Government of **Western Australia**
Curriculum Council

WACE
Western Australian Certificate of Education

CHEMISTRY

Stage 3

WACE Examination 2011

Marking Key

Marking keys are an explicit statement about what the examiner expects of candidates when they respond to a question. They are essential to fair assessment because their proper construction underpins reliability and validity.

When examiners design an examination, they develop provisional marking keys that can be reviewed at a marking key ratification meeting and modified as necessary in the light of candidate responses.

Section One: Multiple-choice **25% (50 Marks)**

Question No.	Answer
1	D
2	B
3	B
4	C
5	A
6	C
7	C
8	D
9	D
10	B
11	C
12	C
13	B
14	D
15	C
16	A
17	A
18	C
19	B
20	D
21	C
22	A
23	D
24	C
25	A

End of Section One

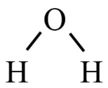
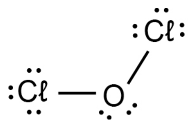
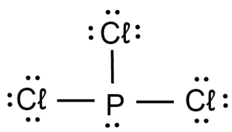
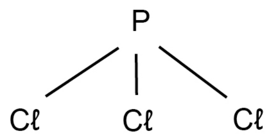
Section Two: Short answer **35% (70 Marks)**

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.

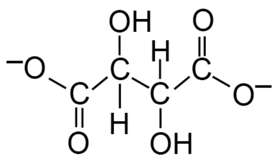
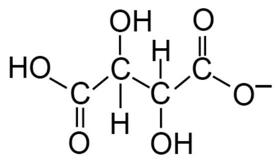
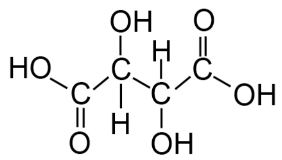
Molecule	Lewis structure	Sketch or name of shape
H_2O	One of $\mathrm{H}:\underset{\cdot\cdot}{\ddot{\mathrm{O}}}:\mathrm{H}$ **or** $\mathrm{H}-\underset{\cdot\cdot}{\ddot{\mathrm{O}}}-\mathrm{H}$ **or** $\mathrm{H}-\underline{\overline{\mathrm{O}}}-\mathrm{H}$	One of bent, **or** 
$C\ell_2O$		v-shaped or bent
$PC\ell_3$		Triangular pyramidal 

Description	Marks
1 mark for each Lewis structure; dashes or dots acceptable for representing electron pairs. Award 1 mark if bonding pairs are correct but lone pairs are missing.	1–2
1 mark for each shape; accept pyramidal	1–2
Question incorrectly answered	0
Question not attempted	–
Total	**4**

N.B. No follow-through marks. Answers must conform to marking key.
e.g. Each cell must be correct

Question 27 **(10 marks)**

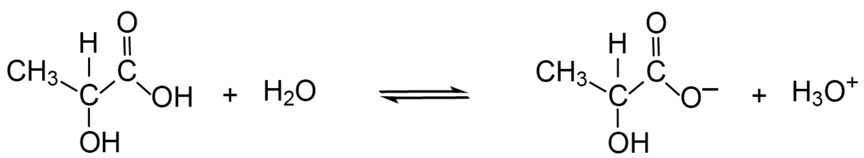
(a) Complete the table by writing the formula or drawing the structure for the conjugate base, species X or conjugate acid in the blank spaces as appropriate. Species X is the species that is able to form both a conjugate base and a conjugate acid. (6 marks)

Conjugate base	Species X	Conjugate acid
CH_3NH^-	CH_3NH_2	$CH_3NH_3^+$
$C_2O_4^{2-}$	$HC_2O_4^-$	$H_2C_2O_4$
		

Description	Marks
1 mark for each cell.	1–6
Question incorrectly answered	0
Question not attempted	–
Total	**6**

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.



$\Delta H = -60 \text{ kJ mol}^{-1}$

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)

Description	Marks
Ratio of P to R less than one <1; OR there are less P than R	1
Question incorrectly answered	0
Question not attempted	–
Total	**1**

(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	Right
Adding hydrochloric acid	Left
Adding sodium hydroxide	Right

Description	Marks
1 mark for each cell	1–3
Question incorrectly answered	0
Question not attempted	–
Total	**3**

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.

$$CH_3OH + HC\ell \rightleftharpoons CH_3C\ell + H_2O$$

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_3OH	65	-98
$HC\ell$	-85	-114
$CH_3C\ell$	-24	-98
H_2O	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 equilbrium (right, left or no change)**
	CH_3OH	$HC\ell$	$CH_3C\ell$	H_2O	
-50	ℓ	g	ℓ	s	right
40	ℓ	g	g	ℓ	no change
70	g	g	g	ℓ	right
110	g	g	g	g	no change

Description	**Marks**
1 mark for correctly identifying phases at each temperature for each substance (All four at each temperature must be correct.)	1–4
1 mark for correct shift in equilibrium; award the mark if the phases are incorrect but the shift is correct based on incorrect phases **	1–4
Question incorrectly answered	0
Question not attempted	–
Total	**8**

** Shift in equilibrium must correspond with phases identified.

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	$HSO_4^-(aq) + H_2O(l) \rightleftharpoons SO_4^{2-}(aq) + H_3O^+(aq)$ or $HSO_4^-(aq) \rightleftharpoons H^+(aq) + SO_4^{2-}(aq)$
A solution of $Mg(OH)_2$ is basic	$Mg(OH)_2 \rightleftharpoons Mg^{2+}(aq) + 2\,OH^-(aq)$ or $2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$ $[OH^-]>\{H^+]$ therefore basic
A solution of Na_2HPO_4 is basic, while a solution of KH_2PO_4 is acidic	$HPO_4^{2-}(aq) + H_2O(l) \rightleftharpoons H_2PO_4^-(aq) + OH^-(aq)$ $H_2PO_4^-(aq) + H_2O(l) \rightleftharpoons HPO_4^{2-}(aq) + H_3O^+(aq)$ or $H_2PO_4^-(aq) \rightleftharpoons HPO_4^{2-}(aq) + H_3O^+(aq)$

Description	**Marks**
1 mark for each equation.	1–4
Question incorrectly answered	0
Question not attempted	–
Total	**4**

N.B. Double arrows not required. i.e., no penalty for single arrows.

