

## Semester Two Examination, 2014

### Question/Answer Booklet

# CHEMISTRY

## Stage 3

Student Number:      In figures

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In words

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### Time allowed for this paper

Reading time before commencing work:

ten minutes

Working time for paper:

three hours

### Material 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.

## 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	50	25
Section Two: Short answer	8	8	60	70	35
Section Three: Extended answer	5	5	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 2014*. 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 question(s) 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.

**Section One: Multiple-choice****25% (50 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.

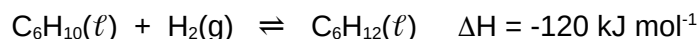
Suggested working time: 50 minutes.

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1. Which of the following statements about elements found in Group 17 of the periodic table is **false**?
  - (a) They have seven electrons in their valence shells.
  - (b) The oxidising strength of the elements increases down the group.
  - (c) The melting points of the elements increase down the group.
  - (d) They react with metals in Group 2 to form solids that are poor conductors of electricity.
  
2. Which of the following covalent group 15 hydrides would be expected to have the **greatest** solubility in methanol?
  - (a)  $\text{NH}_3$
  - (b)  $\text{PH}_3$
  - (c)  $\text{AsH}_3$
  - (d)  $\text{SbH}_3$
  
3. Which of the following statements **best** explains why the carbon disulfide molecule ( $\text{CS}_2$ ) is non-polar?
  - (a) Carbon and sulfur have very similar electronegativities, meaning that the carbon-sulfur bond has virtually no polarity.
  - (b) The small size of a carbon atom makes its electron cloud difficult to polarise.
  - (c) There are four pairs of electrons around the carbon atom.
  - (d) The shape of the molecule causes the polarity of the bonds to cancel out.

4. Chlorine and hydrogen chloride melt at  $-101^{\circ}\text{C}$  and  $-115^{\circ}\text{C}$  respectively. Which of the following statements concerning chlorine and hydrogen chloride is **false**?
- (a) The dispersion forces between chlorine molecules are stronger than those between hydrogen chloride molecules since chlorine has more electrons.
  - (b) Only dispersion forces are broken when melting chlorine, whilst dispersion forces and dipole-dipole forces are broken when hydrogen chloride melts.
  - (c) More energy would be absorbed when 1 mole of hydrogen chloride is melted at  $-115^{\circ}\text{C}$  than when 1 mole of chlorine is melted at  $-101^{\circ}\text{C}$ .
  - (d) The strength of the covalent bonds in the molecules does not play a significant part in determining these melting points.
5. Which of the following mixtures of aqueous  $1\text{ mol L}^{-1}$  solutions would be significantly different in appearance from the other three?
- (a) Copper sulfate, barium nitrate, sodium ethanoate
  - (b) Copper nitrate, barium hydroxide, ammonium chloride
  - (c) Copper chloride, potassium sulfate, lead nitrate
  - (d) Copper ethanoate, silver nitrate, magnesium chloride
6. Which of the following statements about ionisation energies is correct?
- I. An element's first ionisation energy will always be lower than its second
  - II. The first ionisation energy of sodium is lower than that of potassium
  - III. Successive ionisation energies can be used to determine the number of valence electrons in an atom
  - IV. Ionisation energies are always endothermic
- (a) I and III only
  - (b) I, II and IV only
  - (c) I, III and IV only
  - (d) I, II, III and IV
7. Tarquinn dissolved  $0.0100\text{ g}$  of sodium chloride in  $750\text{ mL}$  of distilled water. What is the concentration of chloride ions in the resulting solution, if  $1\text{ millilitre}$  of solution weighs  $1\text{ g}$ ?
- (a)  $1.33 \times 10^{-2}\text{ ppm}$
  - (b)  $13.3\text{ ppm}$
  - (c)  $8.09 \times 10^{-3}\text{ ppm}$
  - (d)  $8.09\text{ ppm}$

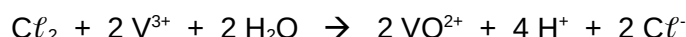
8. Consider the following reaction.



