Curriculum Council
Government of Western Australia

WACE
Western Australian Certificate of Education

Tertiary Entrance Examination, 2008

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)
Question Sheet for Part 4 (inside the front cover of this Question/Answer Booklet)

To be provided by the candidate

Standard items: Pens, pencils, eraser, correction fluid, ruler, highlighter

Special items: A blue or black pen or a B or 2B 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
2: Short Answers	10	10	60	70
3: Calculations	5	5	45	50
4: Extended Answers	1	1	20	20
			Total marks	200

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *TEE/WACE Examinations 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 on the separate Multiple-Choice Answer Sheet. Use a blue or black pen or a B or 2B pencil.

   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 that you are correct. Marks will not be deducted for incorrect answers.

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

   Questions for Part 4 have been repeated on a removable sheet which has been inserted into the front of this booklet so that you can refer to it more easily while answering the questions. Do not write your answers on the Question Sheet. The removable Question Sheet is **not** to be handed in with your answers.

   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 that do not show working will not be awarded full marks.

3. The examiners recommend that you spend most of your reading time 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, $NH_3(g)$, $NH_3(aq)$, $CH_3COOH(\ell)$, $CH_3COOH(aq)$] or **solids** [for example, $BaSO_4(s)$, $Cu(s)$, $Na_2CO_3(s)$].

See next page

Part 1 **60 Marks**

Answer **all** questions in Part 1 on the separate Multiple-Choice Answer Sheet provided, using a blue or black pen or B or 2B pencil. Each question in this part is worth 2 marks.

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1. Which of the following combinations of 0.100 mol L^{-1} solutions will **not** produce a precipitate on mixing?

   (a) sodium nitrate, barium chloride, ammonium carbonate, potassium hydroxide

   (b) potassium nitrate, barium chloride, ammonium nitrate, magnesium chloride

   (c) barium chloride, calcium nitrate, potassium sulfate, mercury(II) nitrate

   (d) ammonium chloride, barium nitrate, sodium sulfate, calcium iodide

2. Which of the following is the electron configuration of a group II element?

   (a) $1s^2$

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

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

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

3. An element was found to have the following electron configuration:

   $$1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^2$$

   Which of the following statements about the place of the element in the Periodic Table is correct?

   (a) The element belongs in the s-block.

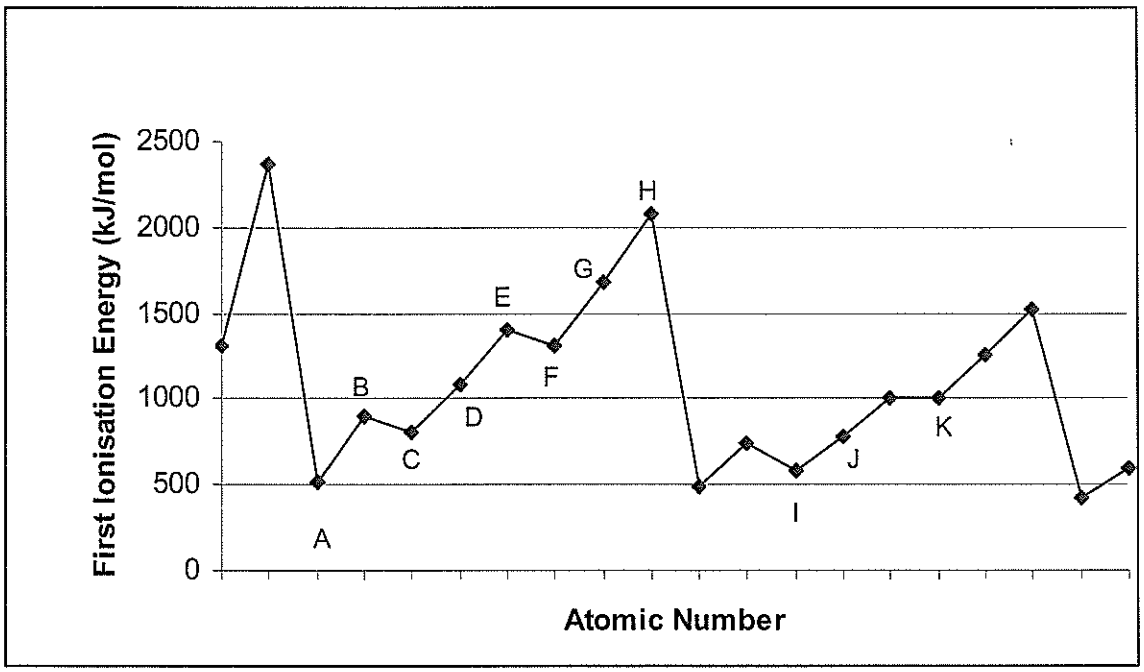
   (b) The element belongs in the p-block.

