Tertiary Entrance Examination, 2006

Question/Answer Booklet

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
Multiple Choice Answer Sheet
Chemistry Data Sheet (inside the 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 (minutes)	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. Which one of the following species has the same electron configuration as Cl^- ?

    (a) Ar

    (b) S^{2-}

    (c) K^+

    (d) All of the above

2. Which one of the following is a correct ground state electron configuration of a neutral atom?

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

    (b) $1s^2 2s^2 2p^3 3s^2$

    (c) $1s^2 2s^2 2p^6 3s^2 3d^{10} 3p^6$

    (d) $1s^2 2s^2 2p^6 3s^3 3d^5$

3. Two elements have the following electron configurations

    X: $1s^2 2s^2 2p^6 3s^2 3p^2$
    Y: $1s^2 2s^2 2p^4$

    Which one of the following represents the most likely formula of a compound formed between X and Y?

    (a) XY

    (b) X_2Y

    (c) XY_2

    (d) X_2Y_3

4. Which one of the following is **not** likely to be true for pure Na_2SO_4?

   (a) It conducts electricity when dissolved in water.

   (b) It has a low solubility in hexane.

   (c) It is a brittle, crystalline solid.

   (d) It is an electrical insulator when molten.

5. Which one of the following statements about the trends in the periodic table is true?

   (a) Elements on the right hand side of the periodic table are stronger reducing agents than elements on the left hand side.

   (b) Elements on the left hand side of the periodic table are more electronegative than elements on the right hand side.

   (c) In group 2, as atomic number increases, the first ionisation energy increases.

   (d) The melting points of group 2 elements are greater at the top of the group than at the bottom.

Questions 6 and 7 refer to the following graph of first ionisation energies.
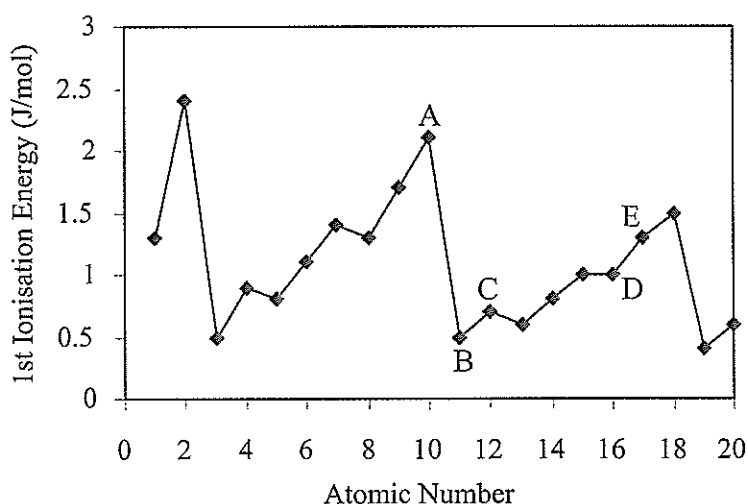
6. Which of the above elements is most likely a noble gas?

   (a) A

   (b) B

   (c) C

   (d) D

SEE NEXT PAGE

7.   Which pair of elements is most likely to form a covalent bond?

(a)   A and B

(b)   A and D

(c)   C and D

(d)   D and E

8.   Which of the following statements are correct as the atomic number increases between Na and $C\ell$?

        I   The elements become stronger oxidising agents.
        II   The oxides become more basic.
        III   The first ionisation energy increases.

(a)   I and II only

(b)   I and III only

(c)   II and III only

(d)   I, II and III

9.   Which one of the following lists the substances in order of increasing strength of intermolecular forces?

(a) $N_2 < C_2H_6 < NH_3 < CH_3CH_2OH < H_2O$

(b) $C_2H_6 < CH_3CH_2OH < N_2 < NH_3 < H_2O$

(c) $N_2 < NH_3 < C_2H_6 < H_2O < CH_3CH_2OH$

(d) $NH_3 < N_2 < CH_3CH_2OH < C_2H_6 < H_2O$

10.   Which of the following will conduct electricity?

              I   molten sulfur
              II   ammonia solution
              III   mercury
              IV   sodium hydroxide solution

       (a)   IV only

       (b)   I and IV only

       (c)   I, II and III only

       (d)   II, III and IV only

11.   Methyl violet produces the following colours when added to solutions of known pH.

pH	Colour
0	Yellow
1	Green
2	Violet
3	Violet

       Methyl violet is added to 1.0 mol L^{-1} solutions of hydrochloric acid, acetic (ethanoic) acid and nitric acid. Which one of the following correctly identifies the colours the indicator will produce in each solution?

