydrogen/oxygen fuel cell in basic conditions is:

A. $O_2 + 2\,H_2O + 4\,e^- \rightarrow 4\,OH^-$

B. $H_2 + 2\,OH^- \rightarrow 2\,H_2O + 2\,e^-$

C. $2\,H_2O \rightarrow O_2 + 4\,H^+ + 4\,e^-$

D. $2\,H_2O + 2\,e^- \rightarrow H_2 + 2\,OH^-$

28. An aqueous solution which contains a mixture of $CuCl_{2(aq)}$ and $NaCl_{(aq)}$, both at a concentration of 1 mol L^{-1}, is electrolysed with a Pt anode and a Cu cathode. Which product is first liberated at the cathode?

A. Cu

B. H_2

C. Cl_2

D. O_2

29. An electric current is passed through an aqueous solution of copper(II) sulfate using platinum electrodes, Pt. The chemical liberated at the anode is:

A. copper.

B. hydrogen.

C. oxygen.

D. platinum ions, Pt^{2+}.

30. 96500 coulombs of electrical charge flow through Pt electrodes into the cells described below. In which case will the mass of the described product be least?

	cell contents	*product*
A.	aqueous silver nitrate	silver
B.	molten aluminium oxide	aluminium
C.	aqueous copper(II) sulfate	copper
D.	dilute sodium chloride solution	oxygen

End of Part 1

PART 2 (70 marks = 35% of paper)

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

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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) and gases evolved (give the colour or describe as colourless). If no change is observed you should state this.

(a) Chlorine gas is bubbled through a solution of iron (II) nitrate.

Equation _____

Observation _____

_____

(b) Dilute sulfuric acid is mixed with a solution of lead (II) nitrate.

Equation _____

Observation _____

_____

c) Potassium metal is placed in water.

Equation _____

Observation _____

_____

d) An excess of 6 mol L^{-1} ammonia solution is added silver oxide.

Equation _____

Observation _____

_____

[4 x 3 = 12 marks]

2. Atom A can be bonded covalently to a number of atoms of X and may also have some valence electrons left over as lone pairs.
For each situation specified in the table below, use electron pair repulsion theory to predict the shape of the molecule.

In each case give an example of a molecule that possesses your predicted shape. (A and X may be different for each case)

The first row is an example

Description	Shape of Molecule (name or sketch)	Example
AX	*Linear*	*HF*
AX_3 with one lone pair on atom A		
AX_3 with no lone pairs on atom A		
AX_2 with one lone pair on atom A		
AX_2 with no lone pairs on atom A		

[8 marks]

3. Give the name or formula of a substance that matches the following descriptions:

(a) the substance used to galvanise iron objects _____

(b) a metal which does not react with dilute HCl(aq) _____

(c) the Group 4 hydride which has the lowest melting point _____

[3 marks]

4. An electric current is passed through a 1 mol L^{-1} sulfuric acid solution using carbon electrodes. Write a half-equation for the reaction occurring at each electrode:

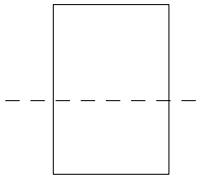
Negative electrode _____

Positive Electrode _____

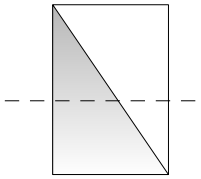
[2 marks]

5. A group of students decided to conduct a mini-research project on **methods of preventing corrosion** of iron structures in a salt water environment.

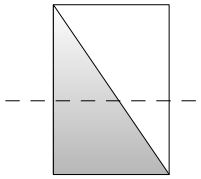
A number of iron plates, numbered 1 to 5, were placed in sea water as shown below.



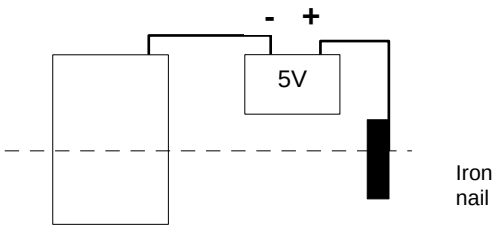
1.
untreated iron



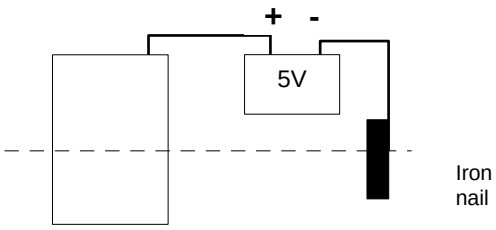
2.
iron partly covered with tin



3.
iron partly covered with zinc



4.
iron attached to
negative terminal of battery



5.
iron attached to
positive terminal of battery

(a) Which two plates showed the **least** degree of corrosion? Give reasons.

