



Western Australian Certificate of Education Examination, 2011

Question/Answer Booklet

CHEMISTRY

Stage 3

Please place your student identification label in this box

Student Number: In figures

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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 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	10	10	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 2011*. 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.

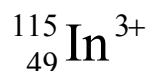
Section One: Multiple-choice

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.

1. Consider the ion below.



Which one of the following lists the number of protons, neutrons and electrons for this ion correctly?

	Protons	Neutrons	Electrons
(a)	115	49	49
(b)	49	66	49
(c)	49	66	52
(d)	49	66	46

Refer to the following table to answer Questions 2 and 3.

The table shows the approximate successive molar ionisation energies (in kJ mol^{-1}) of five elements denoted I to V.

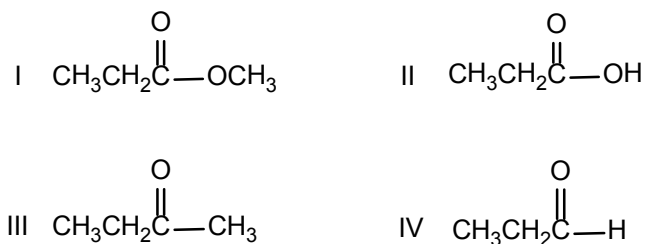
Element	Ionisation energy			
	1st	2nd	3rd	4th
I	502	4570	6919	9550
II	580	1820	2750	11600
III	590	1145	4910	6490
IV	744	1460	7740	10550
V	1250	2300	3820	5160

2. Which two elements are most likely to be Group 2 (alkaline earth) metals?
- (a) I and III
(b) III and IV
(c) II and V
(d) I and V
3. Which element would react with chlorine to form a compound with the general formula ACl_3 , where A represents one of the five elements (I to V) listed in the table above?
- (a) I
(b) II
(c) III
(d) IV

See next page

4. Which of the following statements about the Group 2 metals are true?
- (i) Their first ionisation energy decreases with increasing atomic number.
 - (ii) Two electrons are present in the valence shell of the metal.
 - (iii) Their chemical reactivity increases with increasing atomic number.
 - (iv) Their +2 (positive) ions have noble gas configurations.
 - (v) They are likely to form covalent compounds with Group 17 elements.
- (a) (ii) and (iii) only
 - (b) (iv) and (v) only
 - (c) (i),(ii), (iii) and (iv)
 - (d) (i), (ii), (iii), (iv) and (v)
5. Which one of the following best explains the decrease in atomic radius as the atomic number increases across Period 3 of the Periodic Table?
- (a) increasing nuclear charge
 - (b) decreasing number of neutrons
 - (c) decreasing number of protons
 - (d) the elements becoming more noble gas-like
6. Which one of the following trends occurs as the atomic number increases for the Group 17 elements?
- (a) atomic radii decrease
 - (b) melting points decrease
 - (c) the tendency to gain electrons decreases
 - (d) the elements become more reactive
7. What is the formula of an ionic compound consisting of positive ions with a configuration 2,8 and negative ions with the same configuration?
- (a) LiF
 - (b) MgS
 - (c) NaF
 - (d) KCl

Questions 8 and 9 refer to the compounds shown below.



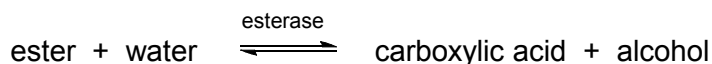
8. Which one of the following lists places these compounds in their correct class?

	I	II	III	IV
(a)	Ester	Aldehyde	Ketone	Carboxylic acid
(b)	Carboxylic acid	Ketone	Aldehyde	Ester
(c)	Ketone	Carboxylic acid	Ester	Aldehyde
(d)	Ester	Carboxylic acid	Ketone	Aldehyde

9. Which of these compounds can be prepared by oxidation of 1-propanol, $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$?

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

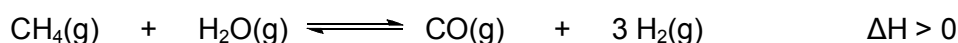
10. An enzyme is a biological catalyst. Esters can be hydrolysed, as represented below by an esterase enzyme.



In the presence of esterase which one of the following statements is true for this process?