	Hydrochloric acid	Acetic acid	Nitric acid
(a)	Yellow	Yellow	Yellow
(b)	Yellow	Violet	Green
(c)	Green	Green	Green
(d)	Yellow	Violet	Yellow

12.   Which one of the following correctly identifies the acidity of the listed salts when dissolved in water?

|	Potassium chloride	Sodium nitrate	Ammonium sulfate	Sodium carbonate
(a)	Neutral	Acidic	Acidic	Neutral
(b)	Acidic	Acidic	Basic	Acidic
(c)	Neutral	Neutral	Acidic	Basic
(d)	Acidic	Neutral	Neutral	Basic

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13. A student obtained the following results when titrating hydrochloric acid solution with 20.00 mL of sodium hydroxide solution.

	Trial 1	Trial 2	Trial 3	Trial 4
Vol of HCℓ (mL)	21.3	22.4	20.5	20.9

Which one of the following could lead to such a set of results?

(a) Using only a few drops of indicator

(b) Washing the conical flasks with distilled water and then rinsing with a small amount of sodium hydroxide solution

(c) Always reading to the bottom of the meniscus in the burette

(d) Washing the burette with water and then rinsing with hydrochloric acid solution

14. Which one of the following substances is the most suitable as a primary standard for acid-base titrations?

(a) Sodium hydroxide

(b) Hydrochloric acid

(c) Oxalic acid

(d) Sodium carbonate

15. 20.0 mL of a 0.0100 mol L^{-1} solution of NaOH is added to 20.0 mL of a 0.0300 mol L^{-1} solution of HCℓ. What is the pH of the resulting solution?

(a) 1.52

(b) 1.70

(c) 2.00

(d) 12.00

16. An electrochemical cell has a positive value of E°. Which one of the following statements about the two half cells forming the cell is true?

(a) Both half cells must have positive standard reduction potentials.

(b) The cathode half cell must have a positive standard reduction potential, while the anode half cell must have a negative standard reduction potential.

(c) At least one of the half cells must have a positive standard reduction potential.

(d) Both half cells may have a negative standard reduction potential.

17. In the Bayer process, the following reaction occurs:
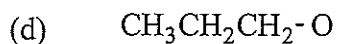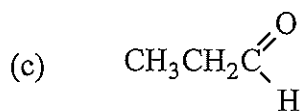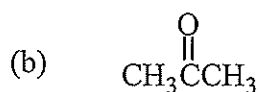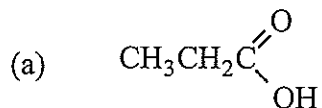
$$A\ell(OH)_3(s) + OH^-(aq) \rightarrow A\ell(OH)_4^-(aq)$$
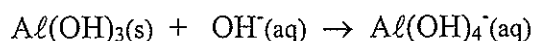
Which one of the following statements is correct?

(a) $A\ell(OH)_3(s)$ is oxidised

(b) $A\ell(OH)_3(s)$ accepts electrons

(c) $A\ell(OH)_3(s)$ acts as an acid

(d) $A\ell(OH)_3(s)$ acts as a base

18. A solution containing 1 mol L^{-1} $MgSO_4$ was electrolysed using copper electrodes.

Which one of the following statements is correct?

(a) Hydrogen gas is produced at the cathode and copper ions are produced at the anode.

(b) Copper is produced at the cathode and copper ions are produced at the anode.

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

(d) Magnesium is produced at the cathode and copper ions are produced at the anode.

19. A "dry cell" cell contains a zinc anode and a carbon cathode. Which one of the following statements best describes the role of these electrodes?

(a) The zinc is reduced and the carbon is oxidised.

(b) The zinc is oxidised and the carbon is reduced.

(c) The zinc is oxidised and reduction of another component occurs at the carbon.

(d) The carbon is reduced and oxidation of another component occurs at the zinc.

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20. When the following 1.00 mol L^{-1} solutions are electrolysed with inert electrodes, which one of them will **not** produce oxygen at the anode?