(b) Which two plates showed the **greatest** degree of corrosion? Give reasons.

[4,4 marks]

6. Hydrazoic acid (hydrogen azide), HN_3, is a weak electrolyte.

(a) Write an equation for the ionisation of hydrazoic acid in water.

_____ [1 mark]

(b) How would the pH of 0.1 mol L^{-1} hydrazoic acid compare to the pH of 0.1 mol L^{-1} HCl and why?

Comparison (higher, lower, same) _____

Explanation _____

_____

_____

_____ [3 marks]

(c) What will happen to the pH of a hydrazoic acid solution if a small quantity of solid sodium azide (NaN_3) is added to the acid? Give an explanation for your answer.

Effect on pH _____

Explanation _____

_____

_____

_____ [3 marks]

(d) Name a suitable indicator for the titration of 0.1 mol L^{-1} hydrazoic acid against 0.1 mol L^{-1} sodium hydroxide solution. Give an explanation for your choice.

Indicator used _____

Explanation _____

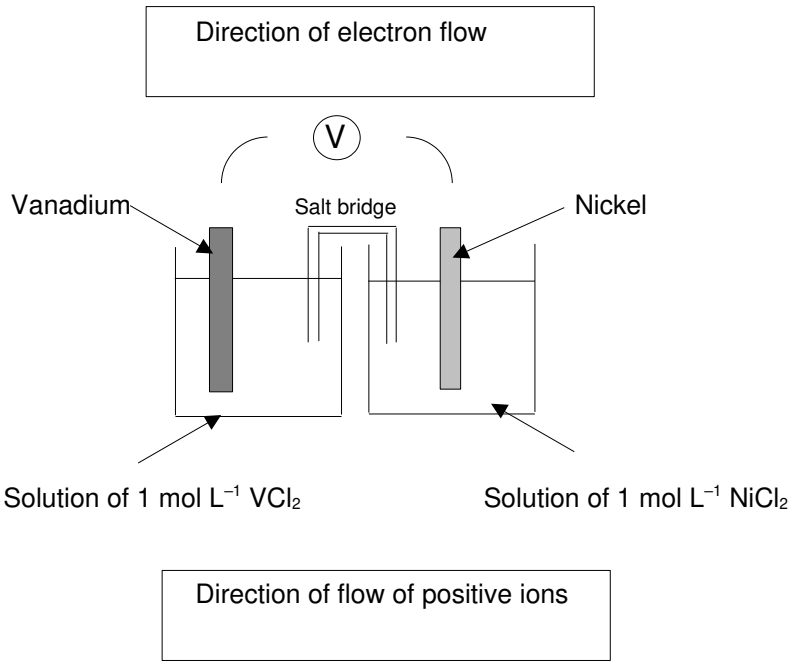
_____

_____

_____ [3 marks]

[total 10 marks]

7. An electrochemical cell was set up as shown below:



The cell was allowed to operate for about 15 minutes and, during this time, it was noticed that a dark coloured solid was deposited on the nickel electrode, and the green colour of the nickel chloride solution faded.

(a) Give the half-equation for the reaction occurring in the nickel half-cell.

_____

(b) Which electrode in the anode? _____

(c) Which is the stronger oxidant, V^{2+} or Ni^{2+} ? _____

(d) In the box provided on the diagram, mark the direction of electron flow in the external circuit.

(e) In the box provided on the diagram, mark the direction of the positive ion flow in the cell.

(f) At the beginning of the experiment the E.M.F generated by the cell was 0.92 volts. Use this information to determine the standard reduction potential (E^0) for the reaction: $V^{2+}_{(aq)} + 2\ e^- \rightarrow V_{(s)}$

