Curriculum Council

Tertiary Entrance Examination, 2004

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
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	12	12	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.

---

1. Which of the following reactions does **not** occur in the blast furnace production of iron?

   (a) $CaCO_3 \rightarrow CaO + CO_2$

   (b) $CaO + SiO_2 \rightarrow CaSiO_3$

   (c) $Fe_2O_3 + 3\ CO \rightarrow 2\ Fe + 3\ CO_2$

   (d) $Fe_3O_4 + 4\ H_2 \rightarrow 3\ Fe + 4\ H_2O$

2. Which one of the following may have 17 protons, 19 neutrons and 18 electrons?

   (a) $C\ell$

   (b) $C\ell^-$

   (c) K

   (d) K^+

3. Which of the following represents a soap?

   (a) $CH_3(CH_2)_{16}COOK$

   (b) NaOH

   (c) CH_3COONa

   (d)
   $$\begin{array}{l} CH_2OH \\ | \\ CHOH \\ | \\ CH_2OH \end{array}$$

4. Which of the following metals exhibit variable oxidation states in compounds?

I iron

II lead

III magnesium

IV manganese

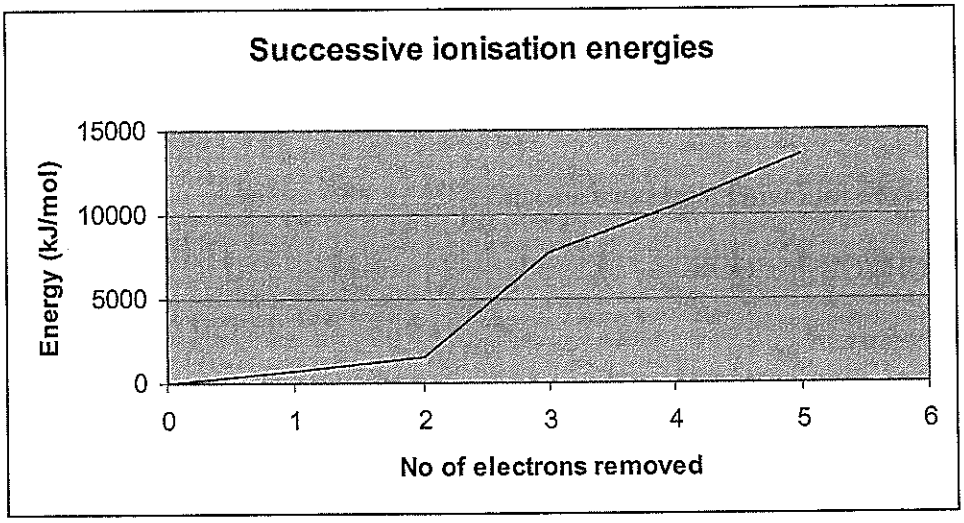
(a) I, II and IV only

(b) I and III only

(c) I and IV only

(d) II and IV only

5. For an element X, the first five successive ionisation energies can be represented on the following graph.



What would be the formula of the compound formed when X reacts with chlorine?

(a) $XC\ell$

(b) $XC\ell_2$

(c) $XC\ell_3$

(d) $XC\ell_4$

6. Which of the following arranges the substances in order of increasing ionisation energy?

(a) F < Mg < Si < S

(b) F < S < Si < Mg

(c) Mg < S < Si < F

(d) none of the above

7. 100 g of mineral water was found to contain 0.00584 g of NaCℓ. What is the concentration of NaCℓ in parts per million by mass?

(a) 1.00

(b) 5.84

(c) 58.4

(d) 584

8. For the reaction

$3\ Au^{+}(aq) \rightarrow Au^{3+}(aq) + 2\ Au(s)$

which one of the following statements is **true**?

(a) $Au^{+}(aq)$ disproportionates.

(b) $Au^{3+}(aq)$ is a reducing agent.

(c) Au(s) is oxidised.

(d) None of (a), (b) or (c) is true.

