2025/4411
Web version of 2024/81475

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

CHEMISTRY

ATAR course examination 2024

Marking key

Marking keys are an explicit statement about what the examining panel expect of candidates when they respond to particular examination items. They help ensure a consistent interpretation of the criteria that guide the awarding of marks.

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

Question	Answer
1	a
2	c
3	c
4	b
5	a
6	d
7	c
8	d
9	c
10	b
11	d
12	a
13	d
14	d
15	a
16	b
17	b
18	a
19	b
20	a
21	c
22	d
23	b
24	c
25	b

Section Two: Short answer **35% (81 Marks)**

Question 26 **(9 marks)**

Consider the following system that is at equilibrium. Cobalt(II) chloride is dissolved in concentrated hydrochloric acid. The colour of the solution at initial equilibrium is blue.

$$\underset{\text{blue}}{CoC\ell_4^{2+}(aq)} + 6\ H_2O(\ell) \leftrightharpoons \underset{\text{pink}}{Co(H_2O)_6^{2+}(aq)} + 4\ C\ell^-(aq) \qquad \Delta H = \text{-ve}$$

For each of the applied changes after equilibrium is re-established, predict the:

- shift in equilibrium position (left, right or no change)
- rate of the forward reaction compared to the original rate (increase, decrease or no change)
- colour of the reaction mixture.

Do **not** use arrows to show direction.

Description	**Marks**
Correctly predicts the shift in equilibrium position	1–3
Correctly predicts the effect on the rate of the forward reaction	1–3
Correctly predicts the colour of the reaction mixture	1–3
Total	**9**
Note: the colour change must represent the correct equilibrium shift direction.	

Change	**Shift in equilibrium position (left, right or no change)**	**Rate of the forward reaction compared to the original rate (increase, decrease or no change)**	**Colour of reaction mixture**
A few drops of $AgNO_3$(aq) are added	Right	Decrease	(More) pink
A small volume of water is added	Right	Decrease	(More) pink
The system is heated	Left	Increase	More blue

Question 27 **(12 marks)**

Write balanced ionic equations for any reactions between the following substances and state any observations before and after mixing.

If there is no reaction, write 'no reaction' for the equation and if there is no change observed write 'no visible reaction'. Use the colours stated in the Data booklet if required.

(a) A magnesium strip is added to excess dilute hydrochloric acid solution. (4 marks)

Description	**Marks**
Equation	
Equation $Mg(s) + 2\,H^+(aq) \rightarrow Mg^{2+}(aq) + H_2(g)$	
Correct species	1
Correct balancing	1
Observations	
grey/silver solid added to a colourless solution	1
effervescence and solid dissolves/disappears	1
Total	**4**
Note: • maximum 1 mark for correct and balanced molecular equations • each observation requires colours of reagents and change in the products • state symbols are not required for full marks • do not accept 'clear solution or liquid' without reference to colour.	

(b) A few drops of bromine liquid are added to a potassium iodide solution. (4 marks)

Description	**Marks**
Equation	
Equation $Br_2(\ell) + 2\,I^-(aq) \rightarrow 2\,Br^-(aq) + I_2(s)$ or $Br_2(\ell) + 2\,I^-(aq) \rightarrow 2\,Br^-(aq) + I_2(aq)$	
Correct species	1
Correct balancing	1
Observations	
red liquid is added to colourless solution	1
grey solid precipitates/brown solution formed	1
Total	**4**
Note: • maximum 1 mark for correct and balanced molecular equations • each observation requires colours of reagents and change in the products • state symbols are not required for full marks • where state symbols given, observation to match • do not accept 'clear solution or liquid' without reference to colour.	

(c) A piece of aluminium foil is added to a 0.1 mol L^{-1} nickel(II) nitrate solution. (4 marks)

Description	**Marks**
Equation	
Equation $2\,A\ell(s) + 3\,Ni^{2+}(aq) \rightarrow 2\,A\ell^{3+}(aq) + 3\,Ni(s)$	
Correct species	1
Correct balancing	1
Observations	
grey/silver solid is added to green solution/liquid	1
black/silver solid precipitates and paler green/colourless solution	1
Total	**4**
Note: • maximum 1 mark for correct and balanced molecular equations • each observation requires colours of reagents and change in the products • state symbols are not required for full marks • do not accept 'clear solution or liquid' without reference to colour.	