- (a) The position of the equilibrium for this reaction is shifted to the right.
 (b) The rate of forward reaction and rate of reverse reaction both increase equally.
 (c) The rate of forward reaction increases more than the rate of reverse reaction.
 (d) The rate of forward reaction increases and rate of reverse reaction decreases.

11. Hydrogen can be produced by the reaction



Which one of the following will increase the equilibrium yield of hydrogen?

- (a) increasing the total pressure of the reaction system
 (b) decreasing the partial pressure of the water vapour
 (c) removing carbon monoxide from the system as it is produced
 (d) decreasing the temperature of the system

12. Which of the properties listed below are characteristic of a gaseous system in dynamic equilibrium?

- (i) The concentrations of reactants are equal to the concentrations of products.
- (ii) The concentrations of reactants and products are constant.
- (iii) The rate of the forward reaction is equal to the rate of the reverse reaction.
- (iv) The pressure of the system is constant.

- (a) (i), (ii) and (iii)
- (b) (i), (ii) and (iv)
- (c) (ii), (iii) and (iv)
- (d) (iii) only

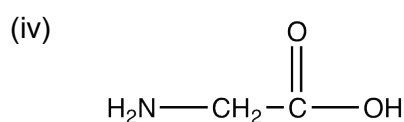
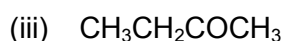
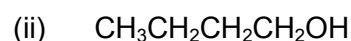
13. In which one of the following will a precipitate be formed when 0.1 mol L^{-1} solutions of the compounds listed are mixed at 25°C ?

- (a) K_2SO_4 , NiCl_2 and NaCl
- (b) BaCl_2 , H_2SO_4 and HNO_3
- (c) $\text{Zn}(\text{NO}_3)_2$, NaBr and H_2SO_4
- (d) K_3PO_4 , $(\text{NH}_4)_2\text{CO}_3$ and CH_3COOH

14. Assuming the substances below dissociate to the same extent, a 500 mL sample of which one of the following 0.01 mol L^{-1} solutions will contain the greatest number of ions?

- (a) $(\text{NH}_4)_2\text{CO}_3$
- (b) $\text{K}_2\text{Cr}_2\text{O}_7$
- (c) $\text{Ca}(\text{OH})_2$
- (d) Na_3PO_4

15. Consider the following substances.



Which one of the following lists the substances in order of **decreasing** solubility in water?

- (a) (i) (iv) (ii) (iii)
- (b) (i) (iii) (ii) (iv)
- (c) (iv) (ii) (iii) (i)
- (d) (ii) (iv) (iii) (i)

16. Which one of the following is the strongest electrolyte?
- (a) NH_4Cl
 (b) H_3PO_4
 (c) H_2O
 (d) CH_3COOH
17. Which one of the following describes the acidity/basicity of a solution of the following compounds when dissolved in distilled water?

	Ammonium chloride	Potassium carbonate	Sodium nitrate	Sodium ethanoate
(a)	acidic	basic	neutral	basic
(b)	acidic	basic	acidic	basic
(c)	basic	acidic	neutral	acidic
(d)	basic	basic	basic	acidic

18. In which one of the following is the reactant in bold reacting as an acid?

- (a) $2\text{Na(s)} + 2\text{H}_2\text{O} \rightarrow 2\text{NaOH} + \text{H}_2$
 (b) $\text{NH}_3 + \text{H}_2\text{O} \rightarrow \text{NH}_4^+ + \text{OH}^-$
 (c) $\text{Fe}(\text{H}_2\text{O})_6^{3+} + \text{H}_2\text{O} \rightarrow \text{Fe}(\text{H}_2\text{O})_5(\text{OH})^{2+} + \text{H}_3\text{O}^+$
 (d) $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3$

19. Which one of the following gives the correct formula for sodium chlorite?

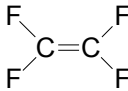
- (a) NaClO
 (b) NaClO_2
 (c) NaClO_3
 (d) NaClO_4

20. Four water samples were found to be contaminated with an arsenic chloride compound. The samples were analysed and the arsenic and chloride content of each sample was reported, as shown below.

Sample	As content (g)	Cl content (g)
(i)	0.68	0.97
(ii)	0.38	0.55
(iii)	0.48	0.68
(iv)	0.41	0.96

Which one of the samples contains a different arsenic chloride contaminant from that in the other three samples?