9. An electrolytic cell with inert electrodes was operated in turn with each one of the following electrolyte solutions.

I $1 \text{ mol } L^{-1} CuSO_4$

II $1 \text{ mol } L^{-1} H_2SO_4$

III $1 \text{ mol } L^{-1} NaOH$

IV $1 \text{ mol } L^{-1} NaC\ell$

For which of the solutions would hydrogen gas be produced at the cathode and oxygen gas at the anode?

(a) I, II, III and IV

(b) II only

(c) II and III only

(d) II, III and IV only

10. What is the concentration of a $Ba(OH)_2$ solution that has a pH of 9.30?

(a) $1.00 \times 10^{-5} \text{ mol } L^{-1}$

(b) $2.00 \times 10^{-5} \text{ mol } L^{-1}$

(c) $2.50 \times 10^{-10} \text{ mol } L^{-1}$

(d) $5.01 \times 10^{-10} \text{ mol } L^{-1}$

11. Which one of the following pairs of substances will react together when mixed?

(a) $C\ell_2 + Cu^{2+}$

(b) $Ni^{2+} + Cu$

(c) $Ni^{2+} + Zn$

(d) $Zn + C\ell^-$

12. 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 NaCℓ. What is the pH of the resulting solution?

(a) 2.00

(b) 7.00

(c) 11.70

(d) 12.00

13. Which one of the following equations **does not** represent the donation and acceptance of protons?

(a) $2\,H^+ + 2\,e^- \rightleftharpoons H_2$

(b) $H^+ + OH^- \rightleftharpoons H_2O$

(c) $H_2O_2 + OH^- \rightleftharpoons HO_2^- + + H_2O$

(d) $H_2C_2O_4 + CO_3^{2-} \rightleftharpoons HC_2O_4^- + HCO_3^-$

14. Which one of the following statements is true?

(a) Ga **can not** form all the chlorides $XC\ell_2$, $XC\ell_3$ and $XC\ell_4$.

(b) Ti **can not** form all the chlorides $XC\ell_2$, $XC\ell_3$ and $XC\ell_4$.

(c) V **can not** form all the chlorides $XC\ell_2$, $XC\ell_3$ and $XC\ell_4$.

(d) Ga, Ti and V can all form all of the chlorides $XC\ell_2$, $XC\ell_3$ and $XC\ell_4$.

15. In a series of experiments the following observations were made about a colourless liquid.

Experiment	Observation
Liquid was added to potassium dichromate solution	No visible reaction
Liquid was added to sodium metal	Colourless, odourless gas evolved, silvery solid dissolved
Liquid was added to ethanol and heated with concentrated sulfuric acid	Fruity smell produced

Which one of the following substances would produce all of these observations?

(a) 2-methyl-2-butanol

(b) butanoic acid

(c) 1-butanol

(d) 2-butanone

16. Ionisation of acetic (ethanoic) acid can be represented by the following equation

$CH_3COOH(aq) + H_2O(\ell) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$

Which one of the following would increase the concentration of acetate ions?

(a) addition of a strong base

(b) addition of a strong acid

(c) addition of a weak acid

(d) dilution with water

17. Solid sodium acetate is added to water. Which one of the following statements best describes what happens?

(a) The pH decreases because the acetate ions react with water to produce acetic acid.

(b) The pH decreases because the sodium ions react with water to produce hydrogen ions.

(c) The pH increases because the acetate ions react with water to produce hydroxide ions.

(d) The pH increases because the sodium ions react with water to produce hydroxide ions.

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18. Ammonia is classified as a weak electrolyte. Which of the following statements best explains this?

(a) A water-solution of ammonia contains more hydroxide ions than hydrogen ions.

(b) Ammonia is very soluble in water.

(c) Hydrogen bonding exists between ammonia molecules.

(d) In a water-solution only some of the ammonia molecules have reacted with water molecules.

