Government of **Western Australia**
School Curriculum and Standards Authority

WACE
Western Australian Certificate of Education

Western Australian Certificate of Education Examination, 2013

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

Number of additional answer booklets used (if applicable):

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 (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: non-programmable calculators approved for use in the WACE examinations

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.

Ref: 13-023

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 2013*. 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, then shade your new answer. Do not erase or use correction fluid/tape. 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. Express numerical answers to three significant figures and include appropriate units where applicable.

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 that you are continuing to answer at the top of the page.

6. The Chemistry Data Sheet is **not** handed in with your Question/Answer Booklet.

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, then shade your new answer. Do not erase or use correction fluid/tape. 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 statements applies to elements with seven valence electrons?

   (a) They have a bonding capacity of one and are in Group 17.
   (b) They have a bonding capacity of seven and have metallic properties.
   (c) They have a bonding capacity of one and are in Group 1.
   (d) They have a bonding capacity of seven and form diatomic molecules.

2. Which one of the following types of force is **most** responsible for the dissolution of ionic compounds in water?

   (a) dipole-dipole attraction
   (b) hydrogen bonding
   (c) ion-dipole interaction
   (d) covalent bonding

3. Which one of the following molecules is **non-**polar?

   (a) H_2S
   (b) CHF_3
   (c) $NC\ell_3$
   (d) SO_3

4. The heat required to melt 1 kg of solid neon (Ne) to liquid is 16.6 kJ, while that required to melt 1 kg of ice is 334 kJ. Which of the statements below help to explain this?

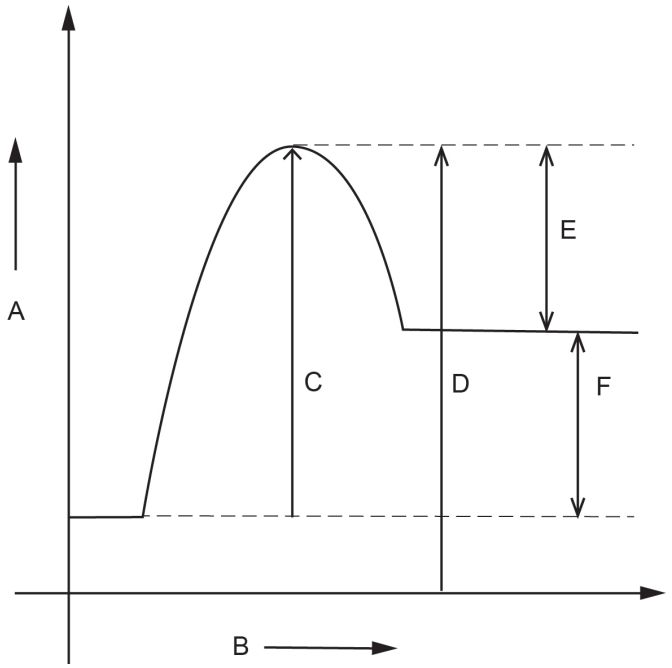
   I. Only dispersion forces act between neon atoms.
   II. There are strong covalent bonds between hydrogen and oxygen atoms in ice.
   III. There is strong hydrogen bonding between water molecules in ice.
   IV. There are weak hydrogen bonds between neon atoms.

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

See next page

Questions 5, 6 and 7 refer to the potential energy diagram below for the reaction

$$CH_4(g) + H_2O(g) \rightleftharpoons 3\,H_2(g) + CO(g) \qquad \Delta H = +206 \text{ kJ}$$



5. Which one of the following is true?

   (a) The forward reaction is endothermic.
   (b) The axis representing potential energy is B.
   (c) The potential energy of the activated complex is C.
   (d) The activation energy for the forward reaction is D minus C.

6. Which one of the following represents the activation energy for the reverse reaction?

   (a) C
   (b) D
   (c) E
   (d) D plus F

7. Which one of the following represents the heat of reaction for the forward reaction?

   (a) C minus D
   (b) E
   (c) C
   (d) F

8. A 0.630 g sample of gas has a volume of 1.00 L at STP. The molar mass of this gas, in g mol^{-1}, is

   (a) 35.6.
   (b) 22.4.
   (c) 14.8.
   (d) 14.3.

See next page

9. Consider the following reaction.

$$2\ H^+(aq) + 2\ NO_3^-(aq) + H_2S(g) \rightarrow 2\ NO_2(aq) + S(s) + 2\ H_2O(\ell)$$

Which one of the following statements is true for this reaction?

(a) The H^+ is oxidised and the H_2O is reduced.
(b) The oxidation number of the nitrogen changes from +5 to +4 during the reaction.
(c) The sulfur is reduced in the reaction.
(d) This is an acid-base reaction, not a redox reaction.

Use the table of standard reduction potentials in the Chemistry Data Sheet to answer Questions 10 and 11.