    (a) $NaNO_3$ solution

    (b) NaI solution

    (c) NaOH solution

    (d) KF solution

21. A garden water feature made of cast iron was observed to be severely corroded. Which one of the following measures would decrease the rate of corrosion?

    (a) Attach a piece of copper to the iron.

    (b) Attach a piece of magnesium to the iron.

    (c) Apply an anodic current to the iron.

    (d) Add bleach (sodium hypochlorite) to the water.

22. When propan-1-ol is oxidised by excess acidified potassium permanganate, which one of the following products would most likely result?

    (a) $CH_3CH_2C\overset{\displaystyle O}{\underset{\displaystyle OH}{}}$

    (b) $CH_3\overset{\displaystyle O}{\overset{\displaystyle \|}{C}}CH_3$

    (c) $CH_3CH_2C\overset{\displaystyle O}{\underset{\displaystyle H}{}}$

    (d) $CH_3CH_2CH_2\text{-}O$

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23.   Which of the following reactants are capable of forming a condensation polymer under suitable conditions?

(a) $HOCH_2CH_2CH_2CH_2CH_2CH_2CH_2COOH$

(b)

(c)

(d) $HOOCCH_2CH_2CH_2CH_2CH_2CH_2CH_2COOH$

and

$HOOCCH_2CH_2CH_2COOH$
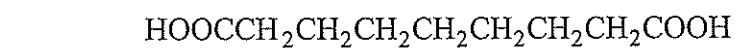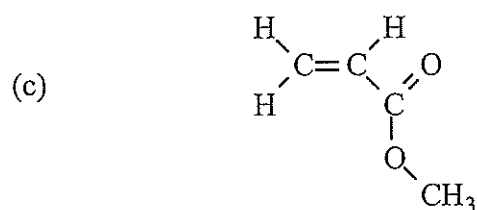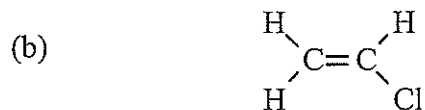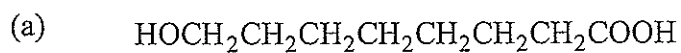
24.   In which of the following substances can geometric isomerism occur?

    I   1, 2-dichloroethane
    II   1, 2-dichloroethene
    III   1, 1-dichloroethene
    IV   1, 1, 2-trichloroethene

(a)   II only

(b)   I and II only

(c)   II and III only

(d)   I, II and IV only

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25. Finely ground aluminium and iron (III) oxide powders are mixed and placed in a container. As this reaction does not occur at room temperature, a burning piece of magnesium is dropped onto the mixture to ignite it. A bright, hot flame is observed. Which one of the following statements about the reaction is true?

    (a) The magnesium acts as a catalyst and the reaction is exothermic.

    (b) The magnesium provides the activation energy and the reaction is exothermic.

    (c) The magnesium acts as a catalyst and the reaction is endothermic.

   (d) The magnesium provides the activation energy and the reaction is endothermic.

Questions 26 and 27 refer to the following graph, which represents the partial pressures of SO_2 and SO_3 in the reaction shown below.

$$SO_2(g) + NO_2(g) \rightleftharpoons (g) + NO(g) \quad \Delta H = -42 \text{ kJ}$$
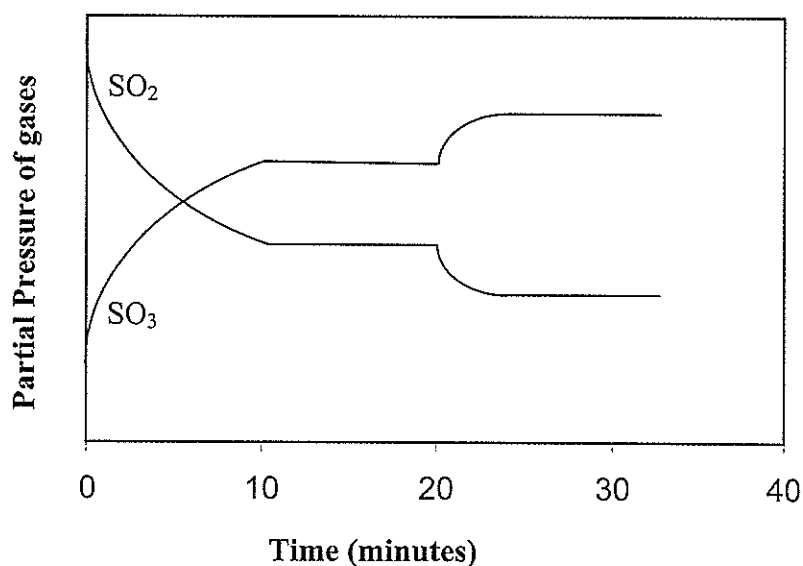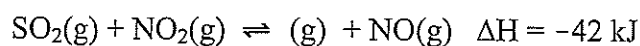
Time (minutes)