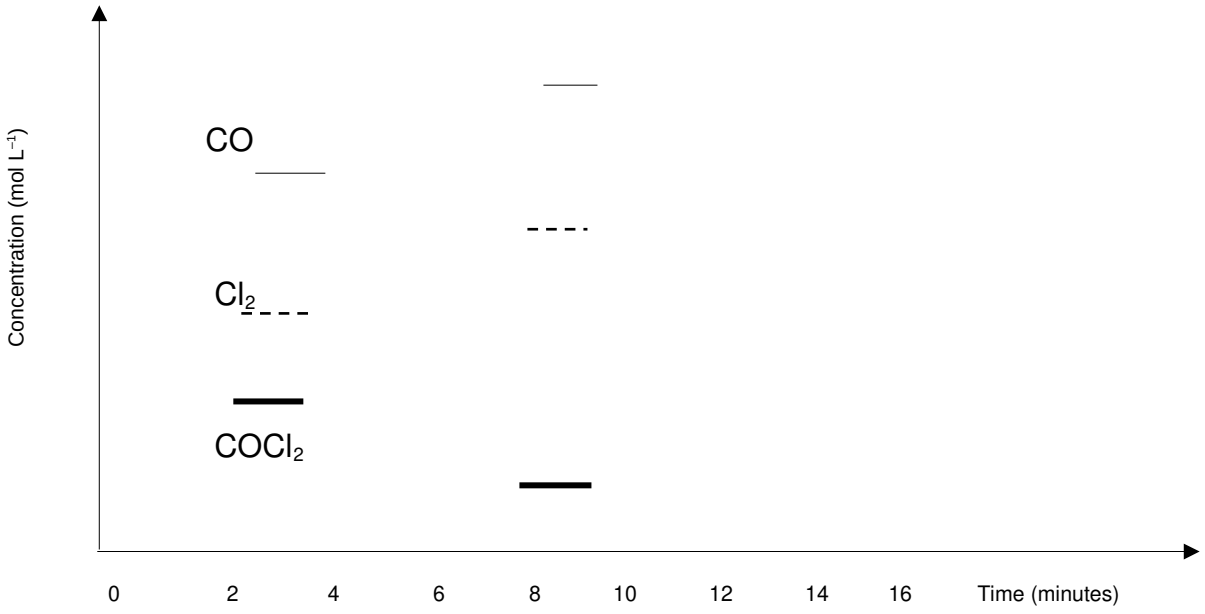
_____

[1 each = 6 marks]

8. Phosgene is prepared from the reaction of carbon monoxide and chlorine in the presence of an activated carbon catalyst.

$$CO_{(g)} + Cl_{2(g)} \rightleftarrows COCl_{2(g)}$$

The following graph shows what happens when all three gases are mixed in the presence of the catalyst:



(a) How would you describe the system 3 minutes after mixing?

[1 mark]

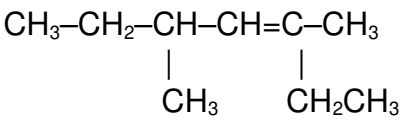
(b) At 4 minutes after mixing the temperature is decreased to a constant value. From the system's response as shown above deduce whether the reaction, as written, is endothermic or exothermic. Briefly explain your reasoning.

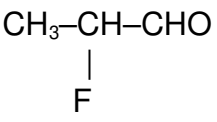
[3 marks]

(c) At 10 minutes after mixing, extra phosgene ($COCl_2$) was rapidly introduced in the system at constant temperature and volume. Show on the graph the effect of this change, on the concentration of the three gases. Assume that he system reaches equilibrium at about 14 minutes.

[3 marks]

9. (a) Give the I.U.P.A.C name of the following organic molecules:





_____ _____

[2 marks]

(b) Draw the structure of the polymer formed from using 1-butene as the monomer. At least three monomer units are required. [2 marks]

(c) Name the organic reactant and the reagent required to produce propanone. [2 marks]

Organic reactant_____

Reagent_____

(d) Draw the structure of and name the organic product of reacting methanoic acid and 2-butanol in the presence of an acid catalyst. [2 marks]

Name_____

Structure

[total 8 marks]

10. Consider the following substances and their melting points:

carbon tetraiodide 171°C ; hydrogen iodide –51°C ; iodine 114°C.

Explain the difference in their melting points.

[6 marks]

End of Part 2

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PART 3 (50 marks = 25% of paper)

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 that may be necessary for solving the problems is located on the separate Chemistry Data Sheet. Show clear reasoning: if you don't, you will lose marks.

---

1. Sodium pyrosulfate, $Na_2S_2O_7$, can be prepared from ore containing iron pyrites, FeS_2, by the following series of reactions:

$$4\ FeS_2 + 11\ O_2 \rightarrow 2\ Fe_2O_3 + 8\ SO_2$$

$$2\ SO_2 + O_2 \rightarrow 2\ SO_3$$

$$SO_3 + H_2O \rightarrow H_2SO_4$$

$$2\ H_2SO_4 + Na_2CO_3 \rightarrow 2\ NaHSO_4 + H_2O + CO_2$$

$$2\ NaHSO_4 \rightarrow Na_2S_2O_7 + H_2O$$

If 1250 kg of ore containing 92.4% iron pyrites produces 1620 kg of sodium pyrosulfate, then determine the percentage efficiency of the process.

[6 marks]

1. cont.

2. An organic compound is found to contain carbon, hydrogen and oxygen.

A 4.14 g sample was burnt in air yielding 4.21 L of carbon dioxide at STP and 3.39 g of water.

Another sample, with mass 2.73 g, was vapourised and occupied 1.12 L at 102.0 kPa and 170.0ºC.

Use this information to determine:

(a) the empirical formula of the compound; and

[6 marks]

(b) the molecular formula of the compound.

[3 marks]

A third sample was added to sodium carbonate and no reaction was observed.