   (c) The element belongs in the d-block.

   (d) This electron configuration does not represent a ground-state configuration and so the element's position cannot be determined.

See next page

Questions 4, 5 and 6 refer to this graph, which shows the trend of first ionisation energies for the first 20 elements below.



4. Which of the following statements best explains the trend in first ionisation energies for the elements labelled A through to H?

   (a) There is an increasing number of electrons in the atoms going from element A to element H.

   (b) The atomic radii increase from element A to element H.

   (c) There is an increasing number of protons in the nuclei going from element A to element H.

   (d) Electrons are being added to the second energy level for elements A to H.

5. Which of the following combinations of atoms is most likely to result in a covalent molecular compound?

   (a) B with F

   (b) C with J

   (c) F with K

   (d) B with C

See next page

6. Which of the following elements, when combined with oxygen, would give the compound with the highest melting point?

(a) A

(b) H

(c) E

(d) K

7. Consider the following 1.00 mol L^{-1} aqueous solutions.

I Sodium chloride
II Ethanol
III Acetic acid
IV Sulfuric acid

Which of the following options lists these solutions from greatest conductivity to lowest conductivity?

(a) $NaC\ell > H_2SO_4 > CH_3COOH > CH_3CH_2OH$

(b) $CH_3CH_2OH > CH_3COOH > H_2SO_4 > NaC\ell$

(c) $H_2SO_4 > NaC\ell > CH_3COOH > CH_3CH_2OH$

(d) $CH_3COOH > NaC\ell > H_2SO_4 > CH_3CH_2OH$

8. Which of the following statements about chemical bonding is/are correct?

I All bonds involve electrostatic attractions between oppositely-charged particles.
II Polar covalent bonds arise due to the unequal sharing of the bonding electrons between the atoms involved in the bond.
III Molten sodium hydroxide conducts electricity due to the presence of delocalised valence electrons.

(a) I only

(b) II only

(c) II and III only

(d) I and II only

See next page

9. Which of the following gives the correct molecular shape around the central atom for each of the species below?

	SO_2	SO_3	SO_3^{2-}
(a)	Linear	Triangular planar	Tetrahedral
(b)	Linear	Pyramidal	Triangular planar
(c)	Bent	Pyramidal	Pyramidal
(d)	Bent	Triangular planar	Pyramidal

10. Which of the following statements about aqueous solutions of weak acids is true?

(a) A weak acid is a concentrated acid that has been diluted.

(b) A 1.00 mol L^{-1} solution of a weak acid contains more molecules of acid than ions.

(c) Less than 1.0 mol of sodium hydroxide is required to react completely with 1.0 mol of a monoprotic weak acid.

(d) The salt produced through the neutralisation of a weak acid by a strong base is slightly acidic.