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

- (a) Adding a catalyst would increase the proportion of particles with enough energy to react.
  - (b) The enthalpy of the products is higher than that of the reactants
  - (c) Increasing the temperature would lower the activation energy
  - (d) It is exothermic in the reverse direction
9. Which of the following solutions could **not** be used to oxidise a  $1.00 \text{ mol L}^{-1}$  aqueous solution of potassium iodide?
- (a) Acidified  $1.00 \text{ mol L}^{-1} \text{H}_2\text{O}_2(\text{aq})$
  - (b) Bromine water
  - (c)  $1.00 \text{ mol L}^{-1} \text{HCl}(\text{aq})$
  - (d)  $1.00 \text{ mol L}^{-1} \text{Fe}_2(\text{SO}_4)_3(\text{aq})$
10. Which of the following equations represents a process in which a substance is simultaneously oxidised and reduced?
- (a)  $2 \text{SO}_3^{2-}(\text{aq}) + \text{I}_2(\text{aq}) \rightarrow \text{SO}_4^{2-}(\text{aq}) + 2 \text{I}^-(\text{aq})$
  - (b)  $3 \text{NO}_2(\text{g}) + \text{H}_2\text{O}(\ell) \rightarrow 2 \text{H}^+(\text{aq}) + 2 \text{NO}_3^-(\text{aq}) + \text{NO}(\text{g})$
  - (c)  $2 \text{CrO}_4^{2-}(\text{aq}) + 2 \text{H}^+(\text{aq}) \rightarrow \text{Cr}_2\text{O}_7^{2-}(\text{aq}) + \text{H}_2\text{O}(\ell)$
  - (d)  $5 \text{H}_2\text{O}_2(\text{aq}) + 2 \text{MnO}_4^-(\text{aq}) + 6 \text{H}^+(\text{aq}) \rightarrow 5 \text{O}_2(\text{g}) + 2 \text{Mn}^{2+}(\text{aq}) + 8 \text{H}_2\text{O}(\ell)$

11. Consider the following reaction, taking place in an electrochemical cell.



Which of the following equations correctly represents the process taking place at the anode?

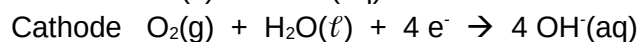
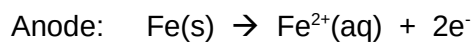
- (a)  $\text{Cl}_2 + 2 \text{e}^- \rightarrow 2 \text{Cl}^-$
- (b)  $2 \text{Cl}^- \rightarrow \text{Cl}_2 + 2 \text{e}^-$
- (c)  $2 \text{V}^{3+} \rightarrow 2 \text{V}^{4+} + 2 \text{e}^-$
- (d)  $\text{V}^{3+} + \text{H}_2\text{O} \rightarrow \text{VO}^{2+} + 2 \text{H}^+ + 2 \text{e}^-$

12. Which of the following substances can act as a reducing agent?

- I. Ag(s)
- II. FeSO<sub>4</sub>(aq)
- III. KMnO<sub>4</sub>(aq)
- IV. H<sub>2</sub>O<sub>2</sub>(aq)

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

13. The anode and cathode processes involved in the rusting of iron can be represented using the following half equations.



Which of the following statements about the rusting of iron is **false**?

- (a) Rusting is a process in which oxygen is reduced.
- (b) Iron(II) ions act as the reducing agent.
- (c) Two moles of iron are needed to react with one mole of water in this process.
- (d) The reaction would have a positive  $E^{\circ}$ .

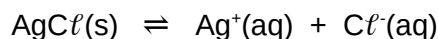
14. A 1 mol L<sup>-1</sup> aqueous solution is found to have the following properties.

- It is a good conductor of electricity
- It has a pH above 7
- It gives no visible reaction with a 1 mol L<sup>-1</sup> solution of sulfuric acid

Which of the following is the most likely identity of the solution?

- (a) NH<sub>3</sub>(aq)
- (b) Ba(OH)<sub>2</sub>(aq)
- (c) KCl(aq)
- (d) NaCH<sub>3</sub>COO(aq)

15. When a saturated solution of silver chloride is made by dissolving an excess of solid silver chloride in distilled water at 25°C, the following equilibrium is established.

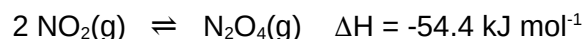


Which of the following statements is **false**?

- (a) Addition of a saturated solution of sodium chloride would cause the equilibrium constant,  $K$ , to increase.
- (b) The equilibrium constant for the reaction would be expected to have a value of less than one.
- (c) Heating the mixture would increase the rate of the backward reaction.
- (d) Addition of water to the mixture would cause a decrease in the mass of  $\text{AgCl(s)}$ .

**Questions 16 and 17 refer to the information below.**

When a sample of nitrogen dioxide is placed in a sealed vessel, the colourless gas dinitrogen tetroxide is formed according to the following equation.



16. Which of the following observations would be made once the mixture had established a new equilibrium if the volume of the vessel were reduced?
- (a) The mixture would appear to fade in colour and its temperature would rise.
  - (b) The mixture would appear to intensify in colour, and its temperature would rise.
  - (c) The mixture would appear to fade in colour, and its temperature would fall.
  - (d) The mixture would appear to intensify in colour, and its temperature would fall.
17. Which of the following changes would cause a **decrease** in the equilibrium concentration of nitrogen dioxide?
- (a) Addition of a catalyst.
  - (b) Addition of a small amount of neon gas at constant volume.
  - (c) Increasing the temperature of the vessel.
  - (d) Removal of a small amount of the mixture of gases at constant volume.