19. In which one of the following will each listed compound dissolve in water to give a basic solution?

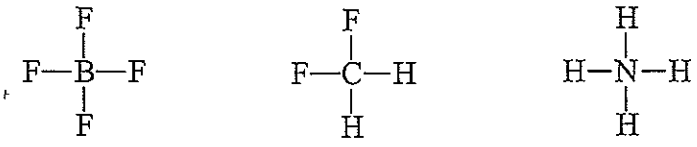
(a) carbon dioxide, sodium chloride, potassium hydroxide, ammonia

(b) ammonia, sodium oxide, potassium carbonate, barium hydroxide

(c) potassium acetate, sodium carbonate, ammonia, ammonium chloride

(d) sodium sulfate, potassium chloride, magnesium oxide, aluminium oxide

20. Consider the following structures



I II III

Which of the following statements is true?

(a) I and II are ions.

(b) I and III are ions.

(c) II and III are ions.

(d) None of I, II and III are ions.

21. Which one of the following descriptions best applies to the term 'valence electrons'?

(a) electrons in the s and p orbitals;

(b) electrons which are lost when bonds form;

(c) electrons in the outer energy level;

(d) electrons which make up a noble gas electron configuration.

22. How many valence electrons are present in a nitrite ion NO_2^-?

(a) 1

(b) 17

(c) 18

(d) 24

23. Which of the following substances will have the highest melting point?

(a) carbon dioxide

(b) nitrogen dioxide

(c) silicon dioxide

(d) sulfur dioxide

24. Which one of the following is **not** a property of iron?

(a) It reacts with dilute hydrochloric acid to produce hydrogen gas.

(b) It reacts with moist air to form a porous oxide layer.

(c) It displaces copper ions from solution.

(d) It reacts with sodium hydroxide solution to form iron hydroxide.

25. How many aldehydes and ketones are there with the molecular formula C_4H_8O?

(a) 2

(b) 3

(c) 4

(d) 5

26. How many isomers have the molecular formula $C_3H_5C\ell$?

(a) 2

(b) 3

(c) 4

(d) 5

27. Which one of the following lists the attractive forces in decreasing order (strongest to weakest)?

(a) hydrogen bonding > ionic bonding > dispersion forces;

(b) covalent bonding > hydrogen bonding > dispersion forces;

(c) covalent network > dispersion forces > metallic bonding;

(d) hydrogen bonding > van der Waals forces > covalent bonding.

28. Which one of the following statements about dispersion forces in a series of molecules is correct?

(a) An increased molecular weight leads to a greater mass of the molecule and hence stronger dispersion forces.

(b) An increased number of protons and electrons leads to stronger dispersion forces.

(c) Larger electronegativity differences lead to stronger dispersion forces.

(d) The presence of an atom such as O or N bonded to H leads to stronger dispersion forces.

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The following reaction is referred to in questions 29 and 30.

$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$ $\Delta H = 178.3$ kJ mol^{-1}

29. Which one of the following is the equilibrium constant expression for this reaction?

(a) $K = [CO_2]$

(b) $K = \dfrac{[CaO][CO_2]}{[CaCO_3]}$

(c) $K = \dfrac{[CaO]+[CO_2]}{[CaCO_3]}$

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

30. Consider a sealed system in which $CaCO_3$, CaO and CO_2 are at equilibrium.

Now consider the following actions:

I Add more $CO_2(g)$ to the system.

II Add more $CaCO_3(s)$ to the system.

III Decrease the volume of the system.

IV Increase the temperature of the system.

One or more of these actions lead to a change in $CO_2(g)$ concentration (after equilibrium is re-established).

Which statement below is true?

(a) All actions lead to a change in $CO_2(g)$ concentration.

(b) Only II, III and IV lead to a change in $CO_2(g)$ concentration.

(c) Only III and IV lead to a change in $CO_2(g)$ concentration.

(d) Only IV leads to a change in $CO_2(g)$ concentration.

END OF PART 1

PART 2 (70 marks)

Answer ALL questions in Part 2 in the spaces provided, using blue or black ballpoint or ink pen.

