Government of **Western Australia**
Curriculum Council

WACE
Western Australian Certificate of Education

Western Australian Certificate of Education Examination, 2010

Question/Answer Booklet

CHEMISTRY

Stage 3

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

To be provided by the candidate

Standard items: pens, pencils, eraser, correction fluid/tape, ruler, highlighters

Special items: non-programmable calculators satisfying the conditions set out by the Curriculum Council for this course

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

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Multiple-choice	25	25	50	25	25
Section Two: Short answer	11	11	60	70	35
Section Three: Extended answer	6	6	70	80	40
				Total	100

Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2010.* Sitting this examination implies that you agree to abide by these rules.

2. Answer the questions according to the following instructions.

   Section One: Answer all questions on the separate Multiple-choice Answer Sheet provided. For each question shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square, do not erase or use correction fluid, and shade your new answer. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

   Sections Two and Three: Write your answers in this Question/Answer Booklet.

3. When calculating numerical answers, show your working or reasoning clearly unless instructed otherwise.

4. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

5. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
   - Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
   - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

See next page

Section One: Multiple-choice **25% (25 Marks)**

This section has **25** questions. Answer **all** questions on the separate Multiple-choice Answer Sheet provided. For each question shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square, do not erase or use correction fluid, and shade your new answer. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 50 minutes.

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1. Which one of the following best explains why fluorine and chlorine are chemically similar to each other?

   (a) They each have seven valence electrons.
   (b) They are both in Group 17 of the Periodic Table.
   (c) Their nuclei have the same number of protons.
   (d) They are both very powerful oxidising agents.

2. In which one of the following sets do all species have the electron configuration of a noble gas?

   (a) S^{2-}, O^{2-}, He^{2+}
   (b) H^{+}, Mg^{2+}, $C\ell^{-}$
   (c) P^{2-}, O^{2-}, Na^{+}
   (d) S^{2-}, K^{+}, Mg^{2+}

3. Which one of the following statements is generally **true** of elements in the Periodic Table?

   (a) Group 17 elements are very strong reducing agents.
   (b) Atomic radius increases across a period.
   (c) Group 1 elements become less metallic as atomic number increases.
   (d) Electronegativity decreases down a group.

4. Which one of the following observations can be explained in terms of hydrogen bonding?

   (a) The boiling point of H_2S is greater than that of PH_3.
   (b) The melting point of CH_4 is less than that of PH_3.
   (c) The boiling point of H_2O is greater than that of H_2S.
   (d) The melting point of HI is greater than that of NH_3.

See next page

5. Hydrochloric acid ($HC\ell$) is a stronger acid than the ammonium ion (NH_4^+). Which one of the statements below is **true**?

   (a) The equilibrium constant for the hydrolysis of $HC\ell$ is smaller than that for NH_4^+.
   (b) $C\ell^-(aq)$ is a weaker base than $NH_3(aq)$.
   (c) Solutions of $HC\ell$ will always have more hydrogen ions than solutions of NH_3.
   (d) The pH of a 0.1 mol L^{-1} solution of $HC\ell$ will be greater than the pH of a 0.1 mol L^{-1} solution of NH_3.

6. Which one of the following pairs of substances forms a buffer in aqueous solution?

   (a) $HC\ell$ and $NaC\ell$
   (b) H_2SO_4 and Na_2SO_4
   (c) $NH_4C\ell$ and $NaNH_2$
   (d) $NaHCO_3$ and Na_2CO_3

7. Bromophenol blue is an acid-base indicator that has a colour change from yellow to blue between pH 3.0 and 4.6. A sodium hydroxide solution (in a conical flask) is titrated with an acetic (ethanoic) acid solution (in a burette), using bromophenol blue indicator.

   Which one of the following statements about this titration is true?

   (a) The end point and the equivalence point occur at the same time.
   (b) The end point occurs after the equivalence point.
   (c) The end point occurs before the equivalence point.
   (d) The indicator will be yellow at the equivalence point of the titration.

8. Which one of the following species **cannot** act as a Brønsted-Lowry acid and a Brønsted-Lowry base?

   (a) $H_2PO_4^-$
   (b) CH_3COCH_3
   (c) H_2O
   (d) HCO_3^-

9. Which one of the following solutions will have the greatest number of ions per litre?

   (a) 0.4 mol L^{-1} $Zn(NO_3)_2$
   (b) 0.1 mol L^{-1} $NaC\ell$
   (c) 0.2 mol L^{-1} $HC\ell$
   (d) 0.2 mol L^{-1} $A\ell_2(SO_4)_3$

10. Which one of the four elements ($C\ell$, Cr, P, Mn) underlined below has the **lowest** oxidation state?

    (a) $H\underline{\mathbf{C\ell}}O_2$
    (b) $K_2\underline{\mathbf{Cr}}O_4$
    (c) $Na_3\underline{\mathbf{P}}O_4$
    (d) $K\underline{\mathbf{Mn}}O_4$

See next page

11. Which of the following are redox reactions?

I. $N_2 + 3\ H_2 \rightarrow 2\ NH_3$
II. $CaCO_3 + 2\ HC\ell \rightarrow CaCl_2 + H_2O + CO_2$
III. $Zn + 2\ HC\ell \rightarrow ZnC\ell_2 + H_2$
IV. $S + O_2 \rightarrow SO_2$

(a) equations I, II, III and IV
(b) equations I, III and IV only
(c) equations II, III and IV only
(d) equation IV only

12. In which one of the following will a metal displacement reaction occur?

(a) a zinc rod is dipped in a 1.0 mol L^{-1} solution of sodium sulfate
(b) a copper rod is dipped in a 1.0 mol L^{-1} solution of cobalt(II) nitrate
(c) a silver rod is dipped in a 1.0 mol L^{-1} solution of gold(III) nitrate
(d) a tin rod is dipped in a 1.0 mol L^{-1} solution of manganese(II) sulfate

13. Solubility rules apply at modest concentrations of about 0.1 mol L^{-1} or higher. In each of the following instances, 0.2 mol of each of the four named substances is added to 1 L of water and the mixture stirred. In which of these will a precipitate/s remain after stirring?