10. Predict in which of the following a reaction would occur. Assume all solutions are 1.0 mol L^{-1}.

I. Acidified potassium permanganate is mixed with potassium iodide solution.
II. Chlorine gas is bubbled through hydrogen sulfide solution.
III. Acidified potassium dichromate is mixed with potassium fluoride.
IV. An iron(II) sulfate solution is placed in a nickel container.
V. A piece of copper metal is placed in a hydrochloric acid solution.

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

Use the following additional table of standard reduction potentials to answer Question 11.

Half-Reaction	**E^o (V)**
$2HC\ell O_2 + 6H^+ + 6e^- \rightarrow C\ell_2(g) + 4H_2O$	1.64
$2HOC\ell + 2H^+ + 2e^- \rightarrow C\ell_2(g) + 2H_2O$	1.63
$2C\ell O_3^- + 12H^+ + 10e^- \rightarrow C\ell_2(g) + 6H_2O$	1.47
$2C\ell O_4^- + 16H^+ + 14e^- \rightarrow C\ell_2(g) + 8H_2O$	1.42
$C\ell O^- + H_2O + 2e^- \rightarrow C\ell^- + 2OH^-$	0.89
$C\ell O_2^- + 2H_2O + 4e^- \rightarrow C\ell^- + 4OH^-$	0.78

11. Which of the species below **cannot** react with hydrogen peroxide to produce oxygen gas?

(a) $C\ell O^-$, $C\ell O_2^-$, $C\ell O_3^-$ and $C\ell O_4^-$
(b) $HC\ell O_2$ and $HOC\ell$
(c) $HC\ell O_2$, $HOC\ell$, $C\ell O_3^-$ and $C\ell O_4^-$
(d) All can react with hydrogen peroxide to produce oxygen gas.

See next page

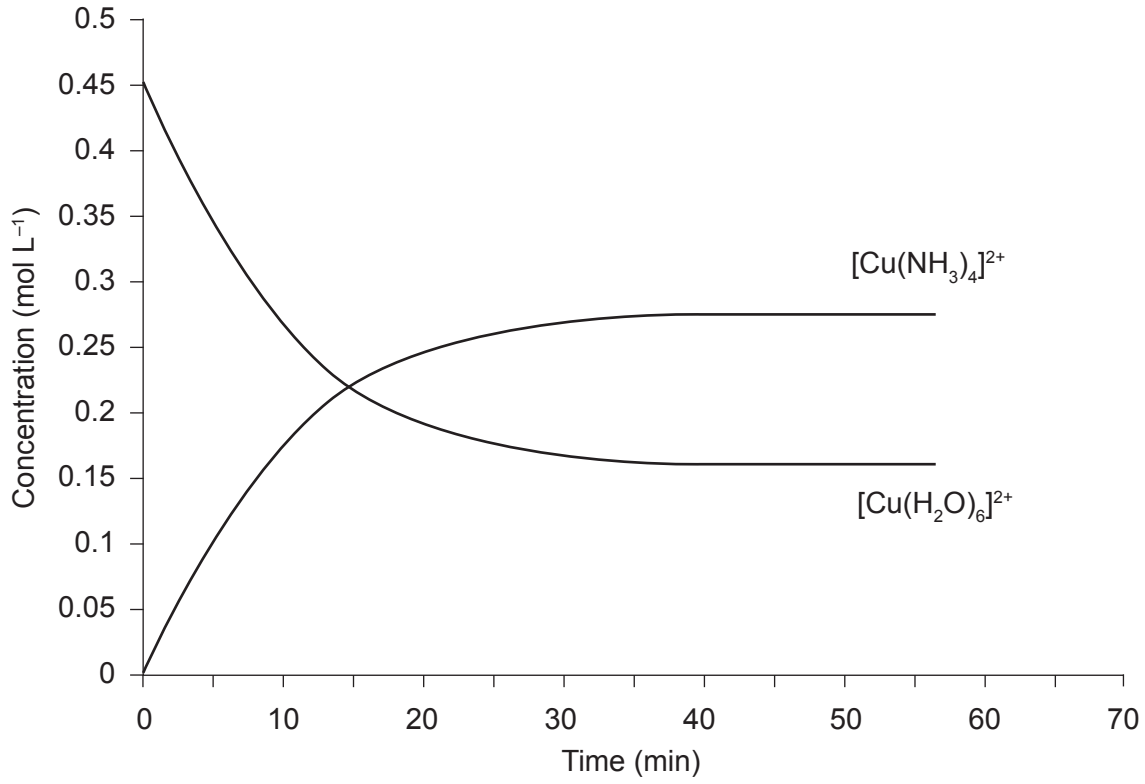
Questions 12 and 13 refer to the information and graph below.

Aqueous solutions of copper(II) ions and ammonia form the equilibrium represented below.

$$[Cu(H_2O)_6]^{2+}(aq) + 4\ NH_3(aq) \rightleftharpoons [Cu(NH_3)_4]^{2+}(aq) + 6\ H_2O(\ell)$$

pale blue — deep royal blue

The following graph shows the changes in concentration with time for $[Cu(H_2O)_6]^{2+}$ and $[Cu(NH_3)_4]^{2+}$ ions when solutions of copper(II) nitrate and ammonia are mixed.