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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)
   - gases evolved (give the colour or describe as colourless).

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

(a) Barium hydroxide solution is mixed with silver nitrate solution.

Equation _____

Observation _____

_____

[3 marks]

(b) Sodium metal is added to $CH_3C(CH_3)_2OH$ (2-methyl-2-propanol).

Equation _____

Observation _____

_____

[3 marks]

(c) Concentrated nitric acid is added to copper metal.

Equation _____

Observation _____

_____

[3 marks]

(d) Concentrated potassium hydroxide is added to zinc metal.

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, water H:Ö:H or H–Ō–H or H–Ö–H and so on]

Species	Structural formula (showing all valence shell electrons)
Nitrogen trifluoride, NF_3	
Boron trifluoride, (BF_3)	
Sulfate ion, SO_4^{2-}	

[6 marks]

3. Write the electron configuration (using s, p, d notation) for the following species:

(a) O^{2-} _____

(b) Ca _____

[2 marks]

4. Identify by name or formula an example of each of the following.

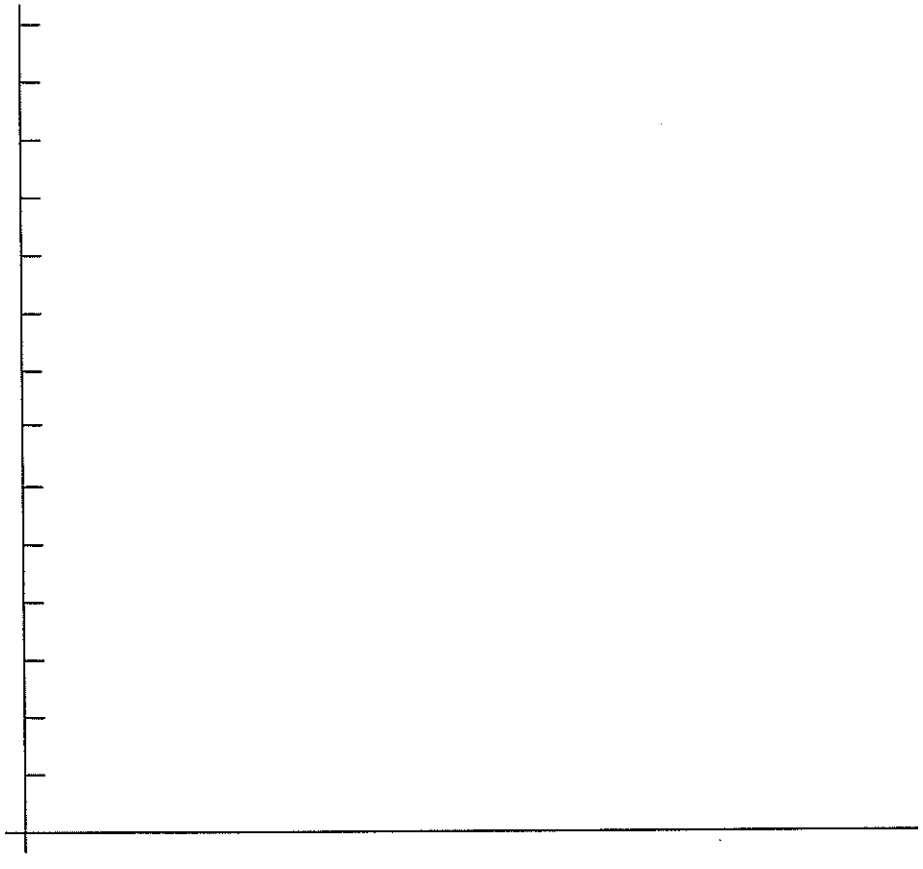
Description	Name or Formula
a coloured (i.e. not white/silver/grey coloured) transition metal	
a cleaning agent you would suggest to remove calcium carbonate from bricks	
a metallic element with only one d electron	
a monomer used to make an addition polymer	
a halogen which is solid at room temperature	
a substance used for bleaching	
a metal that reacts with water to form an alkaline solution	
a primary standard for redox titrations	

[8 marks]

5. (a) A small increase in the temperature of a reaction will often cause a significant increase in the rate of a reaction. Explain, with reference to collision theory, why this is so. Use diagrams if appropriate.