11. Which of the following classifications is correct?

	$KC\ell$	KCH_3COO	$NH_4C\ell$	$KHSO_4$
(a)	Neutral	Basic	Acidic	Acidic
(b)	Neutral	Basic	Acidic	Neutral
(c)	Acidic	Acidic	Basic	Basic
(d)	Neutral	Acidic	Basic	Acidic

See next page

12. A group of students conducted a series of titrations using the following steps:

I Washed burette with distilled water and a small quantity of acid before filling with acid.
II Washed the pipette with distilled water before filling with base.
III Washed the conical flasks with distilled water and a small quantity of base before adding the base from the pipette.
IV Rinsed the sides of the conical flasks with distilled water during the titrations.
V Added two drops of indicator to each conical flask

The students found they could not obtain consistent results. Which of the above steps could have been responsible for the errors?

(a) I and V only

(b) II and III only

(c) II, III and IV only

(d) I, II and IV only

13. In which of the following reactions is the underlined species acting as a base?

(a) $\underline{CH_3NH_2} + CH_3CH_2COOH \rightleftharpoons CH_3NH_3^+ + CH_3CH_2COO^-$

(b) $\underline{NH_4^+} + SO_4^{2-} \rightleftharpoons NH_3 + HSO_4^-$

(c) $\underline{NH_3} + H_2O \rightleftharpoons NH_2^- + H_3O^+$

(d) $2CrO_4^{2-} + 2\underline{HSO_4^-} \rightleftharpoons Cr_2O_7^{2-} + H_2O + SO_4^{2-}$

14. An indicator and the pH range in which it changes colour are given below.

Indicator	pH range for colour change	Colour change (lower to higher pH)
Methyl green	0.2 – 1.8	Yellow to blue

For each of the following 1.00 mol L^{-1} solutions, which set of indicator colours for methyl green is correct?

	Hydrochloric acid	Nitric acid	Acetic acid	Sodium hydroxide
(a)	Yellow	Yellow	Blue	Blue
(b)	Yellow	Blue	Blue	Yellow
(c)	Yellow	Blue	Blue	Blue
(d)	Yellow	Blue	Yellow	Blue

See next page

15. Which of the following best explains the increase in electrical conductivity of the elements going down group IV of the Periodic Table?

(a) Elements with fewer oxidation states are better electrical conductors.

(b) The elements become increasingly metallic as you go down the group.

(c) Their first ionisation energies increase as you go down the group.

(d) The elements become increasingly basic as you go down the group.

16. Which of the following statements about the third row of the Periodic Table is correct?

(a) Elements on the right side of the row have a greater number of oxidation states than elements on the left side.

(b) Elements on the right side of the row are stronger reducing agents than elements on the left side.

(c) Elements on the right side of the row have lower first ionisation energies than elements on the left side.

(d) Elements on the right side of the row form basic oxides, while elements on the left side form acidic oxides.

17. In which of the following is vanadium in its highest oxidation state?

(a) VO_2^+

(b) VO^{2+}

(c) VO_2

(d) V_2O_3

18. Which of the following statements about dry cells is **incorrect**?

(a) The anode reaction is $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$.

(b) The electrolyte is a paste of MnO_2 and $NH_4C\ell$.

(c) The cathode consists of a graphite rod which decomposes as the cell reacts.

(d) If the MnO_2 makes contact with the zinc casing the cell voltage decreases.

See next page

19. An electrolytic cell consists of nickel electrodes in a 1.00 mol L^{-1} $CuC\ell_2$ solution. Under standard conditions, what products would be expected at the anode and cathode?

	Anode Product	Cathode Product
(a)	$C\ell_2(g)$	$Cu(s)$
(b)	$O_2(g)$	$Cu(s)$
(c)	$O_2(g)$	$H_2(g)$
(d)	$Ni^{2+}(aq)$	$Cu(s)$

20. Which of the following compounds **cannot** be used as a primary standard in a redox titration?

(a) Na_2CO_3

(b) $H_2C_4O_2.2H_2O$

(c) $Na_2C_2O_4$

(d) $Fe(NH_4)_2(SO_4)_2.6H_2O$

21. When solid silver chromate is added to water, the following equilibrium is established:

$$Ag_2CrO_4(s) \rightleftharpoons 2Ag^+(aq) + CrO_4^{2-}(aq)$$

A small quantity of sodium chromate solid is added to the solution. Assuming there is no change in the volume of the system, which of the following statements is correct?