12. Which one of the following statements is true for this equilibrium system?

(a) The system reaches equilibrium at approximately 35 minutes.
(b) At equilibrium, the concentration of NH_3 will always be four times greater than the concentration of $[Cu(NH_3)_4]^{2+}$.
(c) Adding ammonia to the system will decrease the equilibrium constant.
(d) At equilibrium, the rate of the forward reaction is less than the rate of the reverse reaction.

13. Which one of the following would be observed if a small quantity of concentrated nitric acid was added to the system after it had reached equilibrium?

(a) The solution would be a deeper royal blue colour.
(b) The solution would be a paler blue colour.
(c) There would be no change in the colour of the system.
(d) Copper(II) nitrate crystals would precipitate from solution.

See next page

14. Consider the following reaction.

$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g) + 198\ kJ$

After equilibrium has been established, which one of the following would immediately increase the rate of the reverse reaction?

(a) adding a catalyst
(b) increasing the concentration of SO_2
(c) cooling the reaction vessel and its contents
(d) adding a small amount of neon gas

15. Which one of the following substances can behave as a Brønsted-Lowry acid or base?

(a) H_2O_2
(b) NH_4^+
(c) CH_3NH_2
(d) $H_2PO_4^-$

16. A solution of hydrochloric acid conducts an electric current more readily than an equimolar solution of acetic acid. Which one of the following **best** explains this observation?

(a) Hydrochloric acid is a smaller molecule than acetic acid.
(b) Hydrochloric acid is more soluble in water than acetic acid.
(c) The equilibrium constant for the ionisation of hydrochloric acid is greater than that for acetic acid.
(d) The pH of hydrochloric acid solution is always greater than that for acetic acid solution.

17. Sodium hydrogensulfate was added to a swimming pool to reduce the pH of the water. Which one of the following equations **best** shows the reaction responsible for this?

(a) $Na^+(aq) + H_2O(\ell) \rightarrow NaOH(aq) + H^+(aq)$
(b) $HSO_4^-(aq) + H_2O(\ell) \rightarrow H_3O^+(aq) + SO_4^{2-}(aq)$
(c) $2HSO_4^-(aq) + H_2O(\ell) \rightarrow H_3O^+(aq) + H_2SO_4(aq) + SO_4^{2-}(aq)$
(d) $HSO_4^-(aq) + H_2O(\ell) \rightarrow OH^-(aq) + H_2SO_4(aq)$

18. A buffer solution is prepared by mixing equal moles of sodium acetate (ethanoate) and acetic acid in water. Which one of the following statements applies to the buffer?

(a) Addition of a few drops of concentrated nitric acid will produce more acetic acid molecules.
(b) The sodium ions play a significant role in the buffering action.
(c) Addition of water to the buffer will reduce its buffering capacity.
(d) Most of the hydrogen ions will be supplied by water.

See next page

19. The pH ranges for the colour change of four indicators are given below.

Alizarin yellow	10.1 – 12.0
Crystal violet	6.4 – 8.2
Bromocresol green	3.8 – 5.4
Malachite green	0.2 – 1.8

Which one of the indicators in the table is **most** suitable for the titration of hydrochloric acid with potassium carbonate solution?

(a) alizarin yellow
(b) crystal violet
(c) bromocresol green
(d) malachite green

20. Carbonated 'soft' drinks are made fizzy by dissolving $CO_2(g)$ into the flavoured liquid. Which one of the following statements relating to the volume of $CO_2(g)$ that can be dissolved in 1 L of soft drink liquid is true?

(a) It does not vary with temperature or pressure.
(b) It increases with increasing temperature.
(c) It decreases with increasing temperature.
(d) It decreases with increasing pressure.

21. A solid is dissolved in water to form a 0.1 mol L^{-1} solution. The resulting solution is found to have the following features.

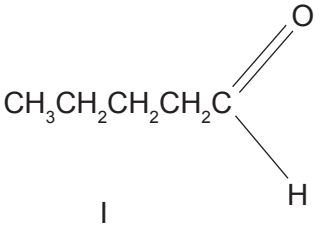
- has a pH in the range 2 to 6
- does not form a precipitate when $AgNO_3$ solution is added
- dissolves slowly a strip of copper metal that is dipped in the solution.

Which one of the following is most likely to be the solid?

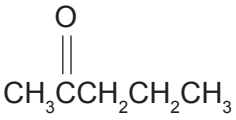
(a) $NH_4C\ell$
(b) $Ba(OH)_2$
(c) $A\ell(NO_3)_3$
(d) $Fe(NO_3)_3$

See next page

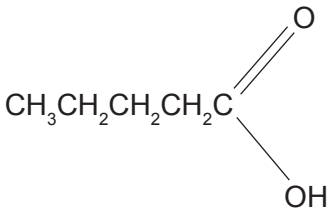
Questions 22, 23 and 24 refer to Compounds I to IV below.