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	Shake a small quantity of each substance with acidified $Cr_2O_7^{2-}$ or acidified MnO_4^-.	When shaken the $Cr_2O_7^{2-}$ mixture changes from orange to green OR When shaken with MnO_4^- will go from purple to colourless (or pale pink)	When shaken with the $Cr_2O_7^{2-}$ remains orange (no observable change acceptable) OR When shaken with MnO_4^-remains purple (no observable change acceptable)
		Addition of sodium (Na)	Reacts faster	Reacts slower (do not accept no visible reaction)
zinc nitrate solution	zinc sulfate solution	Add a little $Ba(NO_3)_2$ or $Pb(NO_3)_2$ solution to each solution Accept Ba^{2+} or Pb^{2+} Accept anything that gives ppt	No observable reaction	A precipitate forms [white]
solid magnesium hydroxide	solid lead sulfate	Add a little of each solid to dilute HNO_3 or H_2SO_4 or HCl or CH_3COOH	Solid dissolves	Solid does not dissolve
		Addition of $H_2C_2O_4$	No visible reaction	[colourless] gas evolved
methanol	methanal	Shake each with a little acidified acetic acid Any carboxylic acid okay	Fruity smell develops; [(acetic) acid odour goes]	No fruity smell develops; [odour of (acetic) acid persists]
		Addition of sodium (Na)	Gas evolved	No visible reaction

Description	Marks
1 mark for description of each test – Must be acidified $Cr_2O_7^{2-}$ or MnO_4^-; any suitable precipitation reaction acceptable for zinc solutions. (Any suitable chemical test – that adequately distinguishes one substance from the other – is acceptable.)	1–4
1 mark for each observation	1–8
Question incorrectly answered	0
Question not attempted	–
Total	**12**

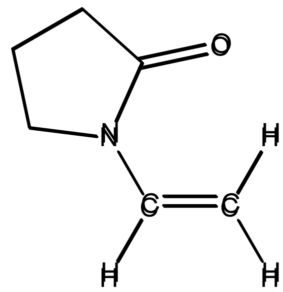
N.B. (i) If $Cr_2O_7^{2-}$ or MnO_4^- not acidified, correct observations should be awarded (i.e. 2 out of 3 for the row)

(ii) If $Cr_2O_7^{2-}$ or MnO_4^- not acidified, but butan-2-ol solution turns brown, award marks (for test and observation)

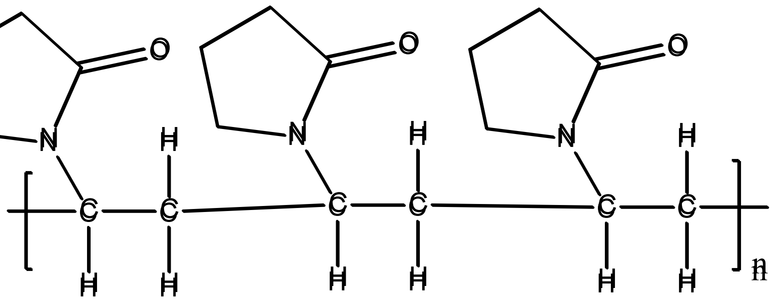
(iii) Look out for any acceptable chemical test that is not listed here.

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)



Description	Marks
3 units correctly combined required to gain mark. ("n" and brackets not needed)	1
Question incorrectly answered e.g. Hs on the ends	0
Question not attempted	–
Total	**1**

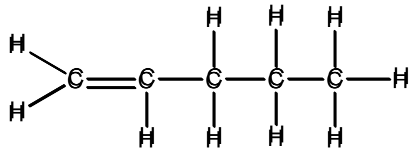
(b) What type of polymerisation reaction occurs to form the polymer from the above monomer? (1 mark)

Description	Marks
Addition	1
Question incorrectly answered	0
Question not attempted	–
Total	**1**

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)



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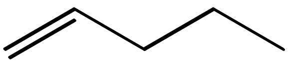
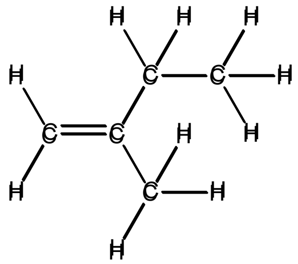


Name: pent-1-ene or 1-pentene



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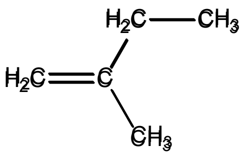

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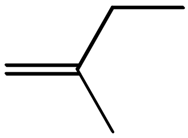
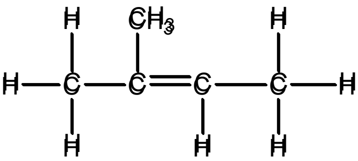