26. At what time is equilibrium first established?

    (a) 5 minutes

    (b) 10 minutes

   (c) 15 minutes

    (d) 30 minutes

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27. At the 20 minute mark, what changes could have been made to the system to produce the effects shown by the graph?

    (a)   The system temperature is increased or the partial pressure of NO is increased.

    (b)   The system temperature is increased or the partial pressure of NO_2 is increased.

    (c)   The system temperature is decreased or the partial pressure of NO is decreased.

    (d)   The system temperature is decreased or the partial pressure of NO_2 is decreased.

Questions 28 and 29 refer to the following chemical reaction taking place in a sealed container:

$$2NO(g) + 2H_2(g) \rightleftharpoons N_2(g) + 2H_2O(g) \quad \Delta H = -664 \text{ kJ}$$
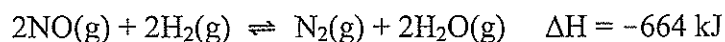
28. Which of the following changes made to the system would increase the **equilibrium yield** of N_2?

    I   Adding a catalyst
    II   Increasing the temperature
    III   Increasing the pressure
    IV   Cooling to cause the $H_2O(g)$ to condense to liquid water

    (a)   I and II only

    (b)   III and IV only

    (c)   II and IV only

    (d)   I, II and III only

29. In the changes referred to in question 28, which would increase the **rate** of the production of N_2?

    (a)   I and II only

    (b)   III and IV only

    (c)   I, II and III only

    (d)   II, III and IV only

30.   Consider the reaction:

$$Ca(HCO_3)_2(s) \rightleftharpoons CaO(s) + 2CO_2(g) + H_2O(g)$$
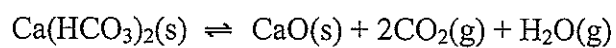
Which one of the following is the equilibrium constant expression for this equation?

(a) $K = [CO_2]^2[H_2O]$

(b) $K = 2[CO_2] + [H_2O]$

(c) $K = \dfrac{[CaO][CO_2]^2[H_2O]}{[Ca(HCO_3)_2]}$

(d) $K = \dfrac{1}{[CO_2]^2[H_2O]}$

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 the equation for the reaction that occurs in each of the following procedures. If no reaction occurs write 'no reaction'.

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

   If no change is observed, you should state this.

   (a)   Barium chloride solution is added to sodium phosphate solution.

   Equation _____

   Observation _____

   _____
                                                                                [3 marks]
   (b)   Dilute sulfuric acid is added to copper metal.

   Equation _____

   Observation _____

   _____
                                                                                [3 marks]

   (c)   A small amount of chlorine gas is added to potassium bromide solution.

   Equation _____

   Observation _____

   _____
                                                                                [3 marks]

   (d)   Hydrochloric acid is added to potassium permanganate solution.

   Equation _____

   Observation _____

   _____
                                                                                [3 marks]

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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, water   H $:\ddot{\underset{..}{O}}:$ H   or   H—$\ddot{\underset{..}{O}}$—H   or   H—$\overline{\underline{O}}$—H   and so on]

Species	Electron dot diagram
Hydrogen sulfide H₂S	
Sulfuric acid H₂SO₄	
Magnesium nitrate Mg(NO₃)₂	

[6 marks]

SEE NEXT PAGE

3.   Consider the following chemical substances.

CO_2 SO_3 NH_3 H_2O N_2 S_8 Cl_2 CCl_4
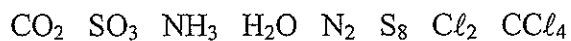
List all the molecules that contain polar bonds.	
List all the polar molecules.	
List all the linear molecules	

(Note: Substances can be listed in more than one category)

[6 marks]

4.   On Earth, water evaporates, forms clouds and falls back to the ground in a process known as the 'water cycle'.
On Saturn's moon Titan, where the average temperature is 94 K (-178°C), methane behaves in the same way as water does on Earth, evaporating and raining onto the surface as a liquid.
Using your knowledge of their structure and bonding, explain why water and methane undergo these processes at such different temperatures.