(a) The concentration of $CrO_4^{2-}(aq)$ will increase and the concentration of $Ag^+(aq)$ will not change.

(b) The concentration of $CrO_4^{2-}(aq)$ will decrease and the concentration of $Ag^+(aq)$ will increase.

(c) The concentration of $CrO_4^{2-}(aq)$ will increase and the concentration of $Ag^+(aq)$ will decrease.

(d) The concentrations of $CrO_4^{2-}(aq)$ and $Ag^+(aq)$ will not change.

See next page

22. Consider the following system, which is at equilibrium:

$$C_2H_4(g) + HC\ell(g) \rightleftharpoons CH_3CH_2C\ell(g) \qquad \Delta H = -70 \text{ kJ mol}^{-1}$$

Which of the following statements about this system is true?

(a) The rate of the forward reaction and the rate of the reverse reaction are zero.

(b) The concentrations of the reactants will remain constant over time.

(c) The concentration of C_2H_4 will equal the concentration of $CH_3CH_2C\ell$.

(d) The sum of the concentrations of C_2H_4 and $HC\ell$ will equal the concentration of $CH_3CH_2C\ell$.

23. In a chemical reaction at constant temperature, which one of the following statements best describes the result of the addition of a catalyst?

(a) Addition of a catalyst increases the amount of products formed.

(b) Addition of a catalyst decreases the time taken to reach equilibrium.

(c) Addition of a catalyst decreases the amount of energy released in the reaction.

(d) Addition of a catalyst increases the amount of energy released in the reaction.

24. All of the following compounds can be used as fertilisers. Which compound will provide the greatest mass of nitrogen per 100 g of compound when dissolved in 5.00 L of water?

(a) NH_4NO_3

(b) $(NH_4)_2SO_4$

(c) KNO_3

(d) NH_3

Use the following information to answer Questions 25 and 26.

A student has 20.0 mL of 0.15 mol L^{-1} $Ba(OH)_2$ solution and 30.0 mL of 0.223 mol L^{-1} $HC\ell$ solution.

25. What is the pH of the $Ba(OH)_2$ solution?

(a) 0.52

(b) 2.52

(c) 13.18

(d) 13.48

26. If the two solutions are mixed, what is the pH of the resulting solution?

(a) 1.13

(b) 1.86

(c) 2.43

(d) 3.16

27. Which of the following can be produced by the oxidation of propan-1-ol?

I CH_3CH_2CHO
II CH_3CH_2COOH
III CH_3COCH_3
IV CO_2

(a) I and II only

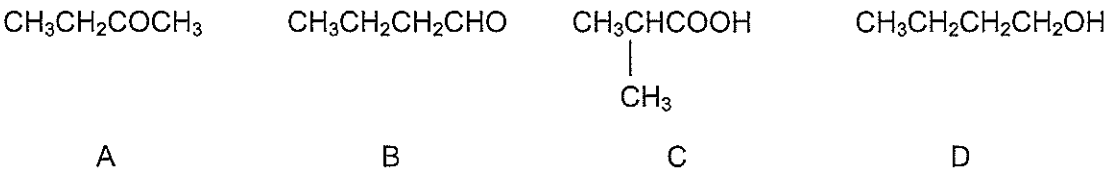
(b) I, II and III only

(c) I, II and IV only

(d) all of them

See next page

Questions 28, 29 and 30 refer to the structures shown below.