Name: 2-methyl-but-1-ene or 2-methyl-1-butene



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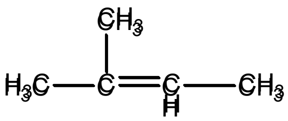

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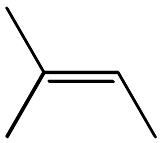
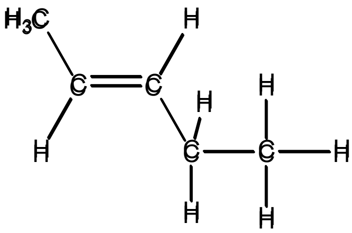


Name: 2-methyl-but-2-ene or 2-methyl-2-butene



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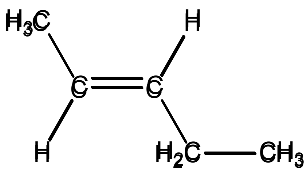

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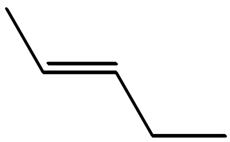
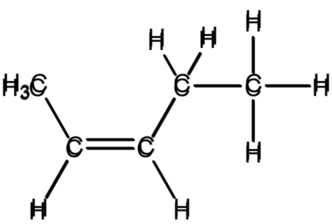


Name: *trans*-pent-2-ene OR *trans*-2-pentene



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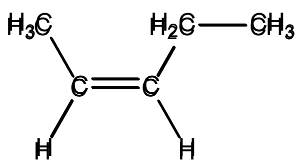

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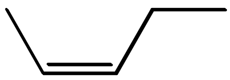
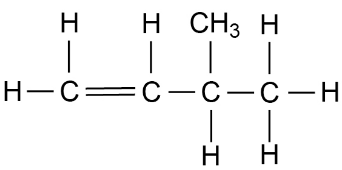


Name: *cis*-pent-2-ene OR *cis*-2-pentene



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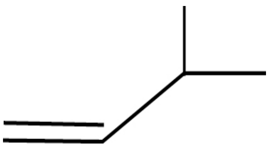


Name: 3-methyl-but-1-ene

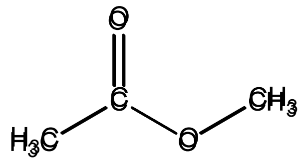
Description	Marks
1 mark for each correct structure. Condensed structures acceptable. Award 4 marks for structures if H atoms consistently left off but structure is otherwise correct.	1–5
1 mark for each correct name	1–5
Question incorrectly answered or not attempted.	0
Total	**10**

N.B. (i) If structure is incorrect (e.g. – cyclic structure), but name is correct, award one mark. Must be C_5H_{10}.

(ii) If there is some systematic error in naming, deduct one mark.

(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)



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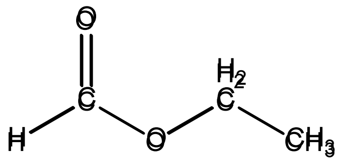


Description	Marks
1 mark for a correct structure. Condensed structure acceptable.	1
Question incorrectly answered	0
Question not attempted	–
Total	**1**

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

methyl ethanoate OR ethyl methanoate

Description	Marks
methyl ethanoate OR ethyl methanoate	1
Question incorrectly answered	0
Question not attempted	–
Total	**1**

N.B. Accept methyl acetate

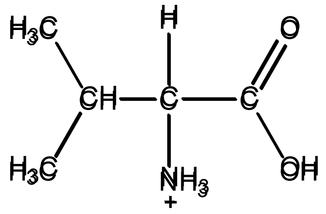
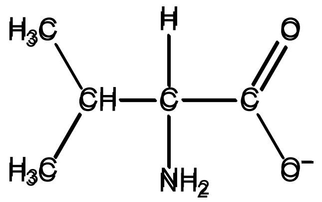
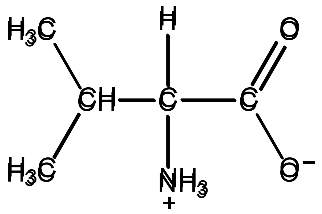
(iii) What is the IUPAC name for a carboxylic acid that has the same molecular formula as the ester above? (1 mark)

propanoic acid

Description	Marks
propanoic acid	1
Question incorrectly answered	0
Question not attempted	–
Total	**1**

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
	acidic (pH < 7) Or any range of acidic values
	basic (pH > 7) Or any range of basic values
	neutral (pH ~ 7)

Description	Marks
1 mark each	1–3
Question incorrectly answered	0
Question not attempted	–
Total	**3**

N.B. Either words or pH range acceptable.

Question 34 **(7 marks)**

Examine the following data for some Group 16 hydrides.