(c) Sketch and name a possible structural formula for the compound.

[2 marks]

2. cont.

3. Two electrolytic cells are connected in series. The first contains a solution of iron(II) chloride with copper electrodes. The second contains molten indium chloride with graphite electrodes.

A current is passed for 40.0 minutes.

(a) If the mass of the anode in the first cell decreases by 2.53 g, then determine the magnitude of the current that was applied.

[4 marks]

(b) If 3.05 g of indium (Z = 49) is deposited at the cathode in the second cell during this time, then determine the oxidation state of the indium in the molten salt.

[3 marks]

(c) Determine the total volume of gas, at 24˚C and 100.9 kPa, evolved from the cells during this time.

[5 marks]

3. cont.

4. In order to determine the dissolved oxygen content of a water sample, the following procedure was used.

(i) A 100.0 mL sample of water was treated with 10.0 mL manganese(II) sulfate solution and 10.0 mL sodium hydroxide solution, forming manganese(III) hydroxide.

$$4\ Mn^{2+}_{(aq)} + O_{2(g)} + 8\ OH^{-}_{(aq)} + 2\ H_2O_{(l)} \rightarrow 4\ Mn(OH)_{3(s)}$$

(ii) The solution was then treated with 20.0 mL dilute sulfuric acid to dissolve the manganese(III) hydroxide, producing a solution of manganese(III) ions.

$$2\ Mn(OH)_{3(s)} + 6\ H^{+}_{(aq)} \rightarrow 2\ Mn^{3+}_{(aq)} + 6\ H_2O_{(l)}$$

(iii) The solution was then treated with 10.0 mL of potassium iodide solution, forming triiodide ions ($I_3^-{}_{(aq)}$).

$$2\ Mn^{3+}_{(aq)} + 3\ I^{-}_{(aq)} \rightarrow 2\ Mn^{2+}_{(aq)} + I_3^-{}_{(aq)}$$

(iv) The solution from part (iii), with a total volume of 150.0 mL was separated into 20.0 mL aliquots, which were then titrated against standardised 0.00120 mol L^{-1} sodium thiosulfate ($Na_2S_2O_3$) using a starch indicator.

$$I_3^-{}_{(aq)} + 2\ S_2O_3^{2-}{}_{(aq)} \rightarrow 3\ I^{-}_{(aq)} + S_4O_6^{2-}{}_{(aq)}$$

The results were:

Volume (mL)	Rough	1	2	3
Initial	2.70	19.40	1.85	17.45
Final	19.40	34.70	17.45	32.70
Titre volume				

Determine the concentration, in parts per million (ppm), of dissolved oxygen in the original water sample. You may assume that the water sample has a density of 1.00 g mL^{-1}.

[10 marks]

4. cont.

5. A mineral residue is found to contain Al, Ca and Fe as well as several other components.

- A 2.401 g sample was treated to convert all of the aluminium to Al_2O_3 and all of the iron to Fe_2O_3. The combined mass of the oxides was 0.9247 g. The 0.9247 g oxide mixture was dissolved in acid and all of the iron converted to Fe^{2+} by treatment with H_2S. The resulting solution required 18.31 mL of acidified 0.0168 mol L^{-1} potassium dichromate solution to be completely oxidised.

- Another sample, with mass 7.00 g, was treated to convert all the calcium to calcium oxalate, CaC_2O_4. The calcium oxalate was dissolved in acid, made up to 250.0 mL in a volumetric flask and 50.0 mL aliquots titrated with 0.1097 mol L^{-1} potassium permanganate solution, of which 25.96 mL was required. The reaction is:

$$5\ C_2O_4^{2-}{}_{(aq)} + 16\ H^+{}_{(aq)} + 2\ MnO_4^-{}_{(aq)} \rightarrow 2\ Mn^{2+}{}_{(aq)} + 10\ CO_{2(g)} + 8\ H_2O_{(l)}$$

Determine the percentage by mass of iron and calcium in the residue.

[11 marks]

5. cont.

End of Part 3

PART 4 (20 marks = 10% of paper)

Answer the following extended answer question. 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, but you will lose marks if what you write is unclear or lacks coherence.

Give an account of the chemistry of water.

You may discuss all aspects of the chemistry of water that you have studied, making particular reference to the points and data below.

- Structure, bonding and intermolecular forces in water

substance	molar mass (g mol^{-1})	melting point (K)
methane, CH_4	16	91
ammonia, NH_3	17	195
water, H_2O	18	273
hydrogen fluoride, HF	20	190

- Chemical equilibrium and the effect of changes of conditions upon it

temperature (^0C)	K_w
0	2.0×10^{-15}
25	1.0×10^{-14}
50	5.5×10^{-14}

- Acid/base chemistry, pH and the role of water in it

End of Examination