[4 marks]

(b) Draw a potential energy diagram for a reaction with activation energy = 50 kJ mol^{-1} and $\Delta H = +20$ kJ mol^{-1}. Label the diagram **and** axes well, showing the transition state, product and reactants, along with the activation energy and ΔH.



[4 marks]

6. When concentrated sulfuric acid needs to be diluted, should water be added to it or should it be added to water? Explain your answer.

[2 marks]

7. Consider 500 mL of a solution in a 1.00 L beaker at 25°C and 101.3 kPa. The solution contains the following equilibrium mixture:

$CuC\ell_2^-(aq) + C\ell^-(aq) \rightleftharpoons CuC\ell_3^{2-}(aq)$

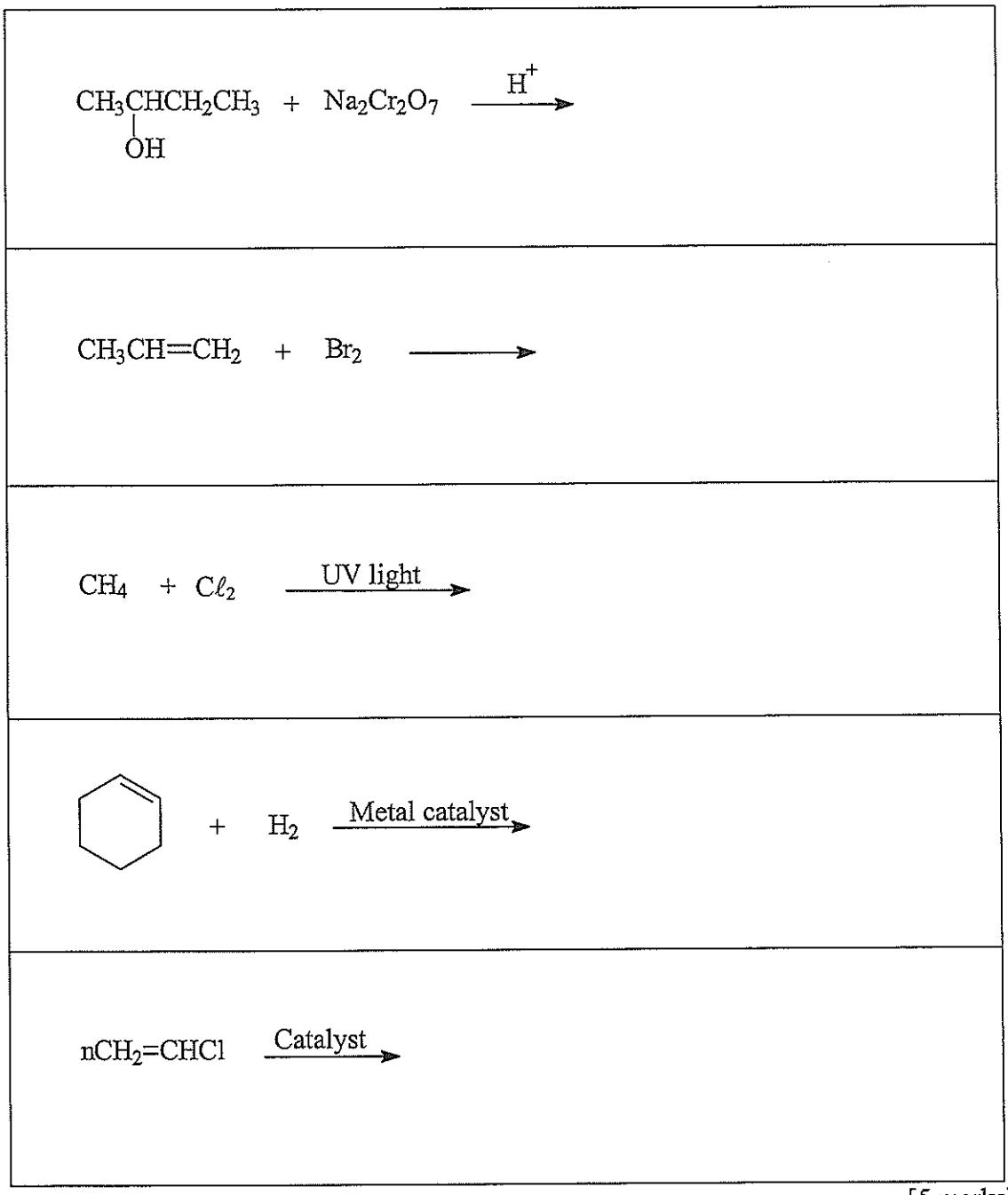
$\Delta H = -21 \text{ kJ mol}^{-1}$

Write 'increase', 'decrease' or 'no change' in the table to indicate the effect of the given changes on the rate of reaction and the equilibrium yield.

Imposed change	**Effect on Rate**	**Effect on Yield**
Increase the temperature to 45°C		
Increase the pressure to 200 kPa		
Dissolve some $NaC\ell$ in the solution		
Divide the solution into ten 50 mL portions in ten 100 mL beakers, to increase the state of subdivision		

[8 marks]

8. Use structural formulae to show the organic products of the following reactions:

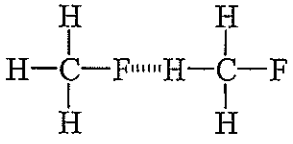
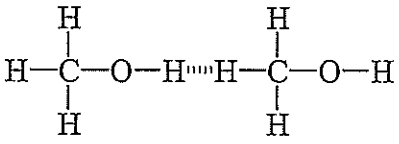
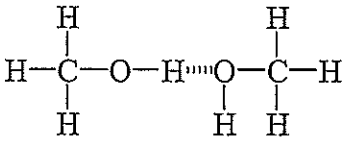
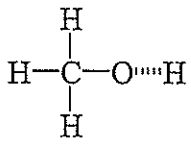


[5 marks]

9. Sodium carbonate is used as a primary standard in acid-base titrations, while sodium hydroxide is not. Explain why this is so.

[4 marks]

10. Which one of the following diagrams best represents a hydrogen bond?
Circle ***A, B, C*** or ***D***.