Group number	Hydride	Period	Melting point (°C)
16	H_2O	2	0
	H_2S	3	–86
	H_2Se	4	–66
	H_2Te	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	H_2O
Hydride with the strongest intermolecular forces	H_2O
Hydride/hydrides with hydrogen bonding	H_2O
Hydride/hydrides with dipole-dipole bonding	H_2O, H_2S, H_2Se, H_2Te or ALL
Hydride/hydrides with dispersion forces	H_2O, H_2S, H_2Se, H_2Te or ALL
Hydride with strongest dispersion forces	H_2Te
Hydride with weakest dispersion forces	H_2O

Description	Marks
1 mark for each cell	1–7
Question incorrectly answered	0
Question not attempted	–
Total	**7**

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	$Cd + 2\,OH^- \rightarrow Cd(OH)_2 + 2\,e^-$
Cathode half-equation	$NiO(OH) + H_2O + e^- \rightarrow Ni(OH)_2 + OH^-$
Overall redox equation	$Cd + 2\,NiO(OH) + 2\,H_2O \rightarrow Cd(OH)_2 + 2\,Ni(OH)_2$

Description	Marks
1 mark for anode reaction	1
1 mark for cathode reaction	1
1 mark for overall equation (i.e. correct with reference to anode and cathode)	1
Question incorrectly answered	0
Question not attempted	–
Total	**3**

If anode and cathode equations are reversed but otherwise correct award 1 mark out of the possible 2 marks for the half- equations

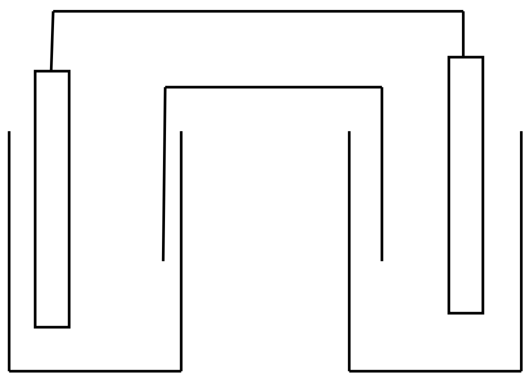
(b) The electrolyte in the Ni-Cd cell is usually a solution of potassium hydroxide. State the role of an electrolyte in an electrochemical cell. (1 mark)

Description	Marks
To enable flow of ions./complete the cell circuit allowing charge flow	1
Question incorrectly answered	0
Question not attempted	–
Total	**1**

(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)

Description	Marks
1 mark for recognition that the hydrogen half-cell is assigned an E° of 0 V or reference cell (or similar)	1
1 mark for recognition that cadmium half-cell E° is determined relative to the hydrogen half-cell.	1
1 mark for recognition that the negative value means that the cadmium half-cell is anodic relative to the hydrogen half-cell (OR electrons flow from the cadmium to the hydrogen cell or some other version)	1
Question incorrectly answered	0
Question not attempted	–
Total	**3**

An example of a possible diagram



End of Section Two

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

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

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

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

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

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

Suggested working time: 70 minutes.

For numerical answers, a 1% tolerance in answers is acceptable.

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.

Description	Marks
$n(C) = n(CO_2) = \frac{PV}{RT} = \frac{101.3 \times 0.866}{8.315 \times 323} = 3.266 \times 10^{-2}\,mol$	1
$m(C) = 12.01 \times 3.266 \times 10^{-2} = 0.3923$ g	1
$n(H) = 2 \times n(H_2O) = 2 \times \frac{0.220}{18.016} = 2.44 \times 10^{-2}\,mol$	1
$m(H) = 1.008 \times 2.44 \times 10^{-2} = 2.462 \times 10^{-2}$ g	1
$m(F) = 19.00 \times 5.71 \times 10^{-2} = 1.085$ g	1
$m(O) = 1.6328 - (0.3923 + 2.462 \times 10^{-2} + 1.085) = 0.13099$ g	1
$n(O) = \frac{0.13099}{16.00} = 8.187 \times 10^{-3}\,mol$	1
C, H, O, F: 0.03266, 0.0244, 0.008187, 0.0571 ÷ by smallest: $\frac{0.03266}{0.008187}$, $\frac{0.0244}{0.008187}$, 1, $\frac{0.0571}{0.008187}$ 3.99, 2.98, 1, 6.97 4, 3, 1, 7 1 mark for ÷ by smallest; 1 mark for rounding	1–2
Thus EF is $C_4H_3OF_7$	1
Question incorrectly answered	0
Question not attempted	–
Total	**10**

N.B.: Any appropriate logic leading to the correct answer is acceptable.
N.B.: $C_7H_{18}OF_{12}$ = rounding error (9 marks)
If reasonable attempt to produce whole numbers from EF developed from H from water and HF then full marks

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 ($H_2C_2O_4$. $2H_2O$) 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.

$$6\,H^+ \quad + \quad 2\,MnO_4^- \quad + \quad 5\,H_2C_2O_4 \quad \rightarrow \quad 2\,Mn^{2+} \quad + \quad 10\,CO_2 \quad + \quad 8\,H_2O$$

	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)	**8.57**	**8.05**	**7.98**	**8.07**

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

Description	Marks
$M(H_2C_2O_4{\cdot}2H_2O) = 126.068\ g\ mol^{-1}$	1
$n(H_2C_2O_4) = \dfrac{2.42}{126.068} = 1.9196 \times 10^{-2} mol$	1
$c(H_2C_2O_4) = \dfrac{1.9196 \times 10^{-2}}{0.250} = 7.68 \times 10^{-2}\ mol\ L^{-1}$	1
Question incorrectly answered	0
Question not attempted	–
Total	**3**

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

Description	Marks
$n(H_2C_2O_4) = 7.68 \times 10^{-2} \times 0.02 = 1.536 \times 10^{-3}$ mol	1
$n(MnO_4^-) = \frac{2}{5} \times n(H_2C_2O_4) = 6.144 \times 10^{-4}$ mol	1
$V_{av}(MnO_4^-) = 8.033$ mL	1
*$n(MnO_4^-)$ in 100 mL = $\frac{6.144 \times 10^{-4}}{8.033 \times 10^{-3}} \times 0.100 = 7.648 \times 10^{-3}$ mol	1–2
Thus n(Mn) in sample = 7.648×10^{-3} mol	1
$m(Mn) = 7.648 \times 10^{-3} \times 54.94 = 0.4202$ g	1
$\%Mn = \frac{0.4202}{5.31} \times 100 = 7.91\%$	1
Question incorrectly answered	0
Question not attempted	-
Total	**8**

*Calculation of the concentration of the MnO_4^- solution and then calculation of $n(MnO_4^-)$ in 100 mL is also acceptable.