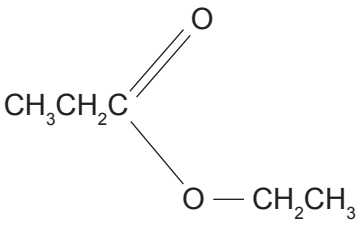
I



II



III



IV

22. Which one of the following lists the functional groups for Compounds I to IV correctly?

	I	II	III	IV
(a)	aldehyde	ketone	ester	carboxylic acid
(b)	carboxylic acid	aldehyde	ester	ketone
(c)	aldehyde	ketone	alcohol	carboxylic acid
(d)	aldehyde	ketone	carboxylic acid	ester

23. Which one of the alcohols below can be oxidised to produce Compound II?

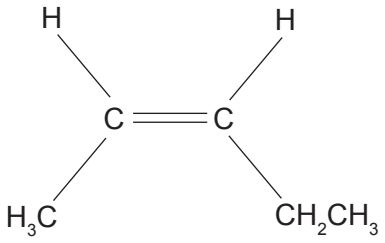
(a) $CH_3CH_2CH_2CH_2CH_2OH$
(b) $CH_3CH_2CH_2CHOHCH_3$
(c) $CH_3CH_2CHOHCH_2CH_3$
(d) $CH_3C(OH)(CH_3)CH_2CH_3$

24. Which one of Compounds I to IV will react with an alcohol in the presence of an acid?

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

See next page

25. Consider the following statements about the compound shown below.



I. It will decolourise iodine water.
II. If 1 mol of the compound is mixed with 2 mol of chlorine, all of the chlorine can react.
III. Its systematic name is *cis*-pent-2-ene.
IV. It is soluble in hexene.

Which of the statements are correct?

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

End of Section One

See next page

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

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

When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to **three** significant figures and include appropriate units where applicable.

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.

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- 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 that you are continuing to answer at the top of the page.

Suggested working time: 60 minutes.

Question 26 **(4 marks)**

Carbon and silicon are Group 14 elements that form very different compounds with oxygen. Some of their properties are shown in the table below:

Oxide	Melting point (°C)	Boiling point (°C)
Carbon dioxide	–78	–57
Silicon dioxide	1680	2230

Explain why these oxides of carbon and silicon have such different properties.

See next page

Question 27 **(5 marks)**

(a) Explain the differences between a covalent bond (**intra**molecular force) and an intermolecular force. (2 marks)

(b) Mixtures of propan-2-ol and propanone can be separated by distillation due to their different boiling points. Explain why these compounds have such different boiling points even though they have very similar molar masses. (3 marks)

	2-propanol	**propanone**
Boiling point (°C)	82	56
Molar mass (g mol^{-1})	60	58

See next page

Question 28 **(4 marks)**

Explain, with reference to the type of bonding, why metals tend to be good electrical conductors and are usually malleable. Diagrams may be used to assist your explanation.

Diagram:

See next page

Question 29 **(4 marks)**

Write the equation and the expression for the equilibrium constant for each of the equilibrium processes below.

Equilibrium process	Equation	Equilibrium constant expression
Vaporisation of water		
Dissolution of solid aluminium sulfate in water		

See next page

Question 30 **(8 marks)**

Consider the following system at equilibrium.

$$4\ NH_3(g)\ +\ 5\ O_2(g) \rightleftharpoons 4\ NO(g)\ +\ 6\ H_2O(g) +\ 920\ kJ$$

Indicate in the table below whether there would be an increase, decrease, or no change in the concentration of $NH_3(g)$ after the changes given in the table are imposed on the system and **equilibrium has been re-established**. Provide a brief explanation for the observation.

Change	**Change in concentration of $NH_3(g)$ (circle the correct response)**	**Brief explanation**
The volume of the reaction vessel is doubled	• increase • decrease • no change	
The temperature of the reaction system is doubled	• increase • decrease • no change	
$N_2(g)$ is injected into the reaction system while keeping the volume constant	• increase • decrease • no change	
Water vapour is injected into the reaction system while keeping the volume constant	• increase • decrease • no change	

See next page

Question 31 **(7 marks)**

An aqueous solution is prepared that contains 0.1 mol L^{-1} Na^+ and 0.1 mol L^{-1} $HC_2O_4^-$.