 ***A***	 ***B***
 ***C***	 ***D***

Explain your choice.

[4 marks]

11. Sketch an electrolytic cell having a Cu cathode, a Pt (inert) anode and an electrolyte of 1 mol L^{-1} $CuSO_4$. On your sketch, show the movement of ions and electrons.

[4 marks]

Write an equation for the reaction occurring at each electrode.

Anode	
Cathode	

[2 marks]

Describe what you would observe during operation of the cell.

[2 marks]

12. Draw structural formulae for three esters with the molecular formula $C_4H_8O_2$.

[3 marks]

END OF PART 2

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.
Answer all Part 3 questions in blue or black ball point or ink pen.

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1. Some baking soda (sodium hydrogencarbonate) is contaminated with sodium chloride. A sample of the contaminated baking soda was treated with dilute nitric acid to convert all of the sodium hydrogencarbonate into carbon dioxide, sodium nitrate and water. An excess of silver nitrate was then added to the solution to react with the chloride ions. A 12.45 g sample of the baking soda produced 1.02 g of silver chloride. Calculate the percentage purity of the baking soda.

[7 marks]

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2. Borax, $Na_2B_4O_7.10H_2O$, can be used as a primary standard in acid-base titrations. It reacts according to the following equation:

$$B_4O_7^{2-} + 2H^+ + 5H_2O \rightarrow 4H_3BO_3$$

2.334 g of borax was dissolved in a 250.0 mL volumetric flask and the flask filled to the mark with distilled water. 20.00 mL aliquots of the borax solution were titrated against a hydrochloric acid solution and the following results were obtained.