- (a) (i)
 (b) (ii)
 (c) (iii)
 (d) (iv)

21. How many moles of electrons must be exchanged to oxidise 1 mole of hypophosphorous acid, H_3PO_2 , to phosphoric acid, H_3PO_4 ?
- (a) 2
(b) 3
(c) 4
(d) 5
22. In which one of the following compounds is rhenium (Re) in the highest oxidation state?
- (a) NaReO_4
(b) ReClO
(c) Re_2O_3
(d) ReCl_5
23. Corrosion is a redox process. Which one of the following explains why coating iron with nickel protects the iron from corrosion?
- (a) Nickel accepts electrons from iron.
(b) Iron and nickel form an alloy that is particularly resistant to redox processes.
(c) Nickel is a stronger oxidising agent than iron.
(d) The thin coating of nickel prevents iron from reacting.
24. Which one of the species below is **not** commonly used as a reducing agent?
- (a) $\text{C}_2\text{O}_4^{2-}$
(b) H_2
(c) Cl_2
(d) C
25. Which one of the following is a polar molecule?
- (a) CO
(b) BCl_3
(c) 
(d) CF_4

End of Section One

See next page

Section Two: Short answer

35% (70 Marks)

This section has **10** 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.

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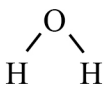
Suggested working time: 60 minutes.

Question 26**(4 marks)**

Complete the table below by drawing the Lewis structures of the molecules listed and either drawing or naming the shape of the molecule.

All valence shell electron pairs should be represented either as : or as — .

The first row has been completed as an example.

Molecule	Lewis structure	Sketch or name of shape
H ₂ O	One of H:Ö:H or H-Ö̈-H or H-Ȫ-H	One of bent, or 
Cl ₂ O		
PCl ₃		

Question 27

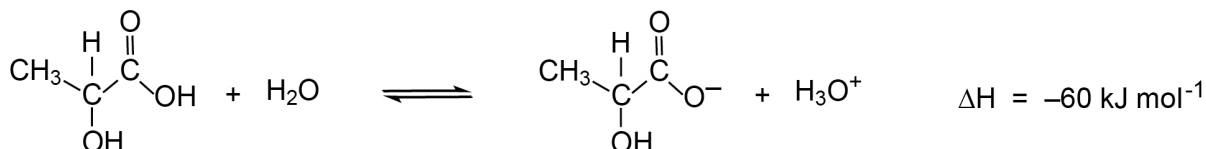
(10 marks)

- (a) Complete the table by writing the formula or drawing the structure for the conjugate base, species X or conjugate acid in the blank spaces as appropriate. Species X is the species that is able to form both a conjugate base and a conjugate acid. (6 marks)

Conjugate base	Species X	Conjugate acid
		CH_3NH_3^+
$\text{C}_2\text{O}_4^{2-}$		

Lactic acid produced by muscles during exercise, is found in many milk products and is used in the brewing of beer. It is also added to a number of canned food items as a buffer.

The equation for the reaction of lactic acid with water is shown below.



The value of the equilibrium constant for the above reaction, at 25°C , is approximately 7.9×10^{-5} .

- (b) State whether the ratio of organic products to organic reactants will be equal to one, less than one (< 1) or greater than one (> 1) for this system at equilibrium at 25°C . (1 mark)
-
- (c) Predict the direction in which the equilibrium will shift immediately after the changes indicated in the table below. Write 'left', 'right' or 'no change'. (3 marks)

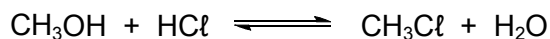
Change	Direction of initial equilibrium shift
Decreasing the temperature	
Adding hydrochloric acid	
Adding sodium hydroxide	

See next page

Question 28

(8 marks)

Chloromethane can be produced industrially by the reaction of methanol and hydrogen chloride at high temperature in the presence of a catalyst. The equation for this reaction is shown below.



The boiling points and melting points for each of the species involved in the reaction are shown below.

Species	Boiling point (°C)	Melting point (°C)
CH ₃ OH	65	-98
HCl	-85	-114
CH ₃ Cl	-24	-98
H ₂ O	100	0

Write the phase, i.e., solid (s), liquid (l) or gas (g), of each species in this system at the temperatures shown in the table below, and predict the effect of an increase in total pressure on this equilibrium at each of the temperatures.