Question 28 **(6 marks)**

Ibuprofen is a chemical used as a pain killer and anti-inflammatory. It is insoluble in water, but it is soluble in ethanol. The structure of ibuprofen is shown below.

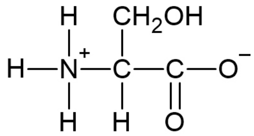
Using your understanding of intermolecular forces, explain the observed solubilities of ibuprofen.

Description	**Marks**
Recognition that ibuprofen contains hydrogen bonding, dipole-dipole forces and dispersion forces	1
Recognition that water contains hydrogen bonding and dispersion forces/predominantly hydrogen bonding	1
Recognition that ethanol contains hydrogen bonding, dipole-dipole forces and dispersion forces	1
Recognition that dispersion forces formed between ethanol and ibuprofen are more significant than dispersion forces formed between water and ibuprofen	1
Recognition that the energy released in the formation of hydrogen bonds, dispersion forces and dipole-dipole forces between ethanol and ibuprofen molecules are sufficient to overcome the existing forces of attraction between ibuprofen molecules and ethanol molecules	1
Recognition that the energy released in the formation of hydrogen bonds and dispersion forces between water and ibuprofen molecules are insufficient to overcome the forces of attraction between ibuprofen molecules and between the water molecules	1
Total	**6**
Note: Also accept responses that refer to strength of intermolecular forces	

Question 29 **(7 marks)**

Formation of zwitterions is a characteristic property of α-amino acids.

(a) Describe the structure of a zwitterion and explain its formation from an α-amino acid. Include the structural formula of the α-amino acid, serine, as a zwitterion in your answer. (4 marks)

Description	Marks
Recognition that a zwitterion is a dipolar ion where positively and negatively charged atoms are present in the same molecule	1
Recognition that the carboxylic acid group (is weakly acidic and) donates H^+ which is accepted by the (basic) amine group (to produce the dipolar ion)	1
Serine zwitterion structure  $\mathrm{H-\underset{H}{\overset{H}{N^{+}}}-\underset{H}{\overset{CH_2OH}{C}}-\underset{\overset{\parallel}{O}}{C}-O^{-}}$	
Correct structure	1
Positive charge on nitrogen and negative charge on carboxylate oxygen	1
Total	**4**
Note: minor transcription error maximum of one mark for serine zwitterion structure.	

(b) Explain why α-amino acids have relatively high melting points compared to other polar compounds with similar molar mass. (3 marks)

Description	Marks
Recognition that α-amino acids exist as zwitterions in the solid state and the attractive force between them is ionic bonding	1
which is stronger than intermolecular forces for other polar molecules (hydrogen bonding and/or dipole-dipole attraction)	1
Recognition that the strong attractive forces between zwitterions requires greater energy to overcome and this results in a higher melting point	1
Total	**3**

Question 30 **(6 marks)**

Two major impacts of increasing atmospheric carbon dioxide levels are decreasing ocean pH and decreasing ocean calcium carbonate availability. Consider the equilibrium reactions, represented by the following equations.

With reference to chemical equilibrium principles and the equations provided, explain each of the following major impacts of increasing atmospheric carbon dioxide concentrations.

(a) Decreasing pH. (4 marks)

Description	Marks
Recognition that increasing atmospheric carbon dioxide levels leads to increased dissolved carbon dioxide in the ocean which shifts the equilibrium to the right (equation 1)	1
Recognition that as the carbonic acid concentration increases, the equilibrium shifts to the right in equation 2 which increases the [H^+]	1
Recognition that as [HCO_3^-] increases as represented in equation 2, the equilibrium in equation 3 shifts to the right which increases the [H^+] Alternative response (both acceptable) Recognition that as both [HCO_3^-] and [H_3O^+] increase, equation 3 may shift to the left due to the greater impact of increased [HCO_3^-], there is still an overall increase in the [H_3O^+] in the system	1
Recognition that increased hydrogen ion concentration results in decreased ocean pH	1
Total	**4**

(b) Decreasing calcium carbonate availability. (2 marks)

Description	Marks
Recognition that as [H^+] increases, the equilibrium represented by equation 4 shifts to the right	1
Recognition that $CaCO_3$ is consumed in this shift of equilibrium, reducing the amount available	1
Total	**2**