	1	2	3	4
Final reading (mL)	20.20	36.80	21.07	37.70
Initial reading (mL)	2.55	20.20	4.35	21.07
Titration volume (mL)				

Calculate the concentration of the hydrochloric acid solution.

[9 marks]

SEE NEXT PAGE

3. The effervescence in indigestion tablets is due to the reaction between sodium hydrogencarbonate and citric acid. An indigestion tablet is found to contain 1.998 g of sodium hydrogencarbonate and 1.111 g of citric acid. Citric acid is a triprotic acid with the molecular formula $C_6H_8O_7$.

(a) What volume of carbon dioxide will be produced from the tablet at 37°C and 99.2 kPa?

[6 marks]

(b) If the tablet has been dissolved in 120.0 mL of water, what will be the concentration (mol L^{-1}) of the excess reactant?

[3 marks]

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4. Aluminium is obtained by electrolysis of alumina.

(a) Write half equations to represent this process.

Anode	
Cathode	

[2 marks]

(b) The process is carried out at very large currents. Calculate how long it would take to produce one tonne (1.000 tonne, 1000 kg) of aluminium at a current of 1.000×10^5 amps.

[6 marks]

(c) If sodium were produced by electrolysis of molten sodium chloride at the same current, would it take a shorter or longer time to produce one tonne? Explain your answer briefly, but there is no need to calculate the exact time taken.

[2 marks]

SEE NEXT PAGE

5. A herbicide which contains only carbon, hydrogen, nitrogen and chlorine, was analysed to determine its empirical formula. A combustion analysis of 0.6678 g of the compound produced 1.09 g of carbon dioxide and 0.390 g of water.

On treatment of 0.3320 g of the compound with silver nitrate 0.221 g of silver chloride was produced.

(a) Determine the empirical formula of the compound.

[12 marks]

(b) 7.20 g of the compound was vapourised and was found to occupy 0.956 L at 150°C and 125.4 kPa. Determine the molecular formula of the compound.

[3 marks]

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SEE NEXT PAGE

PART 4 (20 marks)

Answer the following extended answer question in blue or black ball point or ink pen. 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 $1^1/_2$ - 2 pages. Begin your essay on the lined page following the end of the questions.

Acetic acid (ethanoic acid) is the compound responsible for the sour taste and characteristic odour of vinegar. Vinegar comes from the French, *vin aigre*, which means sour wine. Vinegar can have a number of uses around the home. It can be used to remove the deposits left when hard water evaporates in kettles, it inhibits the growth of bacteria and so is used as a preservative. It is also used as flavouring in cooking and salad dressings.

Pure acetic acid, which was originally obtained by the distillation of vinegar, has a freezing point of 16.7°C, boils at 118.9°C and has a density of 1.049 g mL^{-1} at 25°C. It is flammable. It is miscible with water and with ethanol. Aqueous solutions of acetic acid freeze at temperatures below 0°C.

The main commercial method for producing acetic acid is called the Monsanto process. The first step of the process is the production of methanol. Carbon monoxide and hydrogen react in the presence of a Cu/ZnO catalyst to produce methanol. The gaseous methanol is then reacted with more carbon monoxide at 180°C under a pressure of 30 – 40 atmospheres. The catalyst used in the reaction is iridium(VI) hexa-acetate ($Ir(C_2H_3O_2)_6$). $\Delta H = -135.31$ kJ mol^{-1} for the reaction. Under these conditions the reaction is very fast and produces a high yield.

Using the information above, discuss the production and chemistry of acetic acid. In your answer you may draw on your understandings of

- acids and bases
- equilibrium
- rates of reactions
- bonding
- organic chemistry
- reactions

You do not need to address all of these areas. You must include equations in your answer where relevant.

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.

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