Temperature (°C)	Phase (s, l or g)				Shift in equilibrium (right, left or no change)
	CH ₃ OH	HCl	CH ₃ Cl	H ₂ O	
-50					
40					
70					
110					

Question 29

(4 marks)

Write a relevant equation or equations to explain each of the observations shown in the table below.

Observation	Explanatory equation/s
The pH of a NaHSO ₄ solution is 5	
A solution of Mg(OH) ₂ is basic	
A solution of Na ₂ HPO ₄ is basic, while a solution of KH ₂ PO ₄ is acidic	

See next page

Question 30

(12 marks)

Complete the table below by giving a brief description of a chemical test that could be used to distinguish between the substances listed. List the observations relating to the test for each of Substance 1 and Substance 2.

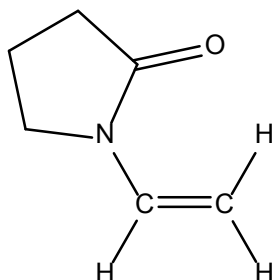
Substances to be distinguished		Description of chemical test	Observation with Substance 1	Observation with Substance 2
Substance 1	Substance 2			
butan-2-ol	2-methylpropan-2-ol			
zinc nitrate solution	zinc sulfate solution			
solid magnesium hydroxide	solid lead sulfate			
methanol	methanal			

See next page

Question 31

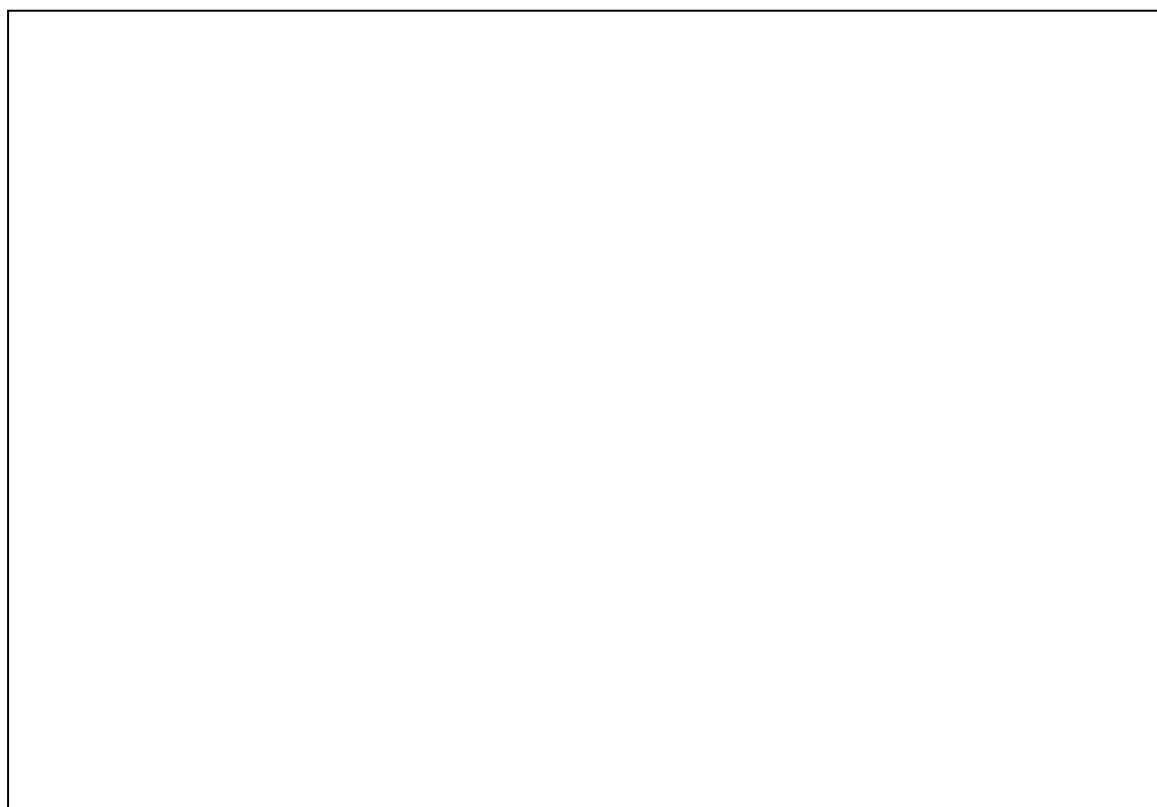
(2 marks)

Polyvinylpyrrolidone is a polymer with a wide range of applications including as a binder in tablets and hair styling agents. It is made from the monomer shown below.