I. $NaCH_3COO$, $(NH_4)_2CO_3$, $MgC\ell_2$, KNO_3
II. $Pb(NO_3)_2$, K_2S, $NaC\ell$, NH_4NO_3
III. $BaC\ell_2$, KCH_3COO, $CuSO_4$, LiBr
IV. KI, $NH_4C\ell$, NaBr, $CuSO_4$

(a) III only
(b) II and III only
(c) I, II and III only
(d) I, II, III and IV

14. Which one of the following statements about absolute zero is correct?

(a) At absolute zero, the volume of an ideal gas is zero.
(b) At absolute zero, ideal gases freeze to give solids.
(c) At absolute zero, solid and liquid water are at equilibrium.
(d) Absolute zero is the lowest temperature so far reached in the laboratory.

15. Which one of the following statements about the addition of a catalyst to a chemical reaction is **false**?

(a) It increases the rate of the reaction relative to the uncatalysed reaction.
(b) It provides a reaction pathway that has a smaller activation energy than that for the uncatalysed reaction.
(c) It causes a greater fraction of collisions between reaction particles to result in a reaction relative to the uncatalysed reaction.
(d) It causes particles involved in a reaction to move faster than those in the uncatalysed reaction.

See next page

16. Consider the following reaction at equilibrium:

$$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g) \quad \Delta H = -197\ kJ\ mol^{-1}$$

Which one of the following changes will increase the concentration of $SO_3(g)$ in the mixture when equilibrium is re-established?

(a) decreasing the concentration of SO_2 at constant temperature and pressure
(b) decreasing the concentration of O_2 at constant temperature and pressure
(c) decreasing the temperature of the system
(d) decreasing the pressure of the system

17. A small rise in temperature of gaseous reactants in a system results in an increase in the rate of reaction. Which one of the following is the **main** reason for this change?

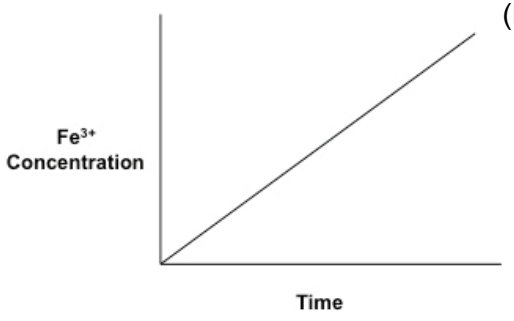
(a) an increase in the speed of reactant particles, leading to a higher rate of collision
(b) an increase in the pressure inside the reaction vessel, leading to a higher rate of collision
(c) an increase in the proportion of collisions with more than the activation energy
(d) an increase in the activation energy of the reaction

18. When aqueous solutions of Ag^+ and Fe^{2+} are mixed, Ag and Fe^{3+} form according to the following equilibrium.

$$Ag^+(aq) + Fe^{2+}(aq) \rightleftharpoons Ag(s) + Fe^{3+}(aq)$$

Which one of the following concentration versus time graphs best represents the way in which the Fe^{3+} concentration varies as the reaction proceeds to equilibrium?

(a)



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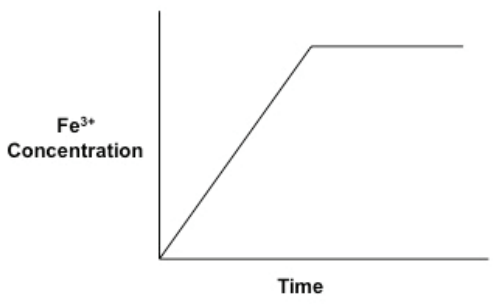
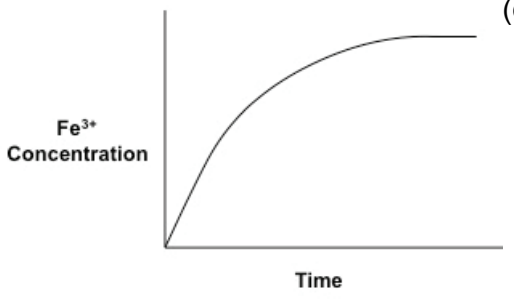
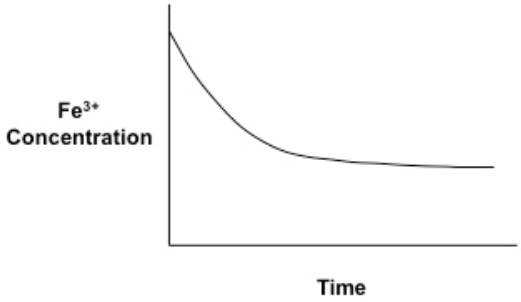


(c)



(d)



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19. An element X has the following five successive ionisation energies (in kJ mol^{-1}):

584, 1823, 2751, 11584, 14837

What is the formula of the compound formed when X reacts with nitrogen?