[3 marks]

SEE NEXT PAGE

5.   Sodium hydrogencarbonate is often used to increase the pH in swimming pools. Explain, with the aid of suitable equations, how adding sodium hydrogencarbonate affects the pH of the water.

[3 marks]

6.   In the Bayer process the following steps occur. Provide a chemical reason for each step. The first one has been done for you.

Step	Description	Reason
1	The bauxite is ground into fine granules.	A larger surface area increases the rate of reaction.
2	The bauxite granules are added to concentrated sodium hydroxide solution and heated.	
3	The solution resulting from step 2 is cooled.	
4	Crystals of pure $A\ell(OH)_3$ are added.	
5	The solid produced in step 4 is heated to $150°C$.	

[4 marks]

SEE NEXT PAGE

7.   Based on your understanding of group I metals, write equations for the following reactions of caesium. If there is no reaction, write 'no reaction'.

(a)   Caesium is added to water.

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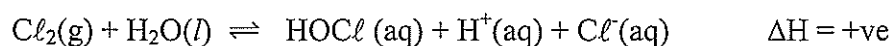

[4 marks]

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8. (a) Write an equation for the preparation of a soap from a fat.

(b) Describe how soap acts to remove grease from a shirt when it is washed.

(c) Briefly explain why sulfonate detergents sometimes perform better than soaps.

[6 marks]

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9. When chlorine gas is added to water, the following equilibrium is established:

$$C\ell_2(g) + H_2O(l) \rightleftharpoons HOC\ell(aq) + H^+(aq) + C\ell^-(aq) \qquad \Delta H = +ve$$

(a) Write the equilibrium constant expression for this reaction.

(b) Complete the following table. Answers should be given as "increases", "decreases" or "no change".

Change made to the equilibrium system	Effect on rate of forward reaction	Effect on equilibrium yield of HOCℓ (aq)
Increase the partial pressure of Cℓ_2(g)		
Increase the temperature of the system		
Acidify the system by the addition of nitric acid solution		
Add a suitable catalyst		

[10 marks]

10. With the aid of diagrams, describe all the forces acting in I$_2$ (s).

[3 marks]

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11.   (a)   Write the equation for ammonium nitrate dissolving in water.

(b)   Given that the reaction is endothermic, describe what you would observe when solid ammonium nitrate is dissolved in a beaker of water.

(c)   Draw an energy profile diagram to represent this reaction. On your diagram you should include and label the following:

a.   Activation energy
b. ΔH
c.   Transition state.

Enthalpy

Reaction progress
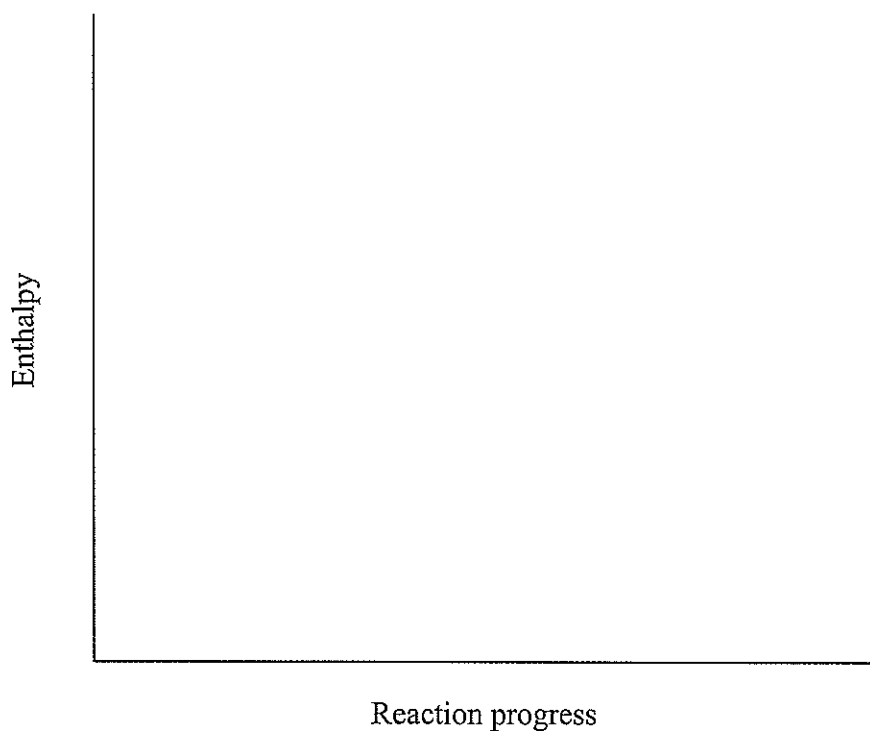
[6 marks]