(a) Draw three units in the polymer formed from this monomer.

(1 mark)



(b) What type of polymerisation reaction occurs to form the polymer from the above monomer?

(1 mark)

Question 32

(13 marks)

- (a) Draw the structure for, and write the name of, any five straight chain isomers for the compounds with the molecular formula C_5H_{10} . Show all atoms in the structures.

(10 marks)



Name: _____



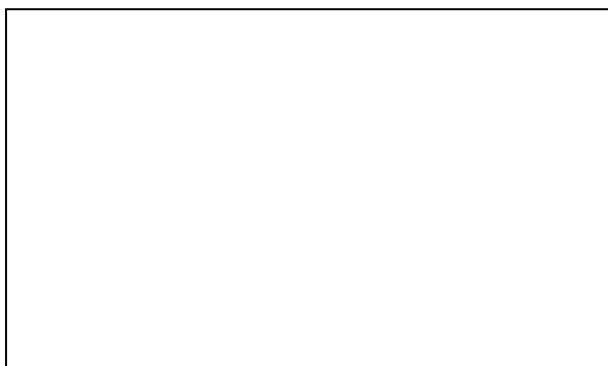
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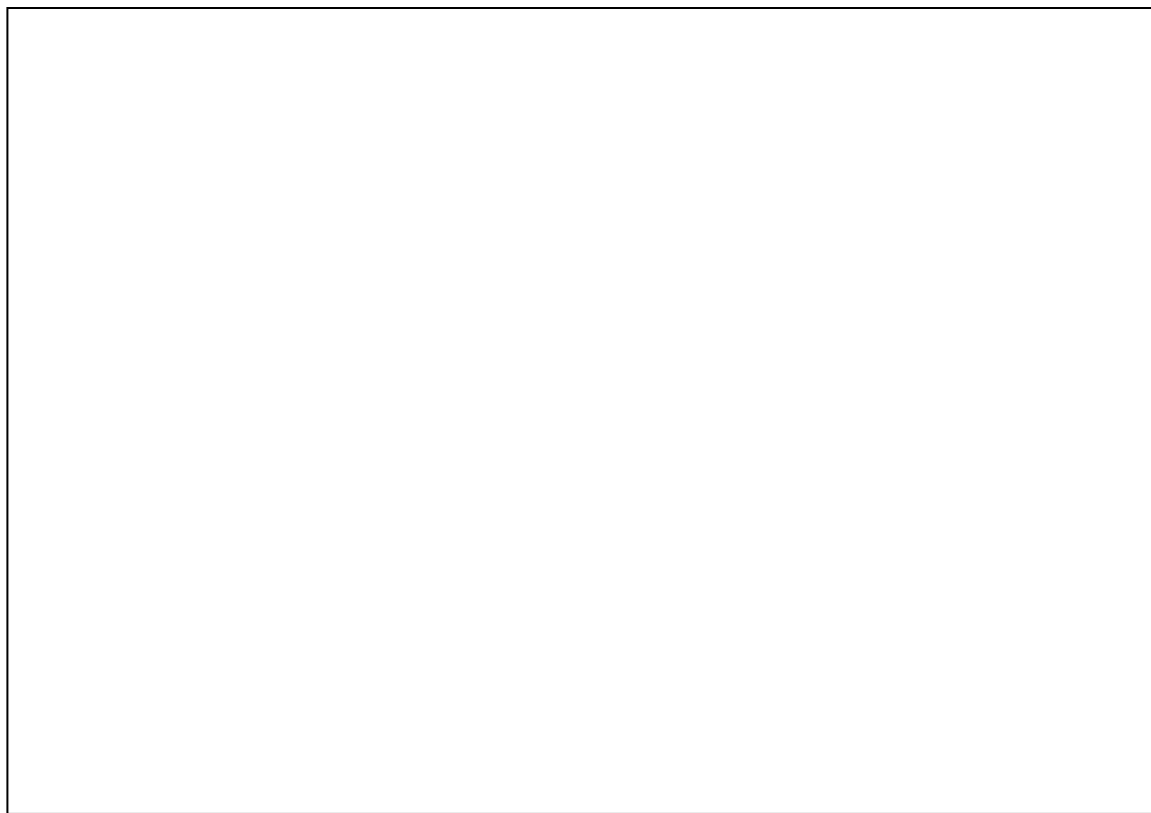
Name: _____



Name: _____

(b) An organic compound is known to be an ester. Its molar mass is 74 g mol^{-1} .