18. What would be the pH of a mixture formed by mixing 100 mL of distilled water with 50 mL of an aqueous  $0.010 \text{ mol L}^{-1}$  solution of nitric acid?
- (a) 1.97  
(b) 2.01  
(c) 2.48  
(d) 3.06
19. Measured with a pH probe, the pH of a solution was observed to change from 9 to 12. Which of the following statements is correct?
- (a) The hydroxide ion concentration increased by a factor of 3.  
(b) The hydroxide ion concentration increased by a factor of 1000.  
(c) The hydroxide ion concentration decreased by a factor of 3.  
(d) The hydroxide ion concentration decreased by a factor of 1000.
20. Bromothymol blue produces the colours shown in the following table when placed in solutions of known pH.

pH	Colour
6	Yellow
7	Yellow
8	Green
9	Blue

- When mixed with a few drops of bromothymol blue, which of the following mixtures of  $0.01 \text{ mol L}^{-1}$  solutions would be **most** likely to produce a blue colour?
- (a) 10 mL of  $\text{Ba(OH)}_2(\text{aq})$  and 10 mL of  $\text{HCl}(\text{aq})$   
(b) 10 mL of  $\text{NaOH}(\text{aq})$  and 10 mL of  $\text{H}_2\text{SO}_4(\text{aq})$   
(c) 10 mL of  $\text{KOH}(\text{aq})$  and 10 mL of  $\text{CH}_3\text{COOH}(\text{aq})$   
(d) 10 mL of  $\text{NH}_3(\text{aq})$  and 10 mL of  $\text{HNO}_3(\text{aq})$
21. Which of the following could **best** be described as a concentrated solution of a strong monoprotic acid?
- (a) Hydrochloric acid with a pH of 2.2  
(b) Acetic acid with a pH of 3.8  
(c) Sulfuric acid with a pH of 0.9  
(d) Nitric acid with a pH of 1.9



22. Which of the following substances would likely have the **lowest** solubility in water?

- (a) Pentanoic acid
- (b) Propan-2-ol
- (c) Hexan-3-one
- (d) Butanal

23. Which of the following molecules can exist as a pair of geometric isomers?

- I. pent-2-ene
- II. 2-methylbut-2-ene
- III. hex-1-ene
- IV. 1,4-dibromo-2,3-dimethylbut-2-ene

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

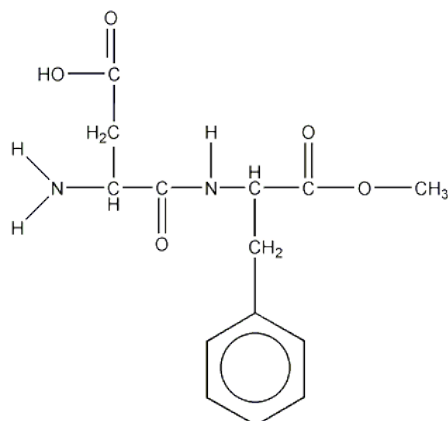
24. An unknown colourless liquid was subjected to a number of tests, the observations of which are shown in the table below.

Test	Observation
The liquid was added to a solution of sodium carbonate	The liquids mixed, but no reaction was observed
The liquid was shaken with bromine water	The bromine water went from orange to colourless
The liquid was mixed with sulfuric acid and a solution of sodium dichromate	The sodium dichromate turned from orange to green

Which of the following represents a possible structure for the unknown liquid?

- (a)  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$
- (b)  $\text{CH}_2(\text{OH})\text{CH}_2\text{CHCHCH}_2\text{COOH}$
- (c)  $(\text{CH}_3)_2\text{C}(\text{OH})\text{CH}_2\text{CHCH}_2$
- (d)  $\text{CH}_3\text{CH}_2\text{CHCHCH}_2\text{CHO}$

25. The sweetener aspartame has the structural formula shown below.



Which of the following statements about aspartame is **false**?

- (a) It could be classified as a primary amine.
- (b) It can react with ammonia in an acid-base reaction.
- (c) It can react with sodium hydroxide in a hydrolysis reaction.
- (d) Each of its nitrogen atoms can form hydrogen bonds with other aspartame molecules.

**End of section one**

**See next page**

## Section Two: Short answer

35% (70 Marks)

This section has **nine (9)** questions. Answer **all** questions. Write your answers in the space 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.