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

Indicator	No indicator needs to be added; MnO_4^- acts as indicator
Description of colour change	Solution will turn from colourless to pale pink

Description	Marks
Recognition that no indicator needs to be added	1
Solution will turn from colourless to pale pink (i.e., that is the end point)	1
Question incorrectly answered	0
Question not attempted	-
Total	**2**

N.B.: “Self indicating” is acceptable

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, $CO(NH_2)_2$, 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.

$$2\,NH_3 + CO_2 \rightarrow CO(NH_2)_2 + H_2O$$

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)

Description	Marks
P = 148 × 101.3 = 1.49924×10^4 kPa (conversion of atm to kPa; alternatively students may use R = 0.08206 in the next step and be awarded 1 mark for remembering it)	1
Calculation of total number of moles: $n_{total} = \frac{PV}{RT} = \frac{1.49924 \times 10^4 \times 5000}{8.315 \times 473} = 1.906 \times 10^4$ mol	1
$n(NH_3) = 0.62 \times 1.906 \times 10^4 = 1.182 \times 10^4$ mol	1–3
$n(CO_2) = 0.38 \times 1.906 \times 10^4 = 7.243 \times 10^3$ mol	
From balanced eq'n: 2 mol NH_3 reacts with 1 mol CO_2 Thus 1.182×10^4 mol NH_3 needs 5.909×10^3 mol CO_2 Hence NH_3 is the limiting reagent. **Any acceptable method for finding LR may be used as long as it is supported with correct working.**	
Question incorrectly answered	0
Question not attempted	–
Total	**5**

N.B.: the 62% may be "applied" in any logical way

Students may choose to get the moles of NH_3 and CO_2 by finding the volume occupied by each of these gases and using the Ideal gas law twice. Gay-Lussac's law may also be used. Any valid method should be accepted. Use of a correct method for LR calculation based on incorrectly calculated moles of reagents should be rewarded.

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

Description	Marks
$n(NH_2CONH_2) = ½ \times n(NH_3) = 0.5 \times 1.182 \times 10^4 = 5.909 \times 10^3$ mol	1
$M(NH_2CONH_2) = 60.062$ g mol^{-1}	1
$m(NH_2CONH_2) = 60.062 \times 5.909 \times 10^3 = 3.55 \times 10^5$ g	1
Question incorrectly answered	0
Question not attempted	–
Total	**3**

N.B.: Award marks for follow through if candidate has used incorrect LR

Award marks for correct method based on incorrect LR

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

Description	Marks
$n(CO_2)$ used = ½ × $n(NH_3)$ = 0.5 × 1.182 × 10^4 = 5.909 × 10^3 mol	1
$n(CO_2)$ remaining = 7.243 × 10^3 - 5.909 × 10^3 = 1.334 × 10^3 mol	1
$m(CO_2)$ remaining = 44.01 × 1.334 × 10^3 = 5.87 × 10^4 g	1
Question incorrectly answered	0
Question not attempted	–
Total	**3**

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

Description	Marks
$P = \frac{nRT}{V} = \frac{1.334 \times 10^3 \times 8.315 \times 298}{5000} = 6.61 \times 10^2$ kPa (or 6.53 atm) 1 mark for correct rearrangement of eq'n; 1 mark for final answer	1–2
Question incorrectly answered	0
Question not attempted	–
Total	**2**

Award marks for follow through for correct working when moles of CO_2 from (c) is incorrect.

(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)

Description	Marks
$m(NH_2CONH_2)$ = 3.76 ×10^5 × 0.83 = 3.1208 × 10^5 g	1
$\text{Yield} = \frac{3.1208 \times 10^5}{3.55 \times 10^5} \times 100 = 87.9\%$	1
Question incorrectly answered	0
Question not attempted	–
Total	**2**

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

(i) What mass of nitrogen is contained in 5 tonne of fertiliser that is 45.0% by weight urea? (1 tonne = 1×10^6 g) (2 marks)

Description	Marks
m(NH_2CONH_2) in fertiliser batch = $0.45 \times 5 \times 10^6 = 2.25 \times 10^6$ g	1
m(N) in fertiliser = $\frac{28.02}{60.062} \times 2.25 \times 10^6 = 1.05 \times 10^6$ g	1
Question incorrectly answered	0
Question not attempted	–
Total	**2**

(ii) What mass of ammonium sulfate, $(NH_4)_2SO_4$, is needed to prepare 5.00 tonne of fertiliser with the same mass of nitrogen as your answer in (i) above? (3 marks)

Description	Marks
n(N) in fertiliser = $\frac{1.05 \times 10^6}{14.01} = 7.492 \times 10^4$ mol	1
n($(NH_4)_2SO_4$) = $0.5 \times 7.492 \times 10^4 = 3.746 \times 10^4$ mol	1
m($(NH_4)_2SO_4$) = $132.144 \times 3.746 \times 10^4 = 4.95 \times 10^6$ g	1
Question incorrectly answered	0
Question not attempted	–
Total	**3**

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)