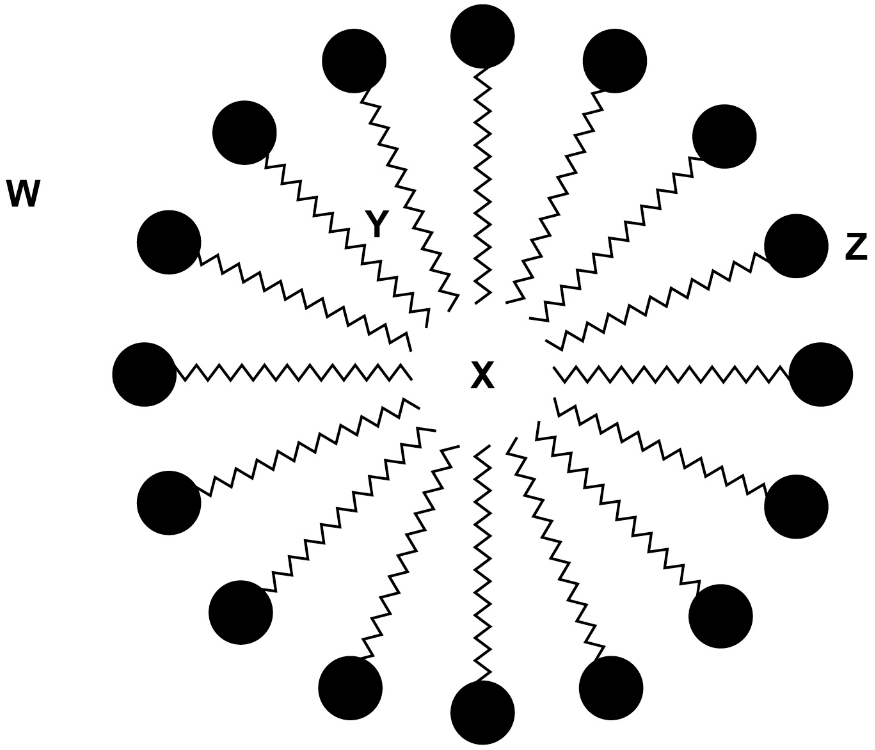
Question 31 **(6 marks)**

A representation showing the general structure of soap and detergent species is shown below.

(a) Identify **one** similarity and **one** difference between the structure of soap and detergent. (2 marks)

Description	Marks
Similarity: recognition that both structures have a long, non-polar tail **or** both structures have polar (or ionic) 'head'	1
Difference: recognition that the structures of soaps have a carboxylate head and the structures of detergents have a sulfonate head	1
Total	**2**

(b) A representation of a micelle, which shows how soap and detergent species assemble in water, is given below. Label the diagram with the letter corresponding to the following features of a micelle. (4 marks)

Description	Marks
W clearly positioned outside the micelle	1
X clearly positioned within the micelle	1
Y clearly positioned within the micelle. May be between hydrocarbon chains or between the hydrocarbon chains and the grease/dirt particle if located within the micelle	1
Z clearly indicating the polar head group of the soap/detergent species	1
Total	**4**
	

Question 32 **(9 marks)**

A buffer solution containing 0.1 mol L^{-1} ammonia and 0.1 mol L^{-1} ammonium chloride is used in a laboratory-scale experiment involving a biological process.

(a) Write the equation for the equilibrium reaction in the buffer solution involving the weak acid and its conjugate base. (2 marks)

Description	Marks
Equation	
$NH_4^+(aq) + H_2O(\ell) \rightleftharpoons NH_3(aq) + H_3O^+(aq)$ …(1) or $NH_3(aq) + H_2O(\ell) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$ …(2)	
Correct reactants and products	1
Double arrow	1
Total	**2**

(b) Label the weak acid and its conjugate base in the above equation. (1 mark)

Description	Marks
NH_4^+ labelled as acid and NH_3 labelled as base	1
Total	**1**

(c) The biological process in the experiment produces a small amount of strong acid. Predict and explain the impact on the pH of the buffer solution. (3 marks)

Description	Marks
Recognition that the strong acid produced in the experiment increases the hydrogen ion concentration	1
Recognition that the buffer equilibrium will shift to the left to counteract the imposed change (as H_3O^+ reacts with NH_3)	1
the pH will only drop slightly	1
Total	**3**
Note: answer must be consistent with the equation provided in (a)	

(d) Define the term 'buffer capacity'. (1 mark)

Description	Marks
Buffer capacity represents the amount of acid or base that can be added before the pH changes by more than one unit of pH/significant change	1
Total	**1**