(a) X_3N
(b) XN
(c) XN_2
(d) XN_3

Questions 20 and 21 refer to the compounds, numbered I to IV, below.

I. $CH_3CH_2CH_2CH_2COOH$
II. $CH_3CH_2CH_2CH_2CH_2OH$
III. $CH_3CH_2CH_2CH_2CHO$
IV. $CH_3CH_2CH_2CH_2CH_2CH_3$

20. Which one of the following lists the compounds in order of decreasing solubility in water?

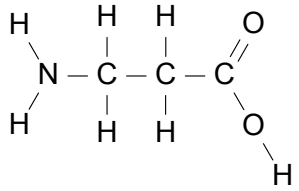
(a) IV > III > II > I
(b) I > II > III > IV
(c) I > III > II > IV
(d) II > I > III > IV

21. Which two of the compounds will react to form an ester?

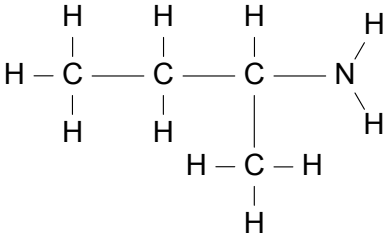
(a) I and II
(b) I and III
(c) II and III
(d) I and IV

22. Which one of the following compounds is an α-amino acid?

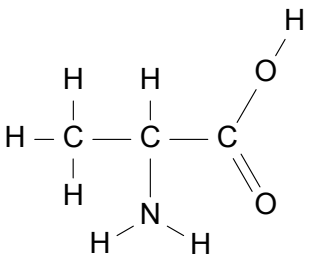
(a)



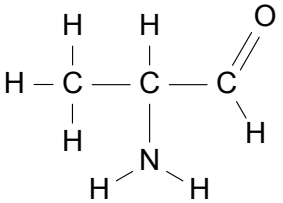
(b)



(c)



(d)



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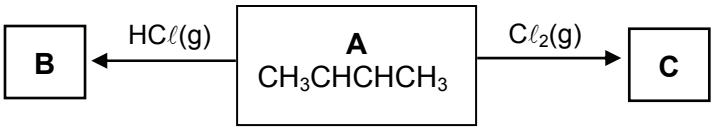
Use the information below to answer questions 23 and 24.



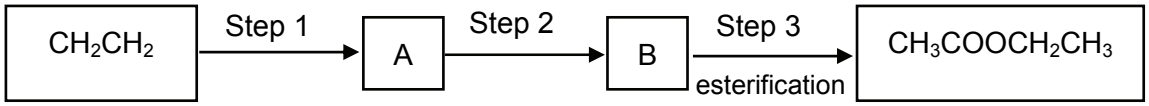
23. Which one of the following is the formula for the product B from the reaction of A with hydrogen chloride?

(a) $CH_3CHCHCH_2C\ell$
(b) $CH_3CHC\ell CHC\ell CH_3$
(c) $CH_3CH_2CHC\ell CH_3$
(d) $CH_3CH_2CH_2CH_2C\ell$

24. Which one of the following is the formula for the product C from reaction of A with chlorine?

(a) $CH_3CHCHCH_2C\ell$
(b) $CH_3CHC\ell CHC\ell CH_3$
(c) $CH_3CH_2CHC\ell CH_3$
(d) $CH_2C\ell CHCHCH_2C\ell$

25. Ethene (CH_2CH_2) can be used to manufacture ethyl ethanoate, $CH_3COOCH_2CH_3$, in three steps, as indicated below:



Which one of the following is the correct sequence of steps 1 and 2?

	Step 1	**Step 2**
(a)	substitution with water	oxidation
(b)	addition of water	oxidation
(c)	oxidation	addition of water
(d)	oxidation	substitution with water

End of Section One

See next page

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Section Two: Short answer **35% (70 Marks)**

This section has **11** questions. Answer **all** questions. Write your answers in the spaces provided.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 60 minutes.

Question 26 **(6 marks)**

Consider the following system:

$$CO(g) + 2\,H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -92\ kJ$$

(a) Predict whether the following changes will increase, decrease or have no effect on the rate of attainment of equilibrium. (3 marks)

Change	Effect
Decreasing the temperature	
Increasing the pressure of hydrogen	
Adding a catalyst	

(b) Predict whether the following changes will increase, decrease or have no effect on the equilibrium yield of the reaction. (3 marks)

Change	Effect
Increasing the temperature	
Increasing the pressure of the system	
Adding a catalyst	

See next page

Question 27 **(2 marks)**

Write the equilibrium constant expression for the following equilbria:

(a) (1 mark)

Equation	$BaSO_4(s) \rightleftharpoons Ba^{2+}(aq) + SO_4^{2-}(aq)$
Equilibrium constant expression	

(b) (1 mark)

Equation	$2\ CrO_4^{2-}(aq) + 2\ H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(\ell)$
Equilibrium constant expression	

Question 28 **(4 marks)**

Like water, ammonia is able to react with itself, in the process known as 'self-ionisation'. The equation for the self-ionisation of ammonia is below.

$$NH_3(aq) + NH_3(aq) \rightleftharpoons NH_4^+(aq) + NH_2^-(aq)$$

(a) Identify the conjugate acid and base pairs in the reaction. Join each pair with a line, and label the conjugate acid and base of each pair appropriately. (1 mark)