Description	Marks
$[H^+] = \frac{1\times10^{-14}}{[OH^-]} = \frac{1\times10^{-14}}{0.4161} = 2.403\times10^{-14}\ \text{mol L}^{-1}$	1
pH = $-\log^{10}[H^+]$ = $-\log 2.403 \times 10^{-14}$ = 13.6 (13.619)	1
Question incorrectly answered	0
Question not attempted	–
Total	**2**

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

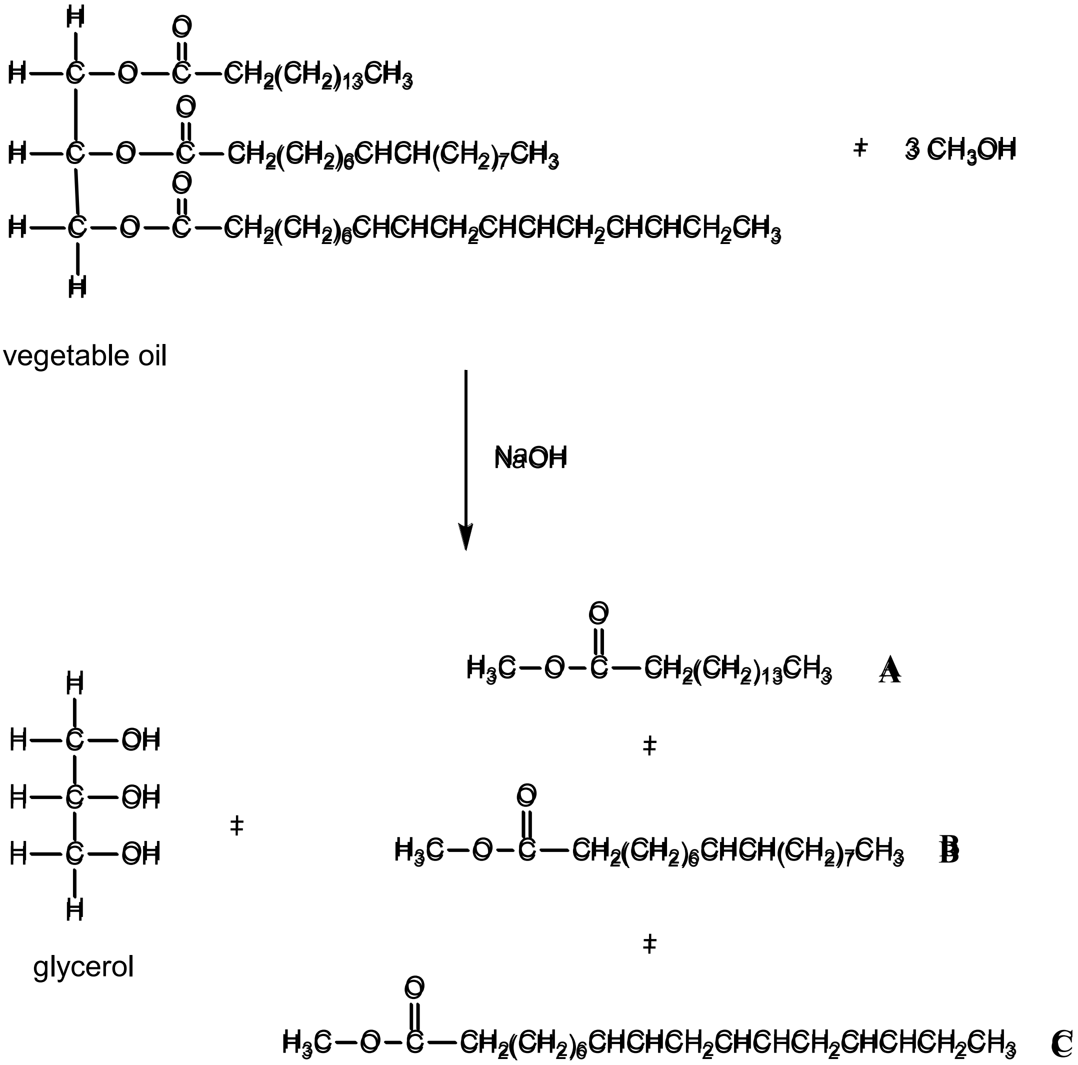
Description	Marks
$n(H^+)$ from HCl = c ×V = 0.010 × 0.0465 = 4.65 × 10^{-4} mol	1
$n(H^+)$ from HNO_3 = c ×V = 0.0555 × 0.0657 = 3.646 × 10^{-3} mol	1
$n(H^+)_{total}$ = 4.65 × 10^{-4} + 3.646 × 10^{-3} = 4.111 × 10^{-3} mol	1
$n(OH^-)$ = c ×V = 0.4161 × 0.0209 = 8.696 × 10^{-3} mol	1
Recognition that 1 mole of H^+ reacts with 1 mole of OH^-; this may be by showing the mole relationship $n(H^+) = n(OH^-)$ or giving the balanced equation	1
$n(OH^-)$ reacted = $n(H^+)_{total}$ = 4.111 × 10^{-3} mol	1
$n(OH^-)$ excess = 8.696 × 10^{-3} - 4.111 × 10^{-3} = 4.585 × 10^{-3} mol	1
$c(OH^-) = \frac{n}{V} = \frac{4.585\times10^{-3}}{(0.0465+0.0657+0.0209)} = \frac{4.585\times10^{-3}}{0.1331} = 3.444\times10^{-2}\text{mol L}^{-1}$	1
$[H^+] = \frac{1\times10^{-14}}{[OH^-]} = \frac{1\times10^{-14}}{3.444\times10^{-2}} = 2.903\times10^{-13}\ \text{mol L}^{-1}$	1
pH = $-\log_{10}[H^+]$ = $-\log 2.903 \times 10^{-13}$ = 12.5 (12.537)	1
Question incorrectly answered	0
Question not attempted	–
Total	**10**

N.B.: Steps may be amalgamated

Students may also calculate pH using:
pOH = $-\log^{10}[OH^-]$ = $-\log 0.03444$ = 1.46 (2 marks)
pH = 14 – 1.46 = 12.54 (1 mark)

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.