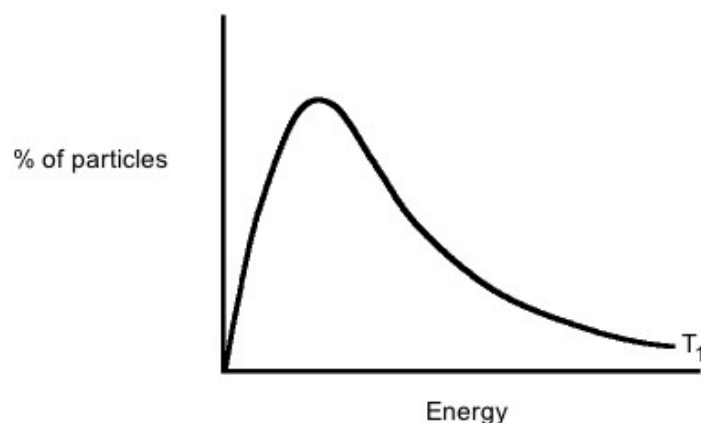
- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s)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

Suggested working time: 60 minutes.

## Question 26

(5 marks)

The graph below shows the distribution of energies amongst particles in a sample of gas at a particular temperature,  $T_1$ .



- (a) Add a line to the graph to show how the distribution would be expected to change if the temperature was raised to some new temperature,  $T_2$ . (2 marks)
- (b) Use the graph, and your understanding of collision theory, to explain why relatively small increases in temperature can lead to quite large increases in the rates of chemical reactions. (3 marks)

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## Question 27

(10 marks)

By referring to the structure and/or bonding present, account for the following:

- (a) Graphite has an extremely high melting point ( $3727^{\circ}\text{C}$ ), but is one of the softest minerals known, and is a good conductor of electricity in the solid state. (4 marks)

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- (b) When hit with a hammer, solid magnesium will dent but not break, whilst solid magnesium chloride will fracture. (4 marks)

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- (c) Moving across the period 3 elements from left to right, we observe a gradual decrease in atomic radius. (2 marks)

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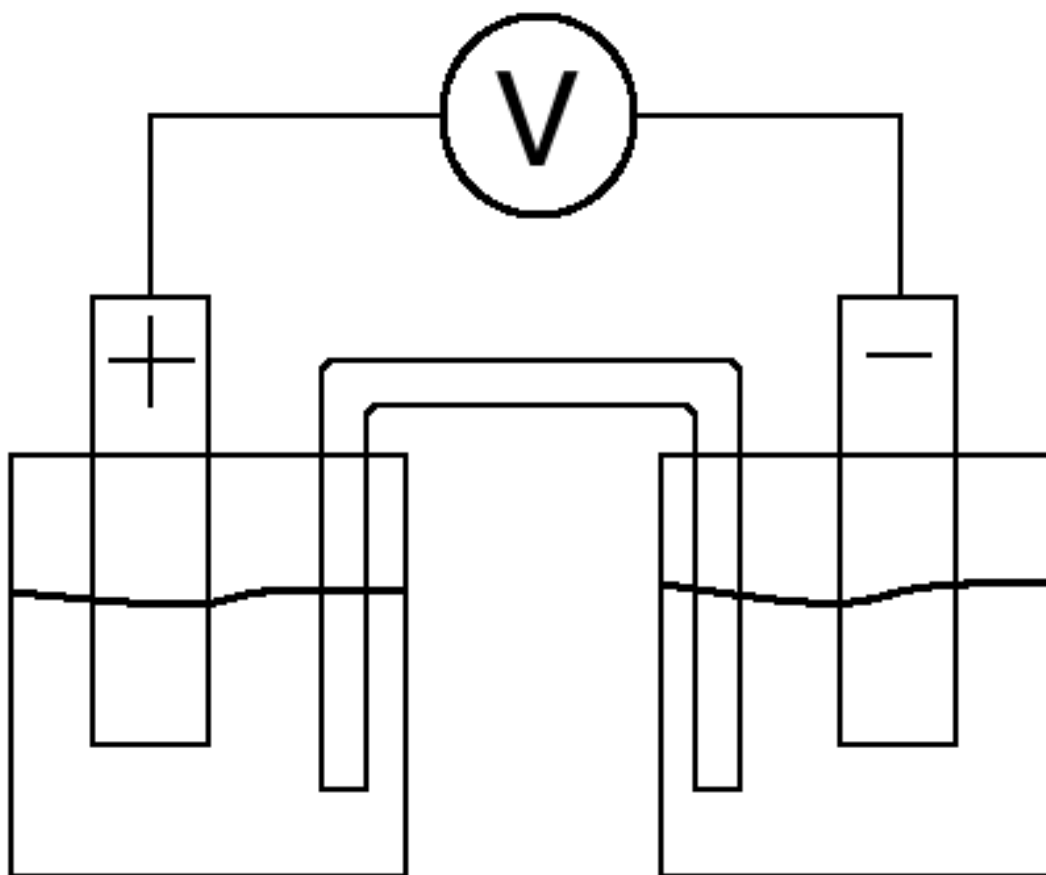
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## Question 28