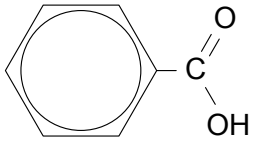
$NH_3(aq) + NH_3(aq) \rightleftharpoons NH_4^+(aq) + NH_2^-(aq)$

(b) At standard temperature and pressure, the equilibrium constant, K, for this reaction is about 1×10^{-30}. The self-ionisation of ammonia is an endothermic process. Will the value of K be less than or greater than 1×10^{-30} at temperatures greater than 0°C? Explain. (3 marks)

See next page

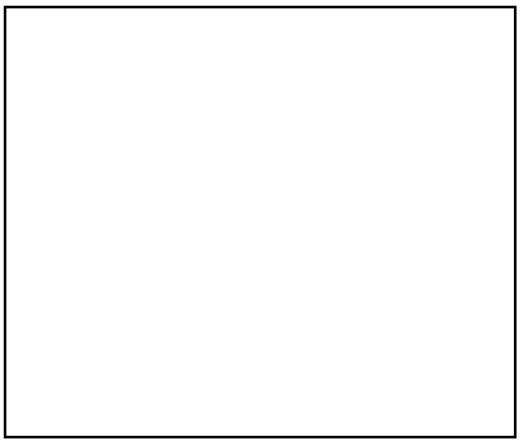
Question 29 **(8 marks)**

Benzoic acid is found in many berries and some other fruits, and is used as a food preservative. The structure of benzoic acid is shown below. In an aqueous environment, benzoic acid ionises and exists in equilibrium with the benzoate ion.



(a) Write the equation for the reaction between benzoic acid and water. (1 mark)

(b) Draw the structure (either benzoic acid or the benzoate ion) that would predominate in the acidic environment of the stomach. (1 mark)



(c) Show, using equations and the principles of equilibrium, how a solution of benzoic acid and the benzoate ion may behave as a buffer. (3 marks)

(d) The ease with which a substance is excreted from the body is determined in part by its solubility in water. Is benzoic acid more or less miscible with water than acetic (ethanoic) acid, and hence more or less readily excreted from the body? Explain**.** (3 marks)

See next page

Question 30 **(6 marks)**

Consider the following reactions and complete the tables that follow.

(a) An excess of 2-butanol is oxidised by acidified $Na_2Cr_2O_7$. (3 marks)

Observations	
Structural formula of organic product Show all atoms	
Name of organic product	

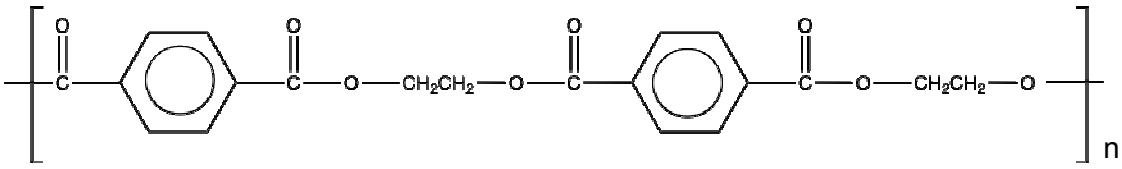
(b) Butanoic acid reacts with methanol in the presence of H_2SO_4. (3 marks)

Observations	
Structural formula of organic product Show all atoms	
Name of organic product	

See next page

Question 31 **(3 marks)**

Condensation polymers form from two monomers, each with functional groups at their terminal carbon atoms (that is, the monomers are difunctional). Examine the polyester structure below.



(a) Circle **all** the ester linkages (functional groups that link the monomers) represented in the above structure. (1 mark)

(b) Identify the two monomer compounds (A and B) used in the production of this polymer and draw their molecular structures. (2 marks)

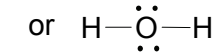
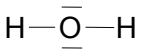
Monomer A

Monomer B

See next page

Question 32 **(12 marks)**

For each species listed in the table below, draw the structural formula, representing all valence shell electron pairs either as **:** or as **—** **and** state or draw the shape of the molecule **and** state the polarity of the molecule.

(for example, water  or  or  bent polar)

Species	**Structure (showing all valence shell electrons)**	**Shape (sketch or name)**	**Polarity of molecule (polar or non-polar)**
nitrogen trichloride $NC\ell_3$			
methanal HCHO			
sulfur dioxide SO_2			
carbon dioxide CO_2			

See next page

Question 33 **(4 marks)**

Using the information in the table below, identify the substances A, B, C and D from the following list:

- aluminium
- calcium carbonate
- copper
- copper(II) sulfate
- octane
- graphite
- iodine
- mercury
- nickel(II) chloride
- silicon dioxide
- potassium chloride

	Electrical conductivity in the solid state	**Electrical conductivity in the liquid state**	**Solubility in water**	**Phase at 25°C**	**Colour at 25°C**	**Name of substance**
A	nil	conducts	soluble	solid	white	
B	conducts	conducts	insoluble	solid	silver	
C	nil	nil	insoluble	liquid	colourless	
D	nil	nil	insoluble	solid	white	