A B C D

28. Which of the following will react to form an ester?

(a) A and B

(b) B and C

(c) A and C

(d) C and D

29. Which of the following, if any, are isomers of each other?

(a) A and B

(b) B and C

(c) C and D

(d) none of the above

30. Which of the following will react with sodium, giving hydrogen gas?

(a) A and B

(b) B and C

(c) B and D

(d) C and D

End of Part 1

See next page

Part 2 **70 Marks**

Answer **all** questions in Part 2 in the spaces provided.

Question 1 **(12 marks)**

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) Chlorine gas is bubbled through a sodium iodide solution. (3 marks)

Equation _____

Observation _____

_____

(b) Solid chromium(III) hydroxide is added to concentrated potassium hydroxide solution. (3 marks)

Equation _____

Observation _____

_____

(c) Iron(III) nitrate solution is added to sodium sulfide solution. (3 marks)

Equation _____

Observation _____

_____

(d) Solid sodium carbonate is added to an excess of acetic acid solution. (3 marks)

Equation _____

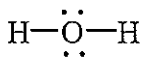
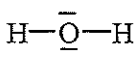
Observation _____

_____

See next page

Question 2 **(6 marks)**

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  or  or  and so on)

Species	Electron dot diagram
Nitrogen gas	
Sodium nitrate	
Hydrazine, N_2H_4	

See next page

Question 3 **(8 marks)**

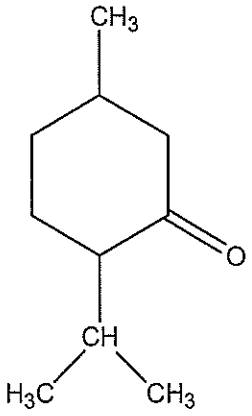
For each of the following substances provide a property and a use related to that property.

Substance	Property	Related use
Magnesium		
Sodium hypochlorite		
Aluminium		
Gold		

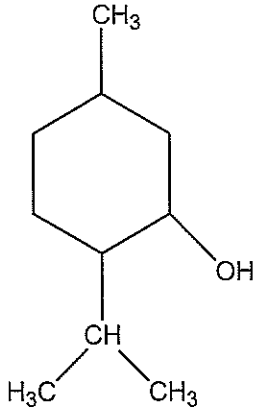
See next page

Question 4 **(3 marks)**

The structures and melting points are provided for two similarly-sized organic substances. Explain the difference in their melting points.



Menthone
-6°C



Menthol
35°C

Question 5 **(9 marks)**

Describe a chemical test that can be used to distinguish between each substance in the following pairs of substances. Describe fully the chemical test and the observations expected for each substance.

Substances	Chemical Test	Expected observations
Cyclohexane (C_6H_{12}) and cyclohexene (C_6H_{10})		C_6H_{12}
		C_6H_{10}
1 mol L^{-1} sulfuric acid solution (H_2SO_4) and 1 mol L^{-1} hydrochloric acid solution ($HC\ell$)		H_2SO_4
		$HC\ell$
Propanone (CH_3COCH_3) and propanal (CH_3CH_2CHO)		CH_3COCH_3
		CH_3CH_2CHO

See next page

Question 6 **(10 marks)**

The following equilibrium is set up by adding solid silver chloride to dilute ammonia solution in three test tubes:

$$AgC\ell(s) + 2NH_3(aq) \rightleftharpoons [Ag(NH_3)_2]^+(aq) + C\ell^-(aq)$$

(a) Write an equilibrium constant expression for this equation. (1 mark)

(b) The following changes are made to the equilibrium system. Each change is applied to a separate test tube and equilibrium is re-established. Complete the table below, indicating the changes in the forward reaction rate, and the concentration of $[Ag(NH_3)_2]^+(aq)$, compared to the original equilibrium system. Use the terms 'increase', 'decrease' or 'no change'.