SEE NEXT PAGE

12. Briefly explain why methyl orange is an inappropriate indicator to use in a titration between sodium hydroxide and acetic (ethanoic) acid.

[3 marks]

13. For each of the following reactions draw the structural formula of the organic product.

| Reaction	Structural Formula
Acidified butanoic acid is added to methanol and heated.	
Hydrogen gas is bubbled through but-2-ene.	
Acidified potassium dichromate is added to ethanol.	
Chlorine gas is added to excess propane and exposed to UV light.	

[4 marks]

END OF SECTION 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 lose marks.

1.   When concentrated nitric acid is added to copper, nitrogen dioxide gas is produced. This reaction can be represented by the following unbalanced equation

$$Cu \quad + \quad HNO_3 \quad \rightarrow \quad Cu(NO_3)_2 \quad + \quad NO_2 \quad + \quad H_2O$$
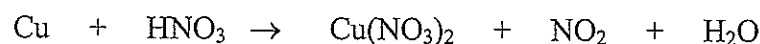
(a)   Balance this equation.

If 4.56 g of copper is added to 120.0 mL of 5.55 mol L^{-1} solution of nitric acid:

(b)   Identify the limiting reagent.

(c)   What volume of NO_2 is formed at 28°C and 99.7 kPa?

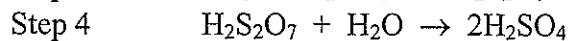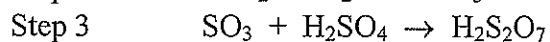(d)   How many moles of excess reactant is left after the reaction?

[9 marks]

SEE NEXT PAGE

2.   The equations for the production of sulfuric acid in the Contact Process are given as follows:

Step 1 $S + O_2 \rightarrow SO_2$
Step 2 $2SO_2 + O_2 \rightarrow 2SO_3$
Step 3 $SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$
Step 4 $H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$

(a)   Calculate the volume of SO_2 produced at 101.3 kPa and 600°C from burning 1.00 tonne of sulfur. (1 tonne = 1000 kg)

Given that Step 2 is 95% efficient:

(b)   Calculate the mass of SO_3 produced from 1.00 tonne of sulfur.

(c)   Calculate the mass of $H_2S_2O_7$ produced from 1.00 tonne of sulfur.

(d)   Calculate the volume of acid produced if the concentration of the sulfuric acid in Step 4 is 8.50 mol L^{-1}.

[9 marks]

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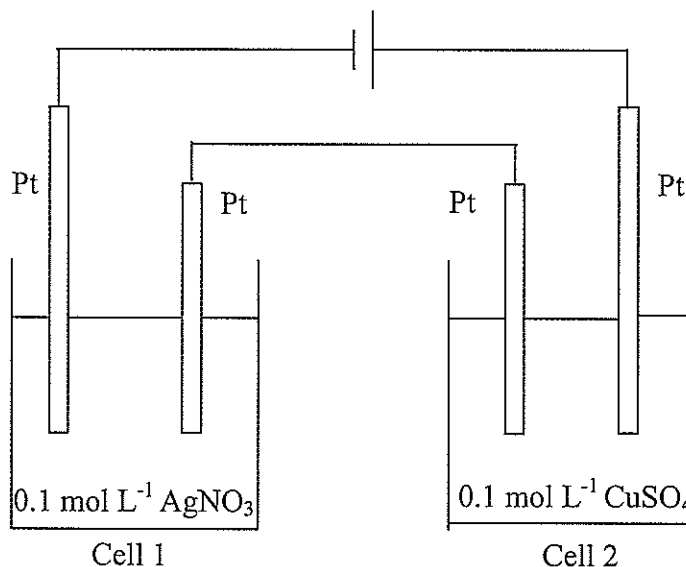
3. A steady current is passed through two electrolytic cells as shown in the diagram below:

After 126 minutes, 4.50 g of silver is precipitated at the cathode of Cell 1.