See next page

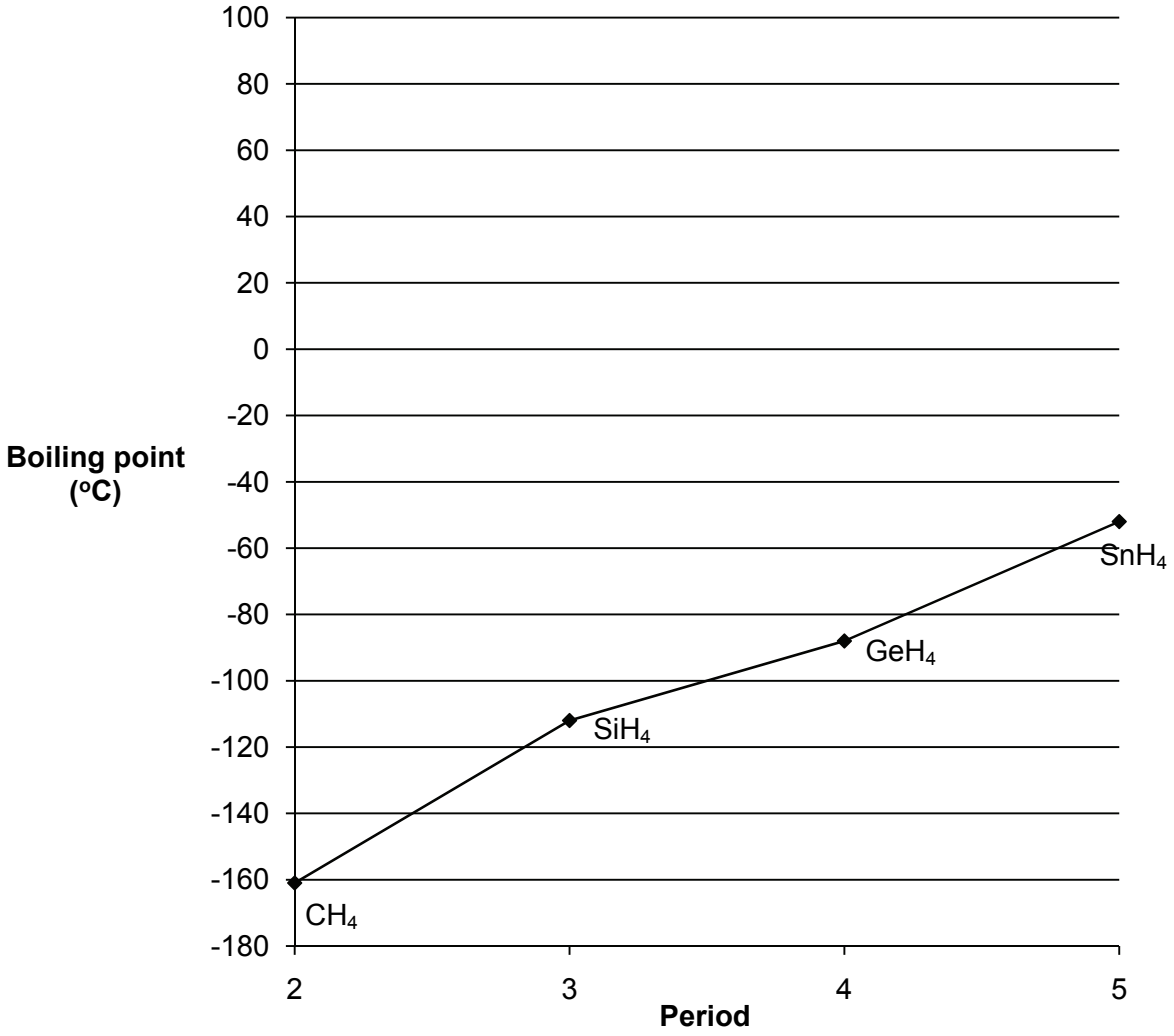
Question 34 **(11 marks)**

The approximate boiling points of the Group 14, 15, 16 and 17 hydrides are listed below.

Group number	Hydride	Period	Boiling point (°C)
14	CH_4	2	– 161
	SiH_4	3	– 112
	GeH_4	4	– 88
	SnH_4	5	– 52
15	NH_3	2	– 33
	PH_3	3	– 88
	AsH_3	4	– 62
	SbH_3	5	– 17
16	H_2O	2	100
	H_2S	3	– 60
	H_2Se	4	– 41
	H_2Te	5	– 2
17	HF	2	20
	HCℓ	3	– 85
	HBr	4	– 66
	HI	5	– 34

See next page

(a) Plot the boiling points for each group on the axes below. The data for Group 14 have been plotted as an example. (3 marks)



(b) The hydrides of Group 14 are non-polar molecules.

(i) Give the name of the shape of a Group 14 hydride molecule

or

Draw a diagram to illustrate the shape of a Group 14 hydride molecule. (1 mark)

Diagram	or	Name

See next page

(ii) Apply your understanding of intermolecular interactions to explain the steadily increasing boiling points of the Group 14 hydrides CH_4, SiH_4, GeH_4 and SnH_4. (2 marks)

(c) The Group 15, 16 and 17 hydrides are polar molecules. Consider the Group 17 hydrides HCℓ, HBr and HI.

(i) List HCℓ, HBr and HI in order of increasing polarity. (1 mark)

(ii) Compare the trend in polarities of HCℓ, HBr and HI with the observed trend in their boiling points. Briefly explain your reasoning. (2 marks)

(d) The first member of each hydride series (NH_3 in Group 15, H_2O in Group 16 and HF in Group 17) has a much higher boiling point than the next hydride in its series. Apply your understanding of intermolecular interactions to explain the anomalous boiling points of NH_3, H_2O and HF. (2 marks)

See next page

Question 35 **(5 marks)**

Concentrated sulfuric acid can behave as an oxidising agent. Depending upon conditions, it can react in one of three ways to form

(i) sulfur dioxide gas;
(ii) hydrogen sulfide gas; or
(iii) elemental sulfur.