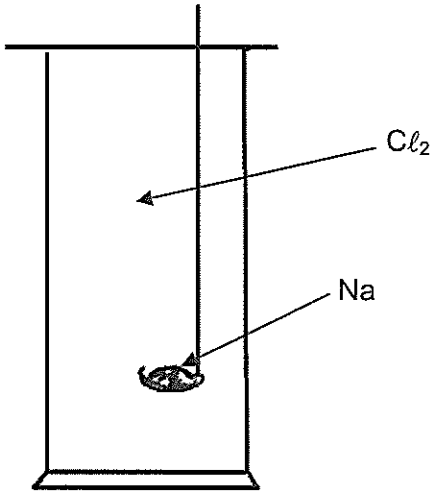
Also describe what you would observe as equilibrium is re-established in the system. (9 marks)

	At new equilibrium		
Imposed change	Effect on forward reaction rate	Effect on $[Ag(NH_3)_2]^+(aq)$	Observation
$NH_3(g)$ is bubbled through the solution.			
$NaC\ell(s)$ is added to the solution.			
A few drops of concentrated $HNO_3(aq)$ are added to the solution.			

See next page

Question 7 **(7 marks)**

When a piece of freshly cut sodium metal is placed in a gas jar of chlorine gas (as shown below) it ignites spontaneously with sparks and flashes of flame. A white powder is left on the sides of the jar.



(a) What do the observations tell us about the size of the (2 marks)

(i) activation energy of this reaction?

_____

(ii) heat of reaction?

_____

(b) Draw an energy profile diagram for this reaction, labelling the axes, activation energy and heat of reaction. (3 marks)

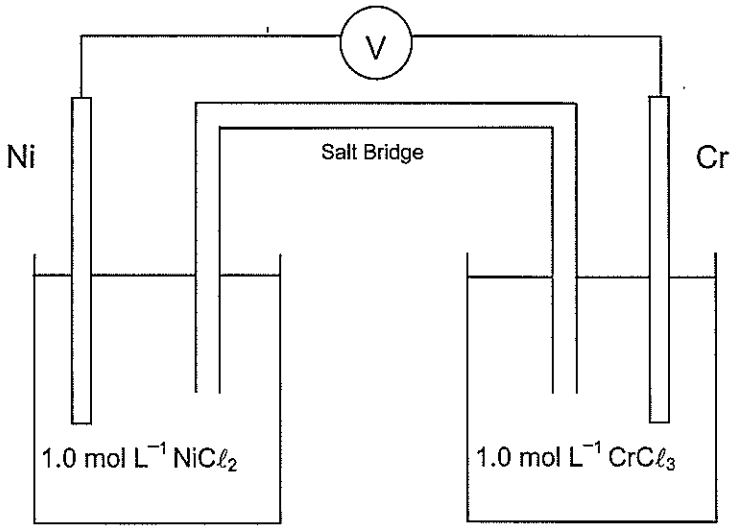
See next page

(c) The white powder produced from this reaction dissolved readily when added to distilled water. This solution is shown to conduct an electric current. Explain how the process of dissolving enables this solution to conduct electricity. (2 marks)

Question 8 **(7 marks)**

Consider the following diagram of an electrochemical cell consisting of a potassium nitrate salt bridge and half cells containing:

I a 1.0 mol L^{-1} nickel(II) chloride solution and a nickel electrode;
II a 1.0 mol L^{-1} chromium(III) chloride solution and a chromium electrode.



(a) Label the cell diagram, showing anode, cathode, direction of electron flow and direction of flow of ions (both positive and negative) in the salt bridge. (3 marks)

(b) Write an equation for the overall reaction in the cell. (2 marks)

(c) Calculate the EMF (voltage) for the cell at standard conditions. (1 mark)

(d) Why would a potassium carbonate salt bridge be an inappropriate choice for this electrochemical cell? (1 mark)

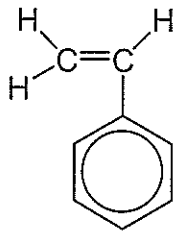
Question 9 **(4 marks)**

A student was given a 0.100 mol L^{-1} sulfuric acid solution and a 0.200 mol L^{-1} hydrochloric acid solution. She tested the pH of the solutions using a pH meter and found that the pH of the sulfuric acid solution was higher than that of the hydrochloric acid solution. Explain this observation. Include equations in your answer.