- (i) Draw the structural formula for the compound. Show all atoms in the structure. (1 mark)



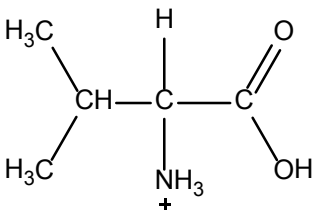
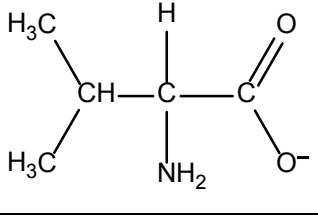
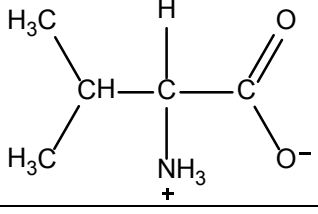
- (ii) Write the name for the compound you have drawn. (1 mark)

- (iii) What is the IUPAC name for a carboxylic acid that has the same molecular formula as the ester above? (1 mark)

Question 33

(3 marks)

Below are the structures for the amino acid valine under different pH conditions. In the spaces provided, give the approximate pH range (acidic, basic or neutral) under which each valine structure would exist.

Valine structure	pH range
	
	
	

Question 34

(7 marks)

Examine the following data for some Group 16 hydrides.

Group number	Hydride	Period	Melting point (°C)
16	H ₂ O	2	0
	H ₂ S	3	-86
	H ₂ Se	4	-66
	H ₂ Te	5	-49

Complete the table below by identifying which one or more of these Group 16 hydrides matches each of the descriptions given.

Note that all hydrides are assumed to be pure samples.

Description	Hydride/hydrides (formula or name)
Hydride with the strongest intramolecular forces	
Hydride with the strongest intermolecular forces	
Hydride/hydrides with hydrogen bonding	
Hydride/hydrides with dipole-dipole bonding	
Hydride/hydrides with dispersion forces	
Hydride with strongest dispersion forces	
Hydride with weakest dispersion forces	

Question 35

(7 marks)

A nickel-cadmium cell consists of a positive nickel(III) oxide-hydroxide, NiO(OH), electrode and a negative metallic cadmium electrode plate. The following processes occur during discharge:

- (i) metallic cadmium reacts in the presence of hydroxide ions to produce cadmium(II) hydroxide; and
- (ii) nickel(III) oxide-hydroxide reacts in the presence of water to produce nickel(II) hydroxide and hydroxide ions.

- (a) Write the half-equations for the reactions occurring at the anode and cathode and the overall redox equation for the Ni-Cd cell. (3 marks)

Anode half-equation	
Cathode half-equation	
Overall redox equation	

- (b) The electrolyte in the Ni-Cd cell is usually a solution of potassium hydroxide. State the role of an electrolyte in an electrochemical cell. (1 mark)

- (c) The standard reduction potential for cadmium metal is -0.4 V. Explain the role of the hydrogen half-cell in determining this value. Comment on the significance of the negative value. You may use diagrams to aid your explanation. (3 marks)

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.

Final answers to calculations should be expressed to **three (3)** significant figures and include appropriate units.

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Suggested working time: 70 minutes.

Question 36**(10 marks)**

Sevoflurane is a gaseous compound (at room temperature) used for inducing and maintaining general anaesthesia. It contains carbon, hydrogen, oxygen and fluorine.

Analysis of a 1.6328 g sample of sevoflurane yielded, on combustion, 866.0 mL of carbon dioxide at 50°C and 101.3 kPa and 0.220 g of water. The fluorine was released as hydrogen fluoride and absorbed by alkaline solution, revealing 5.71×10^{-2} mole of hydrogen fluoride. Determine the empirical formula of sevoflurane.

See next page

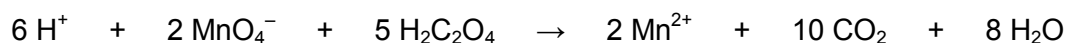
Question 37**(13 marks)**

The percentage of manganese in steel needs to be monitored carefully. To determine this, a 5.31 g sample of steel was dissolved in concentrated acid and the manganese oxidised to permanganate ion, MnO_4^- . The volume of this solution was made up to 100.0 mL in a volumetric flask.