(e) Identify **two** factors that determine buffer capacity of a system. (2 marks)

Description	Marks
actual concentration of both weak acid and its conjugate base	1
relative concentrations of weak acid and its conjugate base	1
Total	**2**

Question 33 **(12 marks)**

(a) Consider the following oxidation-reduction equation:

$$C\ell O_3^- + 3\ H_2O + 3\ SO_2 \rightarrow 3\ SO_4^{2-} + C\ell^- + 6\ H^+$$

Complete the table below by writing the appropriate formula of the species required. (3 marks)

Description	Formula	Marks
Species increasing in oxidation number	(sulfur in) SO_2	1
Species with highest oxidation number	(sulfur in) SO_4^{2-}	1
Species acting as the oxidising agent	(chlorine in) $C\ell O_3^-$	1
	Total	**3**

(b) Write the **two** half-equations and the overall equation for the reaction between excess MnO_4^- (aq) and $CH_3OH(\ell)$ in acidic conditions. (5 marks)

Description	Marks
Reduction half-equation	
Equation $MnO_4^-(aq) + 8\ H^+(aq) + 5\ e^- \rightarrow Mn^{2+}(aq) + 4\ H_2O(\ell)$	
Correct half-equation	1
Oxidation half-equation	
Equation $CH_3OH(\ell) + H_2O(\ell) \rightarrow HCOOH(aq) + 4\ H^+(aq) + 4\ e^-$	
Correct species	1
Correct balancing	1
Overall redox equation	
Equation $5\ CH_3OH(\ell) + 4\ MnO_4^-(aq) + 12\ H^+(aq) \rightarrow 5\ HCOOH(aq) + 4\ Mn^{2+}(aq) + 11\ H_2O(\ell)$	
Correct species	1
Correct balancing	1
Total	**5**
Note: state symbols are not required for full marks.	

(c) Select a species on the Standard Reduction Potential table with which MnO_4^- (aq) would **not** be expected to react. Include a calculation as part of an explanation for why this is so. (4 marks)

Description	**Marks**
Selects an appropriate species, i.e. from above MnO_4^- on the Standard Reduction table or below, and a reductant For example: F^-(aq), $PbSO_4$(s) or $C\ell_2$(g)	1
Provides appropriate voltage calculation For example (half-equations not required) $MnO_4^-(aq) + 8\ H^+(aq) + 5\ e^- \rightleftharpoons Mn^{2+}(aq) + 4\ H_2O(\ell)$ E° + 1.51 V $2\ F^-(aq) \rightleftharpoons F_2(g) + 2\ e^-$ E° - 2.89 V Predicted voltage under standard conditions = - 1.38 V	1
Recognition that if the predicted voltage is negative the reaction will not be spontaneous	1
Recognition that the reaction would require a driving force/external voltage to be applied	1
Total	**4**
Note: for $H_2O(\ell)$ voltage = -0.25 V $PbSO_4$(s) voltage = -0.18 V $C\ell_2$(g) = -0.12 V	

Question 34 **(8 marks)**

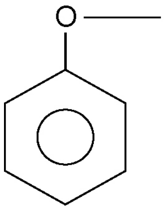
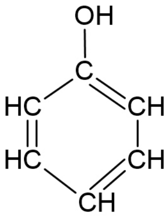
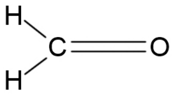
Calculate the final pH of a solution produced by adding 50.00 mL of 0.0877 mol L^{-1} hydrochloric acid solution to 38.00 mL of 0.158 mol L^{-1} barium hydroxide solution.

Description	Marks
Calculate the number of moles of H^+ $n(H^+) = 0.0500 \times 0.0877$ $= 0.004385$ mol	1
Calculate the number of moles of OH^- $n(OH^-) = 2 \times 0.038 \times 0.158$ $= 0.012008$ mol	1–2
Identify the excess reagent Reaction is 1:1, so OH^- in excess as $n(OH^-) > n(H^+)$	1
Calculate the number of moles of excess reagent (OH^-) $n(OH^-\text{excess}) = 0.012008 - 0.004388$ $= 0.00762$ mol	1
Calculate the concentration of $[OH^-]$ $[OH^-] = 0.00762/0.088$ $= 0.08659$ mol L^{-1}	1
Convert $[OH^-]$ to $[H^+]$ $[H^+] = 1 \times 10^{-14}/0.08659$ $= 1.15 \times 10^{-13}$ mol L^{-1}	1
Calculate pH $pH = -\log(1.15 \times 10^{-13})$ $= 12.9$	1
Total	**8**
Note: accept calculation of pOH and then pH.	