(a) Write the **two** possible reactions for the hydrolysis of the $HC_2O_4^-$ ion. (3 marks)

One: _____

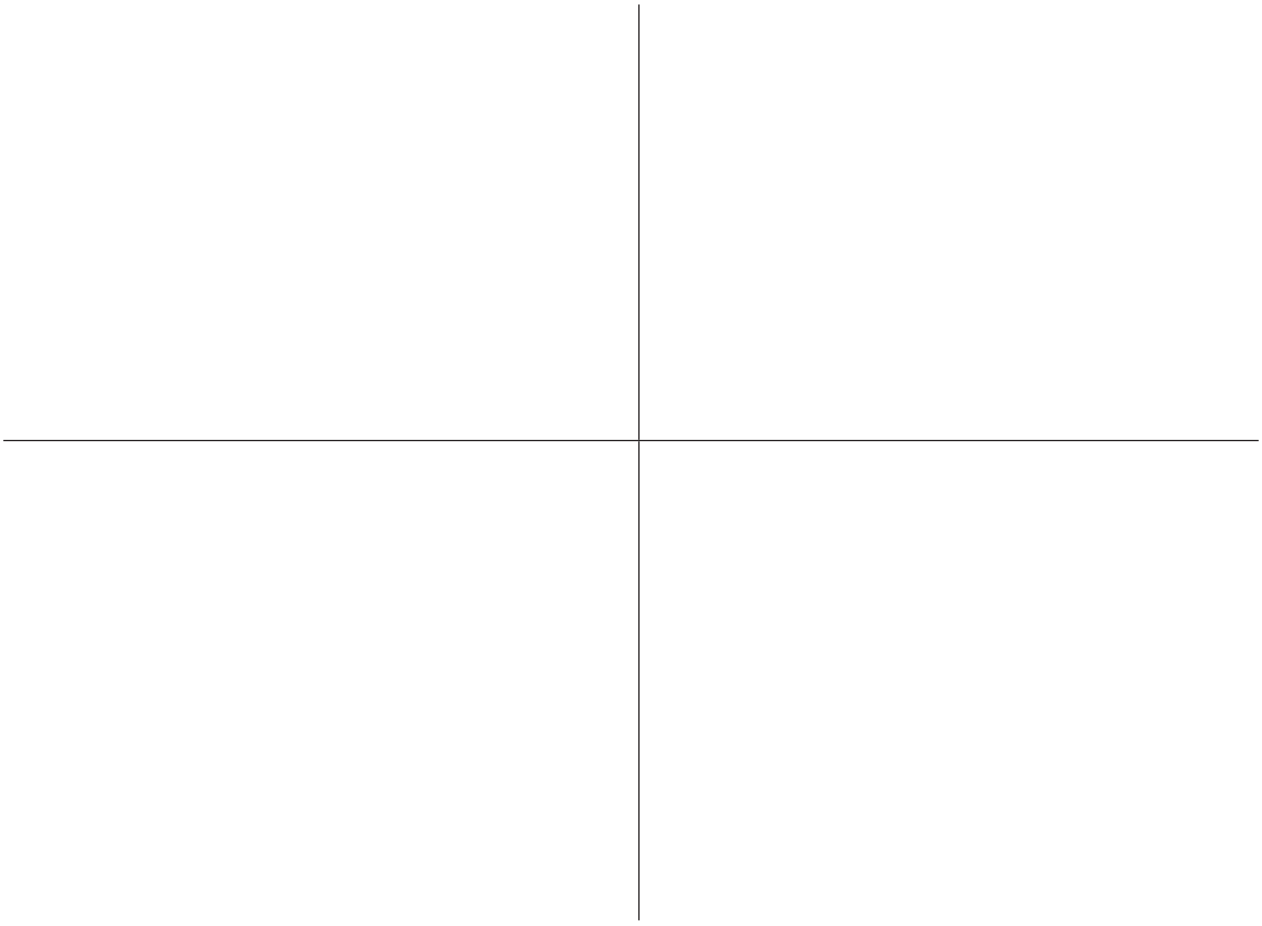
Two: _____

(b) The pH of the solution was measured and found to be less than seven. Based on this observation, state which of the hydrolysis equations has the higher equilibrium constant. Use your understanding of equilibrium concepts to explain your choice fully. (4 marks)

See next page

Question 32 **(8 marks)**

(a) Draw a line on the axis below to show how the volume of an ideal gas varies with temperature. Show clearly where your line intersects each axis. Label your axes and show an approximate scale and unit on your temperature axis. (5 marks)



(b) Label absolute zero on your plot above. (1 mark)

(c) Apply your understanding of Kinetic Theory to explain the concept of absolute zero. (2 marks)

See next page

Question 33 **(9 marks)**

For each of the following pairs of substances, describe a chemical test that may be used to distinguish between them. Give the observation of the test for each of the substances. Assume the concentration of solutions is 0.1 mol L^{-1}.

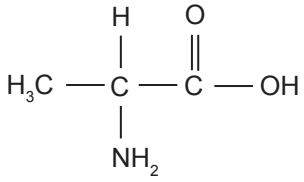
Substance 1	Silver nitrate solution	Magnesium chloride solution	Zinc sulfate solution
Substance 2	Lead(II) nitrate solution	Tin(II) chloride solution	Sodium sulfate solution
Chemical test			
Observation with Substance 1			
Observation with Substance 2			

See next page

Question 34 **(8 marks)**

(a) The chemical formula of the α-amino acid glycine is $C_2H_5NO_2$. Draw the structure of glycine, showing all atoms. (1 mark)

(b) The structure for the α-amino acid alanine is given below.