(11 marks)

The diagram below shows an electrochemical cell made using a nickel rod dipped in a  $1.00 \text{ mol L}^{-1}$  solution of nickel sulfate at one electrode and a magnesium rod dipped in a  $1.00 \text{ mol L}^{-1}$  solution of magnesium sulfate at the other. The relative charge of the electrodes is indicated on the diagram.



a) Label the diagram to show the following:

- Which metal is at each electrode
- The direction of electron flow in the external circuit
- The direction of ion flow in the salt bridge
- The anode and cathode

(4 marks)

A half cell can be constructed in which there is an equilibrium consisting of solid manganese dioxide ( $\text{MnO}_2$ ) and  $\text{Mn}^{2+}(\text{aq})$  ions. When connected to a standard hydrogen electrode, this half cell is found to have a reduction potential of +1.29 V.

- b) State the significance of the sign of this reduction potential in relation to the standard hydrogen electrode. (1 mark)

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Another electrochemical cell was made using an electrode made of a copper rod dipped in a  $1.00 \text{ mol L}^{-1}$  solution of tin(II) sulfate, and connected to the  $\text{MnO}_2/\text{Mn}^{2+}$  half cell.

- c) In the table below, write balanced half equations to show the reactions taking place in each half cell. (3 marks)

Half cell	Half equation
$\text{Sn(s)}/\text{SnSO}_4(\text{aq})$	
$\text{MnO}_2(\text{s})/\text{Mn}^{2+}(\text{aq})$	

- d) Calculate the cell potential,  $E^\circ$ , that would be expected for this electrochemical cell. (1 mark)

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- e) Give TWO reasons why the actual measured cell potential might deviate from the value calculated in d). (2 marks)

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## Question 29

(9 marks)

For each species listed in the table below, draw the Lewis structure, representing all valence shell electron pairs either as : or as — **and** state or sketch the shape of the species.

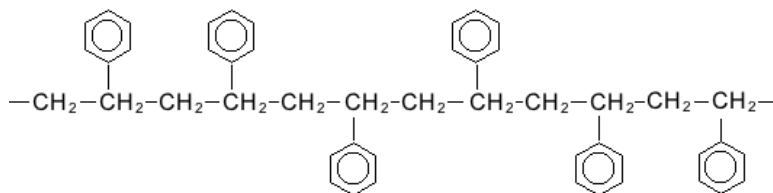
(for example, water  $\text{H}:\ddot{\text{O}}:\text{H}$  or  $\text{H}-\ddot{\text{O}}-\text{H}$  or  $\text{H}-\bar{\text{O}}-\text{H}$  bent)

Species	Lewis structure (showing all valence electrons)	Shape (sketch or name)
Nitrite Ion $\text{NO}_2^-$		
Silicon tetrachloride $\text{SiCl}_4$		
Carbon disulfide $\text{CS}_2$		

## Question 30

(6 marks)

The diagram below shows a section of a polymer widely used in packaging.

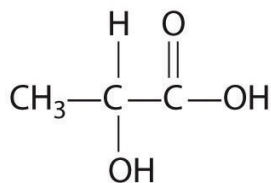


- (a) What is the name given to the type of reaction used to make this polymer? (1 mark)

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- (b) In the space provided below, draw the structure of the monomer used to make this polymer. (2 marks)

The diagram below shows the structure of lactic acid.



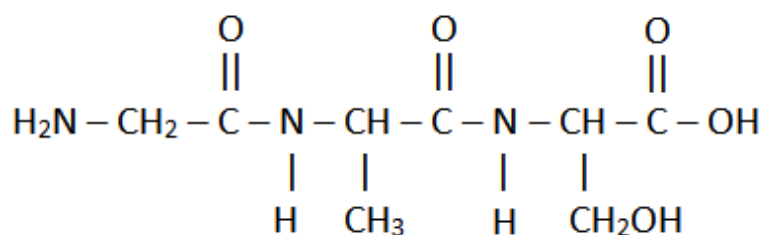
- (c) In the space below, write an equation to show the reaction between THREE lactic acid molecules, making clear the structure of the organic product of the reaction. (3 marks)



## Question 31

(5 marks)

The following diagram shows the structure of a tripeptide formed from the reaction between three different  $\alpha$ -amino acids.