Methyl esters

(a) The vegetable oil in the reaction above has a molar mass of 855.334 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 = 1×10^6 g) (3 marks)

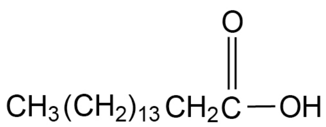
Description	Marks
n(Veg oil) = $\dfrac{1.5 \times 10^6}{855.334} = 1.754 \times 10^3$ mol	1
n(CH_3OH) = 3 × n(Veg oil) = 5.261×10^3 mol	1
m(CH_3OH) = $5.261 \times 10^3 \times 32.042 = 1.69 \times 10^5$ g	1
Question incorrectly answered	0
Question not attempted	–
Total	**3**

(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)

Description	Marks
For 100% efficient: n(A) = n(Veg oil) = 1.754×10^3 mol	1
78% efficient, thus n(A) = $0.78 \times 1.754 \times 10^3 = 1.368 \times 10^3$ mol	1
MF Ester A is $C_{17}H_{34}O_2$ thus M(A) = 270.442 g mol^{-1}	1
m(A) = $1.368 \times 10^3 \times 270.442 = 3.70 \times 10^5$ g	1
Question incorrectly answered	0
Question not attempted	–
Total	**4**

The 78% efficiency step can be done based on the theoretical 100% efficient mass of A rather than number of moles of A.

(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)



Description	Marks
1 mark for structure; condensed or expanded acceptable.	1
Question incorrectly answered	0
Question not attempted	–
Total	**1**

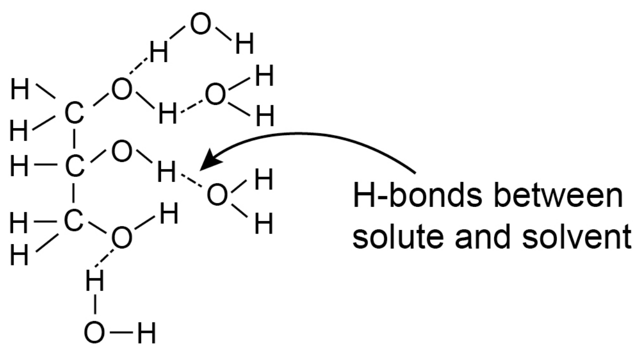
(d) The glycerol produced from this process has a wide range of applications, including anti-freeze in the radiators of engines. A factor that contributes to its use as anti-freeze is its high water solubility. Explain, with the aid of a diagram, why glycerol has high water solubility. (4 marks)

Description	Marks
1 mark for recognition that both water and glycerol have H-bonding as their predominant type of IMF.	1
1 mark for showing that their similar IMFs leads to a high degree of interaction between solvent and solute molecules/formation of H-bonding	1
I mark for recognising that solubility arises due to the strength of attraction between solute and solvent molecules being sufficient to overcome attraction between solute-solute and solvent-solvent molecules**	1
1 mark for a suitable labelled diagram representing H-bonding between water and glycerol molecules.	1
Question incorrectly answered	0
Question not attempted.	–
Total	**4**

**An explanation in terms of the competing forces of attraction between solute-solute molecules, solvent-solvent molecules and between solvent-solute molecules is also acceptable. Students may also discuss the energy released when solvent-solute molecules attract being sufficient to overcome the energy to separate solute-solute molecules and solvent-solvent molecules.

'Like dissolves like', contains no chemistry and should not be awarded any marks.

Possible diagram

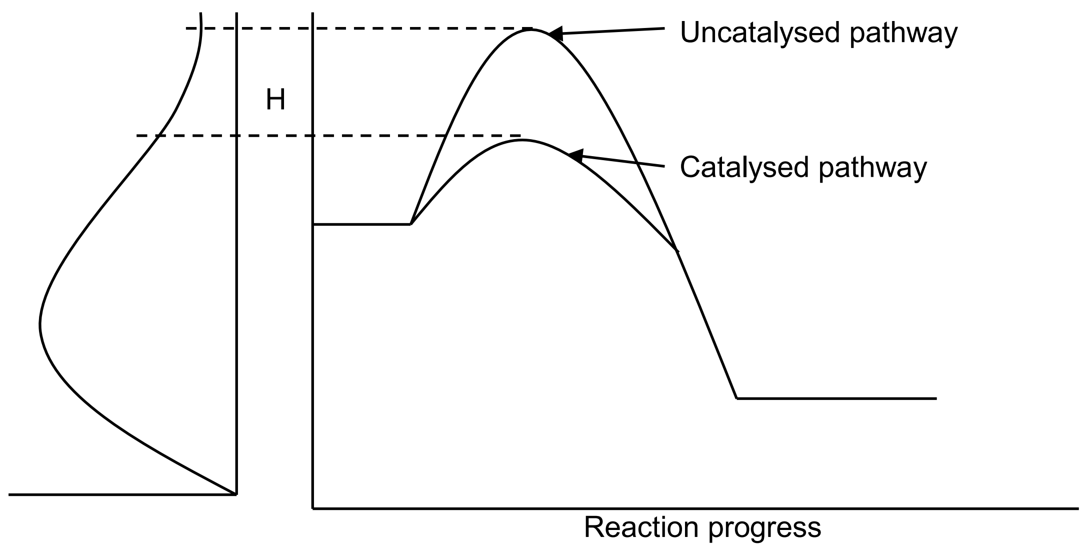


(e) Use your understanding of the collision theory to explain the role of sodium hydroxide in the reaction. (3 marks)