Give the structure for alanine under acidic, neutral and basic conditions by completing the table below. (3 marks)

pH	Structure of alanine
acidic	
neutral	
basic	

See next page

Question 34 (continued)

(c) When crystallised from a neutral solution, alanine exists as a white crystalline solid. The solid has a melting point of 258 °C. This contrasts with a melting point of -47 °C for 2-methylpropanoic acid (molar mass 87 g mol^{-1}), a molecule of similar size to alanine. With reference to the appropriate structure in (b), explain why alanine has such a high melting point. (4 marks)

Question 35 **(7 marks)**

A white solid is analysed and found to have the empirical formula CHO and a molar mass of 116 g mol^{-1}.

(a) Determine the molecular formula of the compound. Justify your answer. (2 marks)

See next page

(b) Two tests were conducted on the white solid, as shown in the table below. Complete the table by drawing a possible functional group that is consistent with the finding of each of the tests. (2 marks)

Test	Observation	Possible functional group
Water solubility	788 g L^{-1}	
Add to bromine water	Bromine water decolourises rapidly	

(c) A further 2.32 g sample of the white solid was analysed and shown to release 0.0400 mol of H^+ ions. Use this information and your answers to (a) and (b) to determine the structural formula of the white solid, and draw it in the box below. Show **all** atoms in your structure.

(3 marks)

See next page

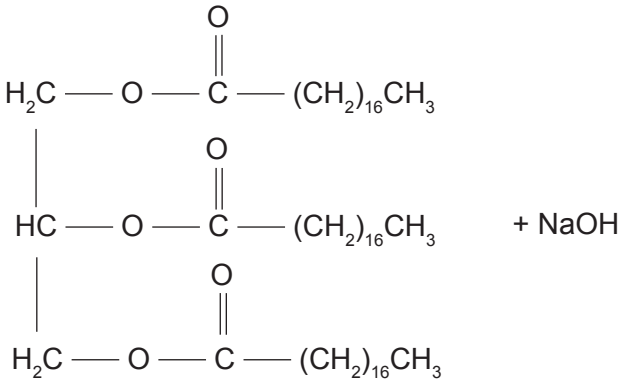
Question 36 **(6 marks)**

Draw the structure in the box provided and name the organic product(s) for each of the following reactions. Include **all** H atoms in your structures.

(a) $CH_3CH_2CHCHCH_3 + Br_2$ (2 marks)

Name: _____

(b) Triglyceride of stearic acid esters heated with sodium hydroxide (4 marks)



Name: _____

Name: _____

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** significant figures.

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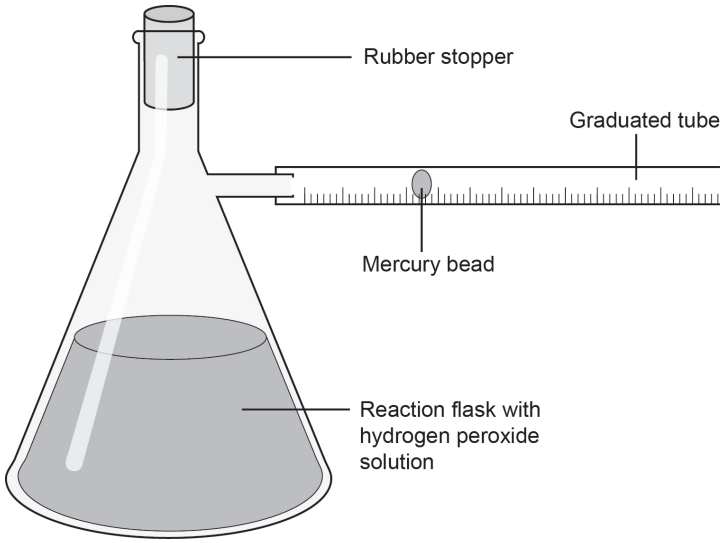
Suggested working time: 70 minutes.

Question 37 **(8 marks)**

Hydrogen peroxide can be decomposed, as shown in the equation below, by a range of catalysts, including enzymes.

$$2\ H_2O_2(aq) \rightarrow 2\ H_2O(\ell) + O_2(g)$$

A researcher set out to determine the effect of enzymes from different foods on the rate of decomposition of hydrogen peroxide. She added equal masses of liver, potato, capsicum and celery (each of which has an enzyme that decomposes hydrogen peroxide) to separate solutions of hydrogen peroxide. She then monitored the decomposition of hydrogen peroxide using the experimental apparatus shown in the diagram below. As the hydrogen peroxide decomposed the bead of mercury moved along the graduated tube, which was open to the atmosphere.