- (a) On the diagram, circle the functional group that would be expected to react with a solution of sodium carbonate. Label this "group A". (1 mark)
- (b) On the diagram, circle the functional group that would be expected to react with a solution of hydrochloric acid. Label this "group B". (1 mark)
- (c) What is the name given to the type of reaction used to produce this peptide from its  $\alpha$ -amino acid monomers? (1 mark)

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- (d) Tripeptides such as these are commonly observed to have a high solubility in water. Use the structure of the tripeptide shown above to explain this observation. (2 mark)

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## Question 32

(8 marks)

The auto-ionisation of ammonia can be represented using the equation below.



- (a) Explain the concept of Bronsted-Lowry conjugate acid-base pairs with reference to this equation. Your answer should identify any conjugate acid-base pairs present. (3 marks)

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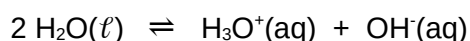
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Water is also capable of auto-ionisation, according to the following equation.



- (b) Given that pure water has a pH of exactly 7 at 25°C and that the forward reaction is endothermic, state and explain what effect heating water above 25°C will have on its pH. (3 marks)

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- (c) Explain why water can always be considered neutral, in spite of the fact that it can have different values of pH. (2 marks)

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## Question 33

(10 marks)

The table below shows the pH of 0.100 mol L<sup>-1</sup> aqueous solutions of three acids.

Acid solution	pH
Ethanoic acid	2.88
Phosphoric acid	1.62
Nitric Acid	1.00

- (a) Use appropriate equations to explain the difference in pH between 0.100 mol L<sup>-1</sup> solutions of ethanoic and nitric acid. (4 marks)

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- (b) Calculate the amount of water that would need to be added to 50 mL of a 0.100 mol L<sup>-1</sup> solution of nitric acid to raise its pH to 1.62. (3 marks)

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Solutions of sodium dihydrogenphosphate (NaH<sub>2</sub>PO<sub>4</sub>) can be prepared by mixing sodium hydroxide with phosphoric acid. These solutions are able to act as buffers.

- (c) Use appropriate equations to show how a solution of sodium dihydrogenphosphate is able to act as a buffer. (3 marks)

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## Question 34

(6 marks)

Complete the table by drawing the structure and giving the IUPAC name of the organic compounds that match each of the following descriptions.

Description	Structure	IUPAC name
A saturated secondary alcohol containing 10 hydrogen atoms		
An ester that is an isomer of pentanoic acid and can react with NaOH(aq) to form ethanol		
A hydrocarbon that could be used to make 1,2-dichloromethylpropane via an addition reaction		

End of section two

See next page

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

This section contains **six (6)** questions. 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.

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.

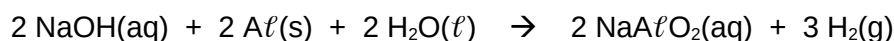
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Suggested working time: 70 minutes.

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**Question 35****(10 marks)**

Aluminium can be considered an unusual metal since it will react with hydroxide ions. When placed in an aqueous solution of sodium hydroxide, aluminium will react to produce a solution of sodium aluminate and bubbles of hydrogen gas. The equation for the reaction is shown below.



A 0.100 g sample of an alloy containing aluminium was reacted with an excess of a solution of sodium hydroxide in order to determine the composition of the alloy. The hydrogen gas was collected over water. When cooled to 20°C, the hydrogen was found to have a partial pressure of 97.9 kPa and to occupy 130 mL.

- (a) Calculate the minimum volume of 0.0100 mol L<sup>-1</sup> sodium hydroxide that would be required to turn all the aluminium in the sample into sodium aluminate. (3 marks)

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- (b) Use the volume of hydrogen collected to calculate the percentage of aluminium in the alloy, assuming any other metals did not react. (4 marks)

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In another experiment, 100 mL of  $0.0120 \text{ mol L}^{-1}$  calcium hydroxide was mixed with a sufficient mass of the alloy to react with exactly half of the hydroxide ions.

- (c) Calculate the pH of the resulting solution, assuming that the products of the reaction have no effect on the pH. (3 marks)

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## Question 36

(17 marks)

In an experiment to determine the molar mass of a weak monoprotic organic acid with the formula  $C_nH_{2n+1}COOH$ , 0.592 g of the acid was placed in an insulated container and  $0.154 \text{ mol L}^{-1}$  barium hydroxide was added in 5 mL portions. A thermometer was used to measure the temperature of the solution after the addition of each portion. The results are shown in the table below.

Volume of $Ba(OH)_2$ (mL)	0	5	10	15	20	25	30	35	40	45
Temperature ( $^{\circ}C$ )	17.1	19.4	21.4	23.1	25.0	25.6	25.1	24.5	23.9	23.3

- (a) Plot the results from the experiment on the graph paper provided below, and use your graph to estimate the volume of barium hydroxide needed to neutralise the acid. (5 marks)



Estimated Volume: \_\_\_\_\_

The experiment was repeated using phenolphthalein as an indicator to judge when the acid had been neutralised. A conical flask was rinsed with the acid, 0.296 g of the acid was placed in the flask, and a few drops of indicator were added. The solution was titrated using  $0.123 \text{ mol L}^{-1}$  barium hydroxide solution from a burette, and 16.3 mL of the alkali was needed to reach equivalence.