(a) Write half-equations showing each of these three possible reactions. (3 marks)

(i) _____

(ii) _____

(iii) _____

(b) Write half-equations and an overall redox equation for the reaction between concentrated sulfuric acid and hydrogen iodide to form hydrogen sulfide, iodine and water. (2 marks)

Reduction half-equation: _____

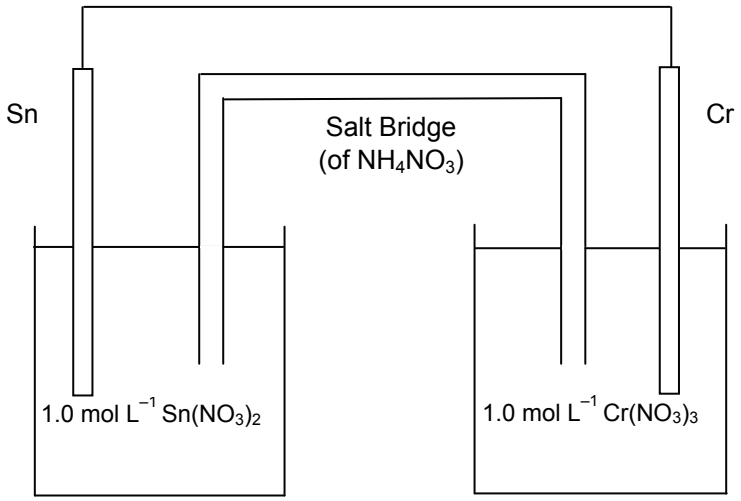
Oxidation half-equation: _____

Overall redox equation: _____

See next page

Question 36 **(9 marks)**

An electrochemical cell consists of a tin electrode in a solution of 1.0 mol L^{-1} tin(II) nitrate, to create a Sn/Sn^{2+} half cell, and a similarly constructed half cell composed of a chromium electrode in a solution of 1.0 mol L^{-1} chromium(III) nitrate. The two electrodes are joined by a piece of copper wire. A salt bridge, as shown in the diagram below, joins the two solutions.



(a) On the diagram, label (3 marks)

(i) the anode
(ii) the direction of electron flow
(iii) the direction of cation flow in the salt bridge.

(b) Write the balanced anode and cathode reactions. (2 marks)

(i) Anode:

_____

(ii) Cathode:

_____

(c) Would sodium carbonate be suitable as a salt for the salt bridge? Explain. (2 marks)

_____

_____

_____

_____

See next page

(d) Why does the rate of production of electrical current from an electrochemical cell decrease as it operates? (1 mark)

(e) During the operation of an electrochemical cell, why is it important that the anode and cathode do not come into contact with each other? (1 mark)

End of Section Two

See next page

Section Three: Extended answer **40% (80 Marks)**

This section contains **six (6)** questions. You must answer **all** questions. Write your answers in the spaces provided.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to three (3) significant figures.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

Suggested working time: 70 minutes.

Question 37 **(12 marks)**

A blast furnace is a large furnace operated at very high temperatures to convert iron(III) oxide (in iron ore) to iron using carbon monoxide, which is itself converted to carbon dioxide during the process.

(a) Write the equation for the reaction of iron(III) oxide with carbon monoxide. (1 mark)

_____

(b) Identify the oxidant and reductant in the above process. (1 mark)

Oxidant: _____

Reductant: _____

(c) 1.00 tonne of iron ore containing 96.5% iron(III) oxide is fed into the blast furnace with 2.70×10^6 L of carbon monoxide at 1.12 atm pressure and 1986°C.
Note: 1 tonne = 1×10^6 g

(i) Determine the limiting reactant for this reaction. (4 marks)

(ii) What mass of iron is theoretically produced in this reaction? (2 marks)

(iii) Calculate the mass of the reactant in excess. (3 marks)

(d) If 5.56×10^{-1} tonne of iron is actually produced, what is the overall percentage yield of the process? (1 mark)

See next page

Question 38 **(13 marks)**

Sodium carbonate is produced by the five-step Solvay process.

Step 1
Brine (sodium chloride solution) is purified by the addition of sodium carbonate to precipitate calcium ion impurities and of sodium hydroxide to precipitate magnesium ion impurities.

Step 2
Limestone is heated in a kiln at between 950°C and 1100°C to decompose it to calcium oxide and carbon dioxide. This is shown below.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

The calcium oxide is removed for use in Step 5.

Step 3
Ammonia gas is dissolved in the purified brine in a reaction tower. The resulting solution is passed to a second tower, where carbon dioxide is added to the solution. The reaction is shown below.

$$NaC\ell(aq) + NH_3(g) + H_2O(\ell) + CO_2(g) \rightarrow NH_4C\ell(aq) + NaHCO_3(s)$$

The reaction is performed at 0°C to precipitate the sodium hydrogencarbonate. The mixture is filtered, the sodium hydrogencarbonate washed and dried, and the ammonium chloride sent to the ammonia recovery plant.

Step 4
The sodium hydrogencarbonate is heated to approximately 300°C to decompose it to sodium carbonate. The reaction is shown below.

$$2\ NaHCO_3(s) + \text{heat} \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(g)$$

The carbon dioxide is recovered for use in Step 3.