Question 35 **(6 marks)**

Bakelite was one of the first commercially-produced plastics. It is formed from monohydroxybenzene, C_6H_5OH, and methanal through a complex reaction that produces species that then undergo a condensation reaction to form the polymer bakelite.

(a) Draw the structures of the initial compounds showing all atoms and bonds. (4 marks)

Description	Marks
Correct structure for monohydroxybenzene  or 	1–2
Correct structure for methanal 	1–2
Total	**4**
Note: inaccurate connectivity – maximum of 1 mark per structure. Minor error – maximum of 1 mark per structure.	

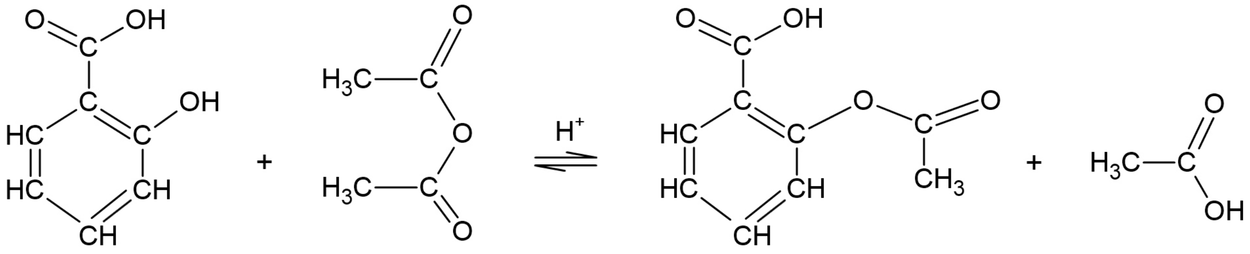
(b) State **two** characteristics of a condensation polymer reaction. (2 marks)

Description	Marks
Recognition that monomer/s have two reactive functional groups	1
Recognition that a small molecule is also produced (as well as the polymer)	1
Total	**2**
Note: accept production of water.	

Section Three: Extended answer **40% (87 Marks)**

Question 36 **(16 marks)**

The active ingredient in aspirin, a painkiller, is acetyl salicylic acid. Acetyl salicylic acid is prepared by a reaction between salicylic acid and acetic anhydride in the presence of a sulfuric acid catalyst. The reaction can be represented by the following equation:



(a) Given the above reaction is endothermic, outline and justify the optimal conditions for the preparation of acetyl salicylic acid. (6 marks)

Description	Marks
Recognition that high rate will be favoured by	
high temperature as a greater proportion of the collisions will be successful due to greater average kinetic energy	1
addition of a catalyst as greater proportion of particles will have sufficient energy to react due to alternative pathway with lower activation energy	1
higher concentration of reactants as more particles available for collision, increasing frequency of successful collisions	1
Recognition that high yield will be favoured by	
high temperature as endothermic reaction direction (which is forward reaction) is favoured by high temperatures	1
increase concentration of reactants, e.g. acetic anhydride, as forward direction will be favoured	1
removal of product, as forward direction will be favoured to reduce change	1
Total	**6**

A packet of aspirin was purchased that was labelled as double strength and should contain 500 mg of aspirin compared to standard strength tablets, which tend to contain between 300 and 320 mg of aspirin. A student removed five tablets from the packet and ground them up. The powder was then reacted with 150.00 mL of 0.0842 mol L^{-1} sodium hydroxide solution.

The resulting solution was added to a 250.0 mL volumetric flask and deionised water added up to the mark. Aliquots (25.00 mL) of the solution were titrated against a standardised 0.03033 mol L^{-1} hydrochloric acid solution.

The molar mass of aspirin is 180.158 g mol^{-1}.

The following results were obtained.

	Trials			
	1	**2**	**3**	**4**
Final volume (mL)	16.40	30.17	18.96	32.70
Initial volume (mL)	2.40	16.40	5.25	18.96
Titre (mL)	**14.00**	**13.77**	**13.71**	**13.74**

(b) Complete the table above and calculate the average titre. (2 marks)

Description	Marks
Calculate average titre without outlier (13.77 + 13.71 + 13.74)/3 =13.74 mL (or 0.01374 L)	2
Includes outlier in calculation Average titre