- (b) Use the data from the second experiment to calculate the molar mass of the acid and the value of  $n$  in the formula  $\text{C}_n\text{H}_{2n+1}\text{COOH}$ . (6 marks)

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- (c) Identify a source of systematic error in the second experiment, and explain what effect it would have on the calculated value of the molar mass of the acid. (3 marks)

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Phenolphthalein is red in acidic solutions and yellow in basic solutions, and changes colour at a pH of 8.2 – 10.0.

- (d) Use a relevant equation to explain why phenolphthalein was a suitable choice of indicator for this titration. (3 marks)

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**(14 marks)**

Hair dyes often involve chemicals, such as hydrogen peroxide, which lighten the hair, combined with other substances, known as dye couplers, which serve to colour the hair once it has been lightened. One such dye coupler, used to provide yellow-green colours is known as 4-chlororesorcinol. Analysis of 4-chlororesorcinol has shown that it is composed of the elements carbon, hydrogen, oxygen and chlorine only.

In a series of experiments to determine the structure of 4-chlororesorcinol, a 0.725 g sample was combusted in excess oxygen. Upon analysis, the products of combustion were found to contain 1.326 g of carbon dioxide and 0.226 g of water vapour.

A second sample of 4-chlororesorcinol weighing 0.339 g was reacted with sodium metal. The products of this reaction were dissolved in water and the solution mixed with aqueous silver nitrate in order to precipitate the chloride ions. The precipitate was washed and dried, and found to weigh 0.336 g.

- (a) Use the information provided to calculate the empirical formula of 4-chlororesorcinol. (10 marks)

This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

This image shows a blank sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

A further 2.34 g sample of 4-chlororesorcinol was heated in an inert atmosphere. The vapour was found to occupy 560 mL at 150°C and 101.3 kPa.

- (b) Use this information to calculate the molecular formula of 4-chlororesorcinol. (3 marks)

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- (c) Explain what effect there would have been on the calculated amount of chlorine in the compound if the precipitate had not been washed and dried before weighing. (1 mark)

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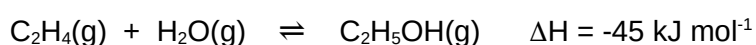
## Question 38

(14 marks)

Ethanol is an essential feedstock to the chemical industry, but its most common use today is as a fuel and a fuel additive. As the global supply of fossil fuels has diminished, ethanol has begun to be used as an alternative to petrol in combustion engines, although most cars cannot use pure ethanol without being modified.

Fermentative production, where glucose is turned into ethanol and carbon dioxide in a reaction catalyzed by yeast, is the most popular means of production of fuel ethanol. The glucose it uses is renewable, since it is obtained from crops such as corn and sugar cane.

Another common method of producing ethanol involves the catalytic hydration of ethene. This process is carried out on an industrial scale by mixing ethene (obtained from crude oil) and water vapour, which react according to the following equation:



The reaction is carried out at a temperature of approximately 300°C and a pressure of approximately 70 atm (1 atm = 101.3 kPa) in the presence of a solid acid catalyst (usually phosphoric acid on solid silica). These conditions give a yield of approximately 5% ethanol. The ethanol that forms is removed from the system by cooling the mixture of gases, and any unreacted ethene is pumped back into the reaction vessel.

Using an understanding of collision theory and Le Chatelier's principle where appropriate, discuss the conditions used in the catalytic hydration of ethene. Your answer should address the following points:

- The temperature and pressure at which the reactions are carried out
- The use of a catalyst
- The removal of ethanol from the mixture
- The recycling of the unreacted gases into the system

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## Question 39

(9 marks)

The element phosphorus exists as several allotropes, including diphosphorus, white phosphorus, red phosphorus, violet phosphorus and black phosphorus. White phosphorus will react with dilute solutions of copper(II) sulfate to deposit metallic copper and produce a highly acidic solution.

In an experiment to investigate this reaction, 0.372 g of white phosphorus reacted in an excess of aqueous copper(II) sulfate to produce 1.91 g of copper.