Step 5
Calcium oxide produced in Step 2 is added to water.

$$CaO(s) + H_2O(\ell) \rightarrow Ca(OH)_2(aq)$$

The calcium hydroxide solution produced in this step is mixed with the ammonium chloride solution produced in Step 3, and the resulting solution is warmed to recover ammonia.

$$2\ NH_4C\ell(aq) + Ca(OH)_2(aq) \rightarrow CaC\ell_2(aq) + 2\ NH_3(g) + 2\ H_2O(\ell)$$

(a) (i) Write the equation for the precipitation of the calcium ions in Step 1. Show only those species participating in the reaction. (1 mark)

(ii) Write the equation for the precipitation of the magnesium ions in Step 1. Show only those species participating in the reaction. (1 mark)

See next page

The reactions for Steps 2, 3 and 4 of the process are shown below.

Step 2 $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

Step 3 $NaC\ell(aq) + NH_3(g) + H_2O(\ell) + CO_2(g) \rightarrow NH_4C\ell(aq) + NaHCO_3(s)$

Step 4 $2\ NaHCO_3(s) + \text{heat} \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(g)$

(b) (i) How many moles of calcium carbonate are consumed to produce one mole of sodium carbonate? (1 mark)

_____

(ii) If a company plans to produce 1.00×10^4 tonnes of sodium carbonate each week, what mass of calcium carbonate will be needed if the overall process is 85.0% efficient?
Note: 1 tonne = 1×10^6 g (6 marks)

The reactions for Step 5 are reproduced below.

Step 5 $CaO(s) + H_2O(\ell) \rightarrow Ca(OH)_2(aq)$

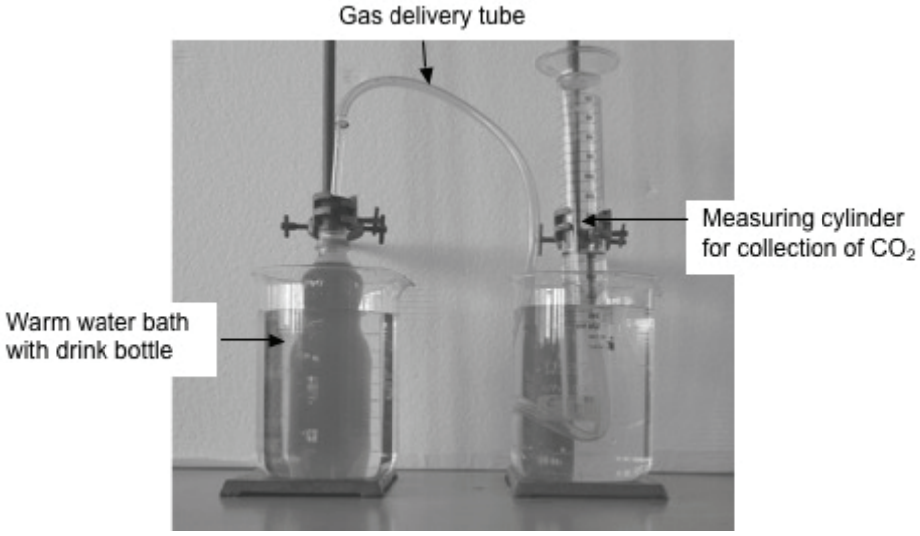
$2\ NH_4C\ell(aq) + Ca(OH)_2(aq) \rightarrow CaC\ell_2(aq) + 2\ NH_3(g) + 2\ H_2O(\ell)$

(c) What volume of ammonia gas at 40.0°C and 1.00 atm pressure can be recovered if 8.50×10^3 tonnes of calcium oxide is obtained from Step 2? (4 marks)

Question 39 **(12 marks)**

A student carried out the experiment described below to determine the volume of carbon dioxide gas dissolved in a particular brand of carbonated, flavoured soft drink.

A 360 mL bottle of the drink was immersed in a beaker of warm water and the gas collected in an inverted 250.0 mL cylinder, as shown in the diagram below.

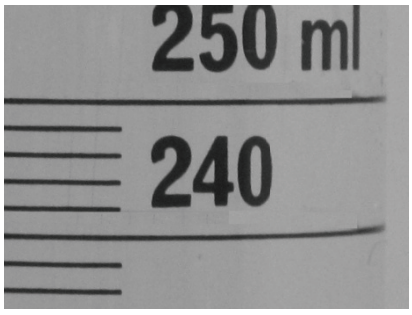


The volume of gas was measured, at 28°C and 102.4 kPa, and recorded when no further change in the height of water in the upturned measuring cylinder was observed. This procedure was carried out four times. The results are shown in the table below.

	Trial 1	Trial 2	Trial 3	Trial 4
Volume of CO_2 (mL)	238.2	241.6	234.6	236.4

(a) The figure below shows the graduations on the measuring cylinder used to collect the gas. Has the student recorded the volume data with an appropriate level of precision (an appropriate number of decimal places) in the table above? Explain.

(2 marks)



See next page

(b) Using all of the student's data, calculate the average number of moles of carbon dioxide in a 360 mL bottle of this brand of drink. (The vapour pressure of water may be ignored.) (3 marks)

The student measured the pH of the drink immediately upon opening and found it to be 3.19.