The concentration of permanganate ion was determined by titration against a standard solution of oxalic acid. The oxalic acid solution was prepared by dissolving 2.42 g of oxalic acid dihydrate ($\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$) in a small volume of water, which was then made up to a final volume of 250.0 mL in a volumetric flask.

A 20.00 mL aliquot of the standard oxalic acid solution was transferred into a conical flask and acidified with some sulfuric acid. The permanganate solution was then titrated against this 20.00 mL aliquot of oxalic acid solution. This was repeated three times. The results are shown in the table below.

The balanced equation for the reaction between oxalic acid and permanganate ion is as below.



	1	2	3	4
Final reading (mL)	9.54	17.59	25.57	33.64
Initial reading (mL)	0.97	9.54	17.59	25.57
Titre volume (mL)				

(a) Calculate the concentration of the standard oxalic acid solution. (3 marks)

- (b) Determine the percentage of manganese in the original sample of steel. (8 marks)

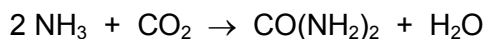
- (c) Suggest the most suitable indicator for this titration and describe the colour change that would be observed during the titration. (2 marks)

Indicator	
Description of colour change	

Question 38

(20 marks)

The sandy soils of Western Australia are deficient in several elements essential to the growth of plant life. One of these elements is nitrogen, and there are a number of nitrogen-containing fertilisers available on the market. Urea, $\text{CO}(\text{NH}_2)_2$, is a commonly-used fertiliser that contains nitrogen. Urea is produced as crystals by the reaction of ammonia with carbon dioxide. Water is also produced in the reaction. The equation for this reaction is shown below.



A reaction vessel designed for the synthesis of urea is operated at 200°C and 148 atmospheres. It has a total volume capacity of 5000 L, and ammonia and carbon dioxide are fed into it in batches so that ammonia occupies 62.0% of the volume and carbon dioxide occupies the remainder.

- (a) Determine the limiting reagent for the reaction under the above operating conditions. Show **all** your workings. (5 marks)

- (b) What mass of urea is theoretically produced in this reaction? (3 marks)

- (c) Calculate the mass of the excess reactant remaining after reaction. (3 marks)

- (d) Calculate the pressure of the remaining gas in the reactor after it is allowed to cool to room temperature (25°C).
(The volume occupied by the urea crystals and water formed can be ignored.) (2 marks)

- (e) 376 kg of impure crystals are formed in the above reaction and found, on analysis, to contain 83.0% urea. Calculate the percentage yield of the above process. (2 marks)

(f) Urea is added to fertiliser preparations at about 45.0% by mass. Ammonium sulfate is an alternative source of nitrogen often used in fertilisers.

(i) What mass of nitrogen is contained in 5.00 tonne of fertiliser that is 45.0% by mass urea? (1 tonne = 1×10^6 g) (2 marks)

(ii) What mass of ammonium sulfate, $(\text{NH}_4)_2\text{SO}_4$, is needed to prepare 5.00 tonne of fertiliser with the same mass of nitrogen as your answer in (i) above? (3 marks)

Question 39

(12 marks)

A student was given three bottles, A, B and C. Each bottle was labelled with its contents as shown in the table below.

Bottle	Contents
A	46.5 mL of 0.010 mol L ⁻¹ HCl
B	65.7 mL of 0.0555 mol L ⁻¹ HNO ₃
C	20.9 mL of 0.4161 mol L ⁻¹ NaOH

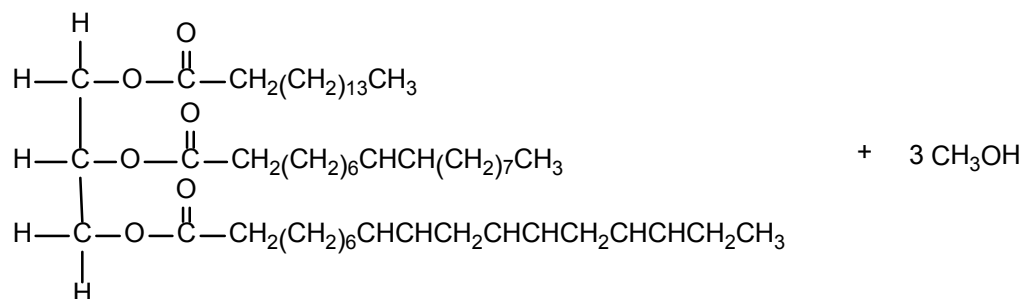
- (a) Calculate the pH of the NaOH solution. (2 marks)