(a) Calculate the mass of copper precipitated in Cell 2.

(b) Identify the gas produced at the anode of each cell. Write an equation to represent the formation of that gas.

(c) Calculate the total volume of gas produced in both cells at S.T.P.

(d) Calculate the current being supplied to the cells.

[11 marks]

SEE NEXT PAGE

4.   An organometallic compound containing nickel, carbon, hydrogen and oxygen was analysed as follows:

A 3.45 g sample of the compound was combusted in excess oxygen. It produced 3.44 g of carbon dioxide and 1.06 g of water.

A second sample of the compound, with a mass of 2.33 g, was treated with H_2S and 1.20 g of nickel sulfide was precipitated.

(a)   Determine the empirical formula of the compound.

(b)   5.32 g of the compound was found to be 3.00×10^{-2} mol. Determine the molecular formula of the compound.

[10 marks]

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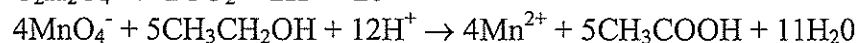
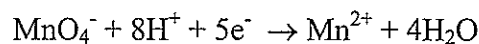_____

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5. The amount of ethanol in wine can be determined by adding a known excess volume of potassium permanganate to the wine and then titrating the left-over $KMnO_4$ with oxalic acid.

100.0 mL of 0.255 mol L^{-1} $KMnO_4$ solution was added to 8.00 mL of white wine and made up to 250.0 mL with distilled water. 20.0 mL samples of the treated wine were then titrated with a 0.0504 mol L^{-1} solution of oxalic acid dihydrate ($C_2H_2O_4.2H_2O$).

The following results were obtained.

Titration results	Trials			
	1	2	3	4
Final volume	29.4	26.45	27.30	24.60
Initial volume	2.6	3.20	4.35	1.50
Titre				

The relevant equations are given below:

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$
$$C_2H_2O_4 \rightarrow 2CO_2 + 2H^+ + 2e^-$$
$$4MnO_4^- + 5CH_3CH_2OH + 12H^+ \rightarrow 4Mn^{2+} + 5CH_3COOH + 11H_2O$$

(a) Write a balanced equation for the reaction between potassium permanganate and oxalic acid.

Using the equations provided:

(b) Determine the concentration of ethanol in the original wine in mol L^{-1}.

(c) Determine the concentration of ethanol in the wine in g L^{-1}.

[11 marks]

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 questions.

Methanol is a colourless liquid that is completely miscible in water. It melts at $-97^{\circ}C$ and boils at $64.7^{\circ}C$. It is used as an antifreeze, fuel and solvent, and is added to ethanol to make methylated spirits.

Methanol is flammable and poisonous. It is used as fuel in some race cars because methanol fires, unlike petrol fires, can be extinguished with water. Methanol is toxic because of the chemicals it forms in the body. Methanol is converted into methanal (formaldehyde) and methanoic acid (formic acid) in the liver. Methanal destroys the optic nerve, causing blindness.

Several methods can be used to produce methanol commercially. One of these methods of production involves two steps.

In the first step there is a reaction between methane and steam to produce carbon monoxide and hydrogen gas. This process occurs at 1000 to 2000 kPa and about $850^{\circ}C$ on a nickel catalyst. This reaction is endothermic.

In the second step, carbon monoxide and hydrogen are converted into methanol. This step is carried out at a higher pressure of 5000 to 10 000 kPa and a temperature of $250^{\circ}C$ using a second catalyst. The reaction is exothermic and the heat produced is used to provide energy for the first step.

Discuss the conditions for the production of methanol described above with reference to **rates of reaction and equilibrium**.

Discuss the properties and use of methanol with reference to the **reactions and properties of alcohols**.

Include equations in your answer where appropriate.

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.