(c) What is the hydrogen ion concentration of the drink? (1 mark)

The label on the bottle shows there is 697 kJ of energy and 40.0 g of sugar in one 360 mL bottle of the drink. The energy in the drink is released when the sugar (in the form of glucose, $C_6H_{12}O_6$) from the drink reacts in the cells of the body through respiration. This process is represented by the reaction:

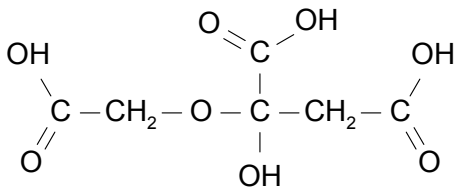
$$C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O + \text{energy}$$

(d) How many moles of glucose are provided by the drink? (2 marks)

(e) How much energy is released by the respiration of one mole of glucose? (2 marks)

See next page

(f) The label on the bottle lists food acid 330 as an ingredient. This is citric acid and has the structure given below:



(i) Circle and label with the letter A **all** the carboxylic acid functional groups in this compound. (1 mark)

(ii) Circle and label with the letter B **all** the alcohol functional groups in this compound. (1 mark)

See next page

Question 40 **(13 marks)**

The manufacturer of the soft drink referred to in question 39 also produces a diet version of the drink, containing artificial sweetener. The quality assurance procedures of the soft drink manufacturer require that incoming batches of the artificial sweetener be analysed to ensure compliance with standards. A combustion analysis of a 1.021 g sample of sweetener produced 1.715 g CO_2, 0.2521 g H_2O, 0.2558 g NO_2 and 0.3568 g SO_2. The sweetener contains the elements C, H, O, N and S. Determine its empirical formula.

See next page

Extra working space for Question 40.

Question 41 **(20 marks)**

Production of excess acid in the stomach leads to heartburn. This can be easily treated with antacids, which contain an active ingredient that neutralises the excess acid.

A commonly used antacid preparation is 'milk of magnesia', a suspension of the active ingredient $Mg(OH)_2$ in water. A suspension of $A\ell(OH)_3$ in water is also often used as an antacid.

A student set out to compare the effectiveness of a given quantity of two antacid preparations, one containing $Mg(OH)_2$ and the other $A\ell(OH)_3$, purchased from his local pharmacy. He titrated each of the preparations against a hydrochloric acid solution to determine how much acid each could neutralise, and to determine the concentration of active ingredient in each of the preparations. He first standardised the hydrochloric acid solution available in the laboratory against a primary standard, and chose anhydrous sodium carbonate as the primary standard.

(a) Did the student select an appropriate primary standard? Explain. (2 marks)

The student prepared 1.00 L of a 0.0248 mol L^{-1} Na_2CO_3 solution. He titrated three 25.0 mL aliquots of this solution against the $HC\ell$ and found an average titre of 24.35 mL.

(b) Calculate the concentration of the standardised $HC\ell$ solution. (4 marks)

See next page

The student proceeded to prepare his antacids for titration against the standardised HCℓ.
He performed the following procedure for each of the antacids.

The antacid suspension was thoroughly shaken and 20.0 g was weighed out and transferred to a 250.0 mL volumetric flask, which was made up to the mark with deionised water and shaken vigorously. 10.0 mL aliquots of this diluted suspension were transferred for titration, using an appropriate indicator, to conical flasks. The titration data for the $A\ell(OH)_3$ suspension are shown in the table below.

Titration Result	**Volume HCℓ (mL)**			
	Trials			
	1	**2**	**3**	**4**
Final reading	23.20	44.96	22.12	42.18
Initial reading	0.58	22.98	0.20	20.26
Titre				

(c) Complete the table and determine the average titre value for the HCℓ solution. (1 mark)

Average titre: _____

(d) The densities, in grams per millilitre, of the original antacid preparations are given below.

Suspension	Density (g mL^{-1})
$Mg(OH)_2$	1.06
$A\ell(OH)_3$	1.12

(i) Calculate the concentration, in mg per mL, of $A\ell(OH)_3$ in the original $A\ell(OH)_3$ suspension. (7 marks)

(ii) From his titration of the $Mg(OH)_2$ diluted suspension, the student found the mass of $Mg(OH)_2$ in the 250 mL **diluted** suspension to be 1.13 g. Determine the concentration of $Mg(OH)_2$ in the original **undiluted** suspension and express your answer in mg per mL. (2 marks)

See next page

(e) The directions for use on each of the antacid preparations suggest a standard adult dose of 10.0 mL. Which of the preparations would be more effective (neutralise the most $HC\ell$) per standard dose? Show your working. (4 marks)

See next page

Question 42 **(10 marks)**

Nitric acid is manufactured by the Ostwald process.

In the first step, ammonia gas reacts with oxygen gas to produce nitric oxide in the presence of a catalyst such as platinum with 10% rhodium. This reaction is carried out at a temperature of approximately 900°C and at a pressure of approximately 10 atmospheres.

$$4\ NH_3(g)\ +\ 5\ O_2(g) \rightleftharpoons 4\ NO(g) + 6\ H_2O(g) + \text{heat}$$

The nitric oxide is next oxidised at approximately 50°C.

$$2\ NO(g)\ +\ O_2(g) \rightleftharpoons 2\ NO_2(g) + \text{heat}$$

The nitrogen dioxide then enters an absorption tower, where water is added through a sprinkler system in the presence of air to give nitric acid.

$$4\ NO_2(g) + O_2(g) + 2\ H_2O(\ell) \rightleftharpoons 4\ HNO_3(aq)$$

Use your understanding of reaction rates and chemical equilibrium to explain the conditions used in the Ostwald process. Your answer should include at least three (3) paragraphs, and should be 1 to 1½ pages in length.

End of questions

Additional working space

Additional working space

Additional working space

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