- (b) The contents of all three bottles are placed in one beaker and mixed thoroughly. Calculate the pH of the final mixture. (10 marks)

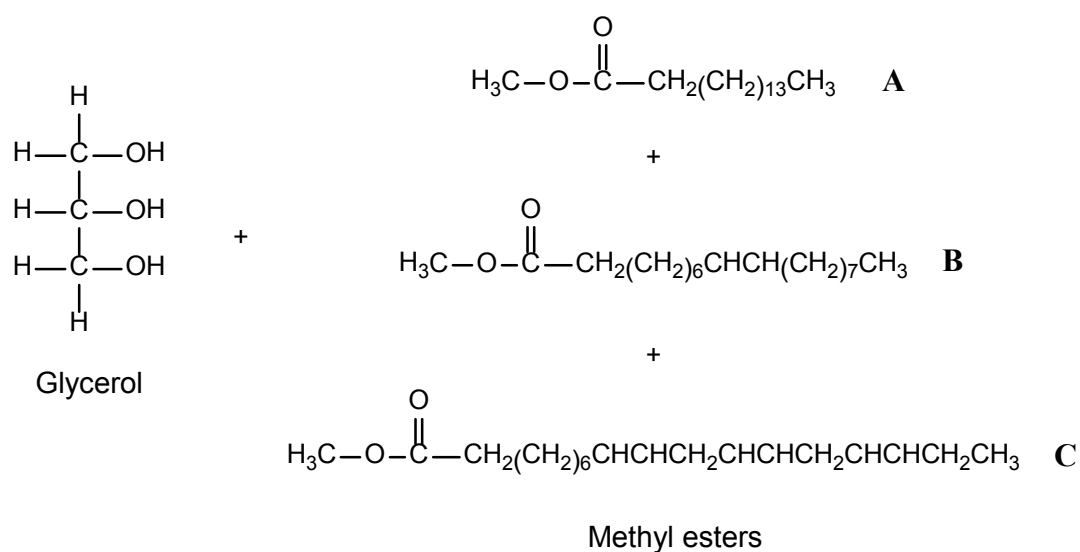
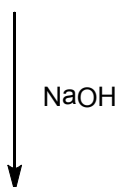
Question 40

(15 marks)

Biodiesel can be produced by a trans-esterification reaction between vegetable oil and an alcohol in the presence of sodium hydroxide catalyst. A typical trans-esterification reaction is shown below. The products are glycerol and three methyl esters.



Vegetable oil




- (a) The vegetable oil in the reaction above has a molar mass of $855.334 \text{ g mol}^{-1}$.
 If 1.50 tonnes of vegetable oil is reacted, what mass of methanol will be required to react with this amount of oil? (1 tonne = $1 \times 10^6 \text{ g}$) (3 marks)

See next page

- (b) Three different methyl esters, denoted **A**, **B** and **C**, are produced from this reaction. What is the mass of Ester **A** produced in this process if the reaction is 78% efficient in production of this ester? (4 marks)

- (c) Esters can also be produced by the reaction of a carboxylic acid with an alcohol. Draw the structure of the carboxylic acid that would be needed to produce Ester A in the reaction above. Show H atoms. (1 mark)



- (d) The glycerol produced from this process has a wide range of applications, including anti-freeze in the radiators of engines. A factor that contributes to its use as anti-freeze is its high water solubility. Explain, with the aid of a diagram, why glycerol has high water solubility. (4 marks)

- (e) Use your understanding of the collision theory to explain the role of sodium hydroxide in the reaction. (3 marks)

Question 41**(10 marks)**

Soaps and detergents are common organic substances. Discuss the chemistry of these two classes of organic substances, including their structure, manufacture and how they act as cleaning agents.

Your answer should

- include relevant chemical content. (8 marks)
- display coherence and clarity of expression. (2 marks)

A comprehensive answer should consist of at least three (3) paragraphs and be at least one page in length.

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