(a) What was being measured by the movement of the mercury bead? (1 mark)

See next page

Question 37 (continued)

(b) What other quantity needed to be measured to determine the rate of decomposition? (1 mark)

(c) List **three** variables that needed to be controlled in this experiment. (3 marks)

	Variable
One	
Two	
Three	

(d) In this experiment, the rate of reaction was measured by the rate of formation of oxygen. What other parameter in the system changes as the reaction proceeded? (1 mark)

(e) State the role of a catalyst in a chemical reaction and explain how its effect is achieved. (2 marks)

See next page

Question 38 **(18 marks)**

Ilmenite, a titanium-iron oxide mineral, is used to produce titanium dioxide and metallic titanium. The ilmenite is first reacted with sulfuric acid to convert iron(II) oxide to iron(II) sulfate according to the equation below.

Equation 1: $FeO(s) + H_2SO_4(aq) \rightarrow FeSO_4(aq) + H_2O(\ell)$

The iron(II) sulfate is crystallised and filtered off to give synthetic rutile which still contains some iron combined with the titanium. This synthetic rutile is treated with carbon and chlorine gas to give titanium tetrachloride, as shown in the following equation.

Equation 2: $2\ FeTiO_3(s) + 7\ C\ell_2(g) + 6\ C(s) \rightarrow 2\ TiC\ell_4(\ell) + 2\ FeC\ell_3(s) + 6\ CO(g)$

(a) Given that the titanium remains in the +4 oxidation state throughout the reaction in Equation 2, identify the following. (2 marks)

Substance/s oxidised in Equation 2

Substance/s reduced in Equation 2

The titanium tetrachloride from Equation 2 can be reacted with oxygen gas to produce titanium dioxide and chlorine gas as shown in Equation 3.

Equation 3: $TiC\ell_4(\ell) + O_2(g) \rightarrow TiO_2(s) + 2\ C\ell_2(g)$

(b) Determine the volume of chlorine gas at STP needed in Equation 2 to produce 1.00×10^3 kg of titanium dioxide in Equation 3. (4 marks)

See next page

Question 38 (continued)

(c) The chlorine gas produced in Equation 3 is recycled for use in Equation 2. If Equation 2 is 78% efficient, what **additional** volume of chlorine gas (at STP) needs to be supplied for Equation 2 for the production of 1.00×10^3 kg of titanium dioxide? Assume Equation 3 is 100% efficient. (4 marks)

The titanium tetrachloride can be reduced to metallic titanium by reaction with liquid magnesium metal in a stainless steel vessel at 1200 °C. As titanium tetrachloride is very reactive, oxygen gas and water are excluded from the vessel during the process and the reaction occurs in an atmosphere of argon gas.

(d) Write the balanced equation for the production of metallic titanium from the titanium tetrachloride. (2 marks)

(e) When $TiC\ell_4$ reacts with H_2O, one product is $HC\ell(g)$. Write the balanced equation for the reaction between $TiC\ell_4$ and H_2O given that the oxidation state of Ti does not change. (2 marks)

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(f) Use your understanding of atomic structure to compare and explain why argon and other Group 18 elements are generally unreactive, while sodium and other Group 1 elements are very reactive. (4 marks)

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Question 39 **(11 marks)**

Most food labels list the amount of protein in the food. Most of the nitrogen present in food is contained in the protein, so the quantity of protein in a food is determined from its nitrogen content. The standard approach to determining the amount of nitrogen in a sample is the Kjeldahl method, which consists of three steps:

1. A sample of food is heated in boiling sulfuric acid, which leads to ammonium sulfate among other products:

   Food sample + $H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq) + CO_2(g) + SO_2(g) + H_2O(g)$

   The ammonium ions contain the nitrogen that was initially present in the sample.

2. The ammonium ions are then converted into ammonia gas by adding sodium hydroxide to the solution of ammonium sulfate:

   $(NH_4)_2SO_4(aq) + 2\ NaOH(aq) \rightarrow Na_2SO_4(aq) + 2\ H_2O(\ell) + 2\ NH_3(g)$

3. The ammonia gas goes inside a condenser and ends up in a flask that contains a solution of boric acid. The ammonia is neutralised by the boric acid, as follows:

   $B(OH)_3(aq) + H_2O(\ell) + NH_3(g) \rightarrow NH_4^+(aq) + B(OH)_4^-(aq)$

   When all the ammonia has reacted with the boric acid, the quantity of borate ions ($B(OH)_4^-$) is determined by titration with a strong acid such as hydrochloric acid.

   $B(OH)_4^-(aq) + H^+(aq) \rightarrow B(OH)_3(aq) + H_2O(\ell)$

The protein content of the food is then calculated by multiplying the amount of nitrogen by a conversion factor appropriate to the food class being analysed. The conversion factor for milk and milk products is 6.38: that is, the mass of nitrogen is multiplied by a factor of 6.38 to get the mass of protein.