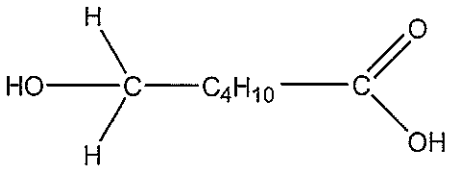
See next page

Question 10 **(4 marks)**

In the boxes below draw diagrams of an addition polymer and condensation polymer using the monomers provided. You may use one or both monomers in both polymers. (You must show a minimum of two repeating units.)



Monomer 1



Monomer 2

Addition polymer	
Condensation polymer	

End of Part 2

See next page

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See next page

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, distinguish each section clearly, 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.

Question 1 **(9 marks)**

The first step in the production of nitric acid involves a reaction between ammonia and oxygen which can be represented by the following equation:

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$$

In a production run, a rigid container of capacity 4.49×10^6 L, fitted with an entry valve to prevent the exit of gas, initially contains only air at a pressure of 105.3 kPa and a temperature of 175°C. 457.3 kg of ammonia is injected and the oxidation reaction is catalysed by hot platinum. When the reaction is complete the mixture is cooled to 25°C.

Air contains 20.9% oxygen by volume.

(a) Determine the limiting reagent.

(b) What mass of NO will be produced?

(c) What will be the mass of the excess reagent in the reaction vessel after cooling to 25°C?

See next page

See next page

Question 2 **(9 marks)**

Chlorine is used as a bleaching agent in the manufacture of fabrics. Excess chlorine is removed at the end of the bleaching process by reaction with sodium thiosulfate ($Na_2S_2O_3$) solution according to the equation:

$$S_2O_3^{2-}(aq) + 4C\ell_2(aq) + 5H_2O(\ell) \rightarrow 2HSO_4^-(aq) + 8C\ell^-(aq) + 8H^+(aq)$$

265 L of a chlorine bleach is used to bleach some fabric. This bleach solution has a density of 1.00 kg L^{-1} and contains 83.0% by mass of chlorine.

Some chlorine remains unreacted at the end of the bleaching process. 14.2 L of 5.45 mol L^{-1} sodium thiosulfate solution is required to remove this excess chlorine.

(a) Calculate the mass of chlorine remaining after the bleaching process.

(b) Calculate the concentration of chlorine (in ppm) in the 265 L of the solution after the bleaching process.

Before the used bleach solution can be released into the environment, the acid produced in the reaction with sodium thiosulfate must be neutralised.

(c) What volume of 6.88 mol L^{-1} sodium hydroxide solution would be required to react completely with all of the acid (H^+ and HSO_4^-) in the used bleach solution?

See next page

See next page

Question 3 **(10 marks)**

A bottle of anhydrous oxalic acid ($H_2C_2O_4$) was found to be contaminated with potassium chloride. 2.05 g of the mixture was dissolved in distilled water and the volume made up to 250.0 mL in a volumetric flask. 20.0 mL aliquots of the solution were titrated against 0.115 mol L^{-1} sodium hydroxide solution and the following results were obtained:

Titration Results	Trials (mL)			
	1	2	3	4
Final Volume	32.05	32.10	31.11	33.25
Initial volume	0.50	2.45	1.40	3.65
Titre				

(a) Write an equation for the reaction between oxalic acid and sodium hydroxide.

(b) Complete the table.

(c) Calculate the average titre.

(d) Calculate the concentration of the oxalic acid solution.

(e) Calculate the percentage purity of the oxalic acid mixture.

(f) What would be an appropriate indicator for this titration? Justify your answer.