Description	Marks
1 mark for recognising that the NaOH speeds the reaction	1
1 mark for recognising the NaOH provides an alternative reaction pathway that has lower E_a than the uncatalysed pathway	1
1 mark for recognising a higher proportion of collisions will occur with energy above the E_a (cat) and so be successful in forming products	1
Question incorrectly answered	0
Question not attempted	–
Total	3

N.B.: Must show some understanding of catalytic action of NaOH

An appropriately labelled energy profile diagram showing the catalysed and uncatalysed reaction pathways may be drawn to aid explanation. For a correct diagram on its own with no supporting explanation award 2 marks.



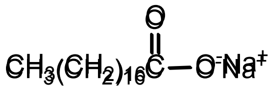
Question 41 **(10 marks)**

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)

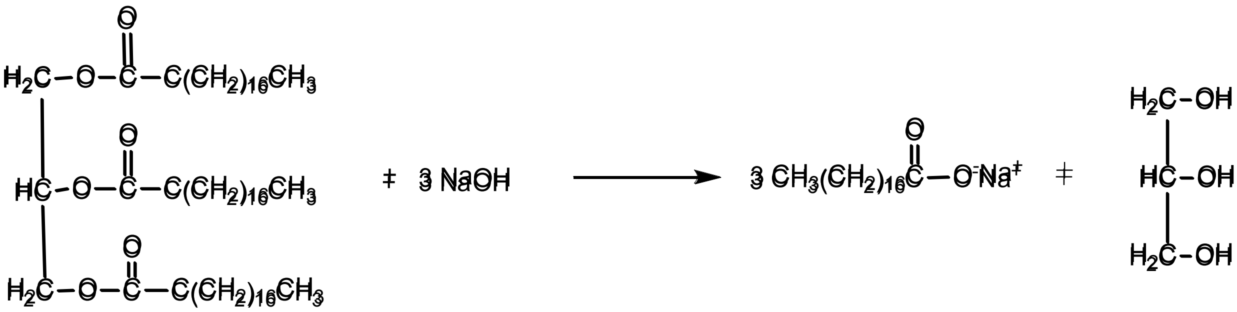
A comprehensive answer should consist of at least three (3) paragraphs and be at least one page in length.

- Soaps are sodium (or potassium) salts of long chain fatty acids.

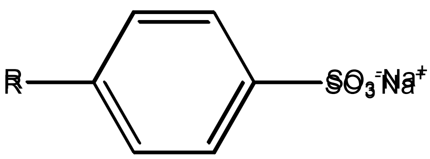


Typical soap molecule

- Soaps are manufactured by reaction of sodium (or potassium) hydroxide with an animal fat or vegetable oil. Fats and oils are esters of glycerol (1,2,3-propantriol). Known as a saponification reaction. The hydroxide hydrolyses the ester to give the sodium salt.
- General equation for saponification

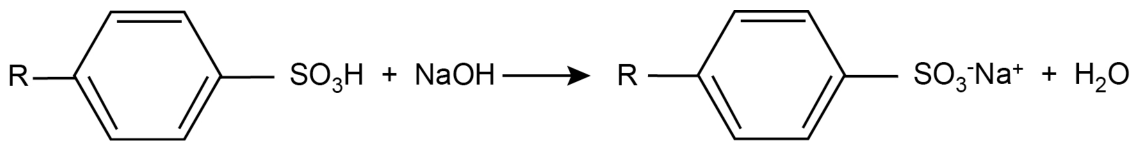


- Detergents are sodium (or potassium) salts of an alkylbenzene sulfonate.



R = long chain alkyl group

- Detergents are manufactured by reaction of alkylbenzenes with concentrated sulfuric acid to give the alkylbenzene sulfonate which is then reacted with sodium hydroxide to give the detergent.
- General equation



- Soaps and detergents are surfactant molecules comprised of a large non-polar part and a small polar part.
- The non-polar section of the soap/detergent molecule will dissolve in the (usually) non-polar dirt or grease with the polar section dissolved in the polar water.
- Agitation can then enable the soap/detergent molecule to lift the dirt/grease from the object to be cleaned.

Description	Marks
Coherent sentences and clarity of expression	1–2
Structure for general soap molecule or specific example (can be part of the saponification equation) (ion or salt)	1
Comparison of effectiveness of detergents vs. soaps **or** manufacture of either (soap or detergent) This would include reference to reaction of soap with Mg^{2+} and Ca^{2+} ions to form scum	1–2
Structure for general detergent molecule or specific example acceptable (can be part of the detergent equation) (ion or salt)	1
Recognition of non-polar and polar nature of soap/detergent molecules	1
Recognition that the non-polar part of the molecule dissolves in the dirt/grease and the polar part of the molecule dissolves in the water	1–3
Question incorrectly answered	0
Question not attempted	–
Total	**10**