An analytical chemist treated a 5.235 g sample of a powdered milk product as described above to determine its protein content. The borate solution from Step 3 was titrated with a standard 0.752 mol L^{-1} hydrochloric acid solution and the volume of acid used in the titration was 25.78 mL.

(a) Calculate the number of moles of ammonium ions formed from the treatment of the milk powder sample (Step 1). (4 marks)

See next page

(b) What was the mass of nitrogen in the sample? Express your answer to **three** significant figures. (3 marks)

(c) Calculate the mass of protein in the powdered milk product. (1 mark)

(d) Food labels usually give the protein content as the mass in a typical serving size. If the typical serving size for this product was 25 g, what mass of protein would be consumed in a single serving? (2 marks)

(e) Suggest what the chemist might do to increase the reliability of the value of the protein content he found for the milk product. (1 mark)

See next page

Question 40 **(13 marks)**

Monomethyl hydrazine is a commonly used rocket fuel. It has the formula $CH_3(NH)NH_2$, and is often used in combination with dinitrogen tetroxide, N_2O_4, as oxidant. The reaction between monomethyl hydrazine and dinitrogen tetroxide is shown below.

$$4\ CH_3(NH)NH_2(g) + 5\ N_2O_4(g) \rightarrow 12\ H_2O(g) + 9\ N_2(g) + 4\ CO_2(g) + 4742\ kJ$$

At lift-off, Space Shuttle Star Truck carries 10.1 tonnes of $CH_3(NH)NH_2$ and 16.0 tonnes of slightly impure N_2O_4 in its external tanks.

An anticorrosive agent is often added to the oxidant mix. In the case of Star Truck, a solution of HF is added to the N_2O_4 so that the final 16.0 tonnes of oxidant mixture contains 1.50% H_2O by mass and 0.600% HF by mass.

(a) Determine which is the limiting reagent in the combustion reaction. Show your reasoning. (6 marks)

See next page

(b) Determine the total volume of gas produced from the combustion of the entire propellant mixture when measured at STP. (3 marks)

(c) The combustion chamber of Star Truck is at very high pressure and temperature to generate thrust and allow lift-off as the exhaust gases are expelled. At full thrust, the chamber is at a pressure of 2.03×10^4 kPa and temperature 3.30×10^3 °C. The chamber is designed to hold, at any one time, 0.05% by volume of the total gas produced. Determine the volume of the combustion chamber. (4 marks)

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Question 41 **(18 marks)**

Lead-acid storage batteries use Pb and PbO_2 electrodes. Pb is the reducing agent, while PbO_2 is the oxidising agent. Sulfuric acid solution is used as the electrolyte.

(a) The overall battery reaction during discharge is given below. Write and balance the anode and cathode reactions for the lead-acid storage battery. (2 marks)

Anode reaction	
Cathode reaction	
Overall reaction	$Pb(s) + PbO_2(s) + 4\ H^+(aq) + 2\ SO_4^{2-}(aq) \rightarrow 2\ PbSO_4(s) + 2\ H_2O(\ell)$

(b) Draw a schematic diagram of the lead-acid battery showing the two half-cells. Label the anode, cathode and salt bridge, and indicate the direction of electron flow with an arrow. (4 marks)

(c) (i) With reference to the 'electrical potential' of a galvanic cell, describe how the lead-acid storage battery produces current. (2 marks)

(ii) What determines the magnitude of the electrical potential of a cell? (1 mark)

See next page

(d) (i) Determine the number of moles of $H^+(aq)$ in a lead-acid battery that contains 4.50 L of 3.55 mol L^{-1} sulfuric acid solution. (1 mark)

(ii) Use the overall battery equation to determine the number of moles of $H^+(aq)$ consumed when discharge of this battery forms 138.1 g of $PbSO_4(s)$. The molar mass of $PbSO_4$ is 303.26 g mol^{-1}. (2 marks)

(iii) Use your answers to (i) and (ii) to determine the concentration of $H^+(aq)$ in the electrolyte in the discharged battery. Assume that the electrolyte volume remains constant, and ignore any changes due to the formation of water. (2 marks)

(iv) Use your answers to (i) and (iii) to show that when this battery discharges as described above, the change in pH of the electrolyte solution is negligible. Note that in any acid solution whose $H^+(aq)$ concentration is greater than 1 mol L^{-1}, the pH is negative. (3 marks)

See next page

Question 41 (continued)

(e) A flat (fully discharged) lead-acid battery can be 'jump started' by connecting it to a battery in a car whose engine is running. The current forced through the battery in this way causes the formation of a mixture of hydrogen and oxygen gas through the hydrolysis of water. State why the formation of the hydrogen and oxygen gas mixture may be dangerous. (1 mark)

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Question 42 **(12 marks)**

Using examples, describe ‘condensation’ and ‘addition polymerisation’.

Your answer should include:

- an explanation of the term ‘polymer’
- the structure and name of an example of each polymer type
- structures of starting materials for the production of each example of a polymer type
- polymerisation reactions.

End of questions

Spare answer page

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