- (a) Use this information to calculate the number of moles of copper deposited for each mole of phosphorus. (2 marks)

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- (b) Use the concept of oxidation numbers to show whether the copper is acting as a reductant or an oxidant in this process. (2 marks)

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- (c) Calculate the change in the oxidation number of phosphorus in the reaction. (3 marks)

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- (d) In the reaction, the phosphorus forms an acid with the formula  $\text{HPO}_x$ . Use your answer to part (c) to determine the value of  $x$ . (2 marks)

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## Question 40

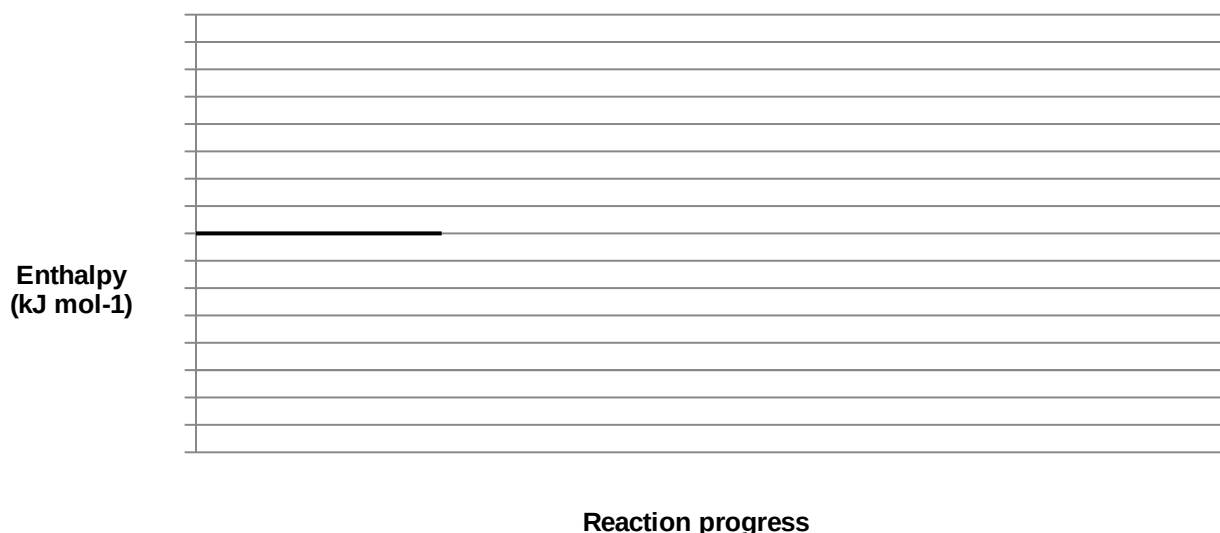
(16 marks)

The enthalpy of combustion of a substance,  $\Delta H_c$ , is defined as the enthalpy change when 1 mole of a substance is burned completely in excess oxygen. The enthalpies of combustion of the first four alkanes are shown in the table below.

Name of alkane	Enthalpy of combustion ( $\text{kJ mol}^{-1}$ )
Methane	-890
Ethane	-1560
Propane	-2220
Butane	-2877

- (a) Write a balanced equation for the complete combustion of methane in excess oxygen. (2 marks)

- (b) Using the axes provided below, sketch a reaction profile for the complete combustion of methane, assuming the activation energy is  $2650 \text{ kJ mol}^{-1}$ . You should ensure that you draw your diagram approximately to scale, and label clearly the reactants, products, the enthalpy change, and the activation energy. (4 marks)





A typical Bunsen burner set on a roaring flame operating in a laboratory at 20°C burns 0.0800 L of natural gas per second, measured at 101.5 kPa. Natural gas is composed of 95% methane, with the other 5% being made up of small amounts of ethane, propane, butane and hydrogen sulfide, as well as some nitrogen and carbon dioxide.

- (c) Calculate the number of moles of methane burnt when a Bunsen burner is used to heat a beaker of water for five minutes. (1 mark)

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A roaring Bunsen flame will burn at approximately 700°C.

- (d) Calculate the volume of the exhaust gases produced at this temperature during the five minutes. You may assume that the pressure of the laboratory is unaffected by the Bunsen burner. (2 marks)

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Alkanes will react with chlorine gas in the presence of bright UV light.

- (e) Give the name of this type of reaction. (1 mark)

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- (f) Give the name of a possible **organic** product formed when propane reacts with chlorine in the presence of bright UV light. (1 mark)

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Another substance commonly found in natural gas is hydrogen sulfide. When this is heated in the presence of oxygen it can also combust, forming an oxide of sulfur in which sulfur has an oxidation number of +4. Water is also formed in the reaction.

- (g) Write a balanced equation for the reaction between hydrogen sulfide and oxygen to form sulfur dioxide and water. (2 marks)

The sulfur dioxide formed in this process is known to cause acid rain when it is released into the Earth's atmosphere.

- (h) With the help of equations, explain how sulfur dioxide is able to cause the acidification of rain water. (3 marks)

**End of questions**

**Question number:** \_\_\_\_\_

[illegible]

**Question number:** \_\_\_\_\_

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