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Question 4 **(10 marks)**

A lead-acid accumulator battery is being recharged. During recharge a current of 15.0 A is passed though the cell for 6.50 hours. The cathode reaction can be represented by the following equation:

$$PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}(aq)$$

(a) Calculate the mass of lead produced during the recharge, assuming 65.0% efficiency.

(b) A competing reaction involving the reduction of sulfate ions to sulfur dioxide gas can occur at the cathode. Write the half equation for this reduction reaction.

(c) Assume 1.40% of the current causes sulfate reduction. If a mechanic recharging a battery forgets to loosen its caps, what pressure due to sulfur dioxide production will be built up in the space above the electrolyte, given that the volume is 300.0 mL and the temperature is 28°C?

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Question 5 **(12 marks)**

An old drum of pesticide has been found on a farm. The label has fallen off and for safe disposal its contents need to be analysed.

Elemental analysis shows the presence of carbon, hydrogen, phosphorus and oxygen. A 5.21 g sample of the pesticide produces 6.32 g of carbon dioxide and 3.23 g of water when combusted completely in excess oxygen.

A second, 3.15 g, sample of the pesticide is treated with excess nitric acid to convert all of the phosphorus to phosphate ions. The resulting solution is treated with excess calcium nitrate solution to produce 3.37 g of calcium phosphate.

(a) Determine the empirical formula of the pesticide.

(b) Mass spectral analysis shows the molar mass of the pesticide to be 290.18 g mol^{-1}. What is the pesticide's molecular formula?

End of Part 3

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Part 4 **20 Marks**

Answer the following question. Marks are awarded for the relevant chemical content of your answer, and also for coherence and clarity of expression. **Where applicable, use equations, diagrams and illustrative examples of the chemistry you are describing.**

Your answers should be presented in about 1½–2 pages. Begin your response on the lined page following the end of the questions.

Nickel is a silver-coloured transition metal with a melting point of 1453°C. It is resistant to corrosion and is magnetic. Nickel is used in alloys such as stainless steel, for plating iron and in coins. Some nickel compounds are used as the green tint in glass.

Nickel ores are predominantly sulfides and oxides. While there are many methods for producing pure nickel from the sulfide or oxide, two will be described here.

Method 1

This method is used for nickel sulfide ores and involves two steps:

Step 1. The nickel sulfide reacts with ammonia and excess oxygen under a pressure of 900 kPa at 85°C. This is called ammonia pressure leaching. The nickel reacts to produce an ammine complex according to the equation:

$$NiS(s) + 6NH_3(aq) + 2O_2(g) \rightarrow [Ni(NH_3)_6]^{2+}(aq) + SO_4^{2-}(aq)$$

Step 2. The resulting solution is electrolysed to produce pure nickel. The cathode is pure nickel, the voltage is between between 2.5 V and 4 V and the reaction is carried out between 50°C and 80°C.

Method 2

This method is used for nickel oxide ores and is called the Mond process. It involves three steps, with each step conducted at moderate pressures.

Step 1. Nickel oxide is reacted with hydrogen at 200°C to produce impure nickel metal and water. The impurities present include iron and cobalt. This step goes to completion.

Step 2. The impure nickel is converted into gaseous nickel carbonyl ($Ni(CO)_4$, a complex in which the central atom's oxidation state is zero) using an excess of carbon monoxide at 50-60°C. This reaction is exothermic.

Step 3. The nickel carbonyl is separated from the residue and passed over platinum heated to 220-250°C. The nickel carbonyl decomposes, giving pure nickel and carbon monoxide. The carbon monoxide is recovered for purifying further batches of nickel.

From the information provided and your understanding of chemical principles:

- For Method 1, discuss the purpose of each step and compare and contrast this method with aluminium or gold extraction processes and refining methods. You should not describe these methods in detail, but you must comment on the similarities and differences between the ways that the specific properties of each metal and its compounds are used in achieving separation from the raw materials.
- Explain the conditions used to maximise yield in Method 2 (the Mond process), in terms of rates of reaction and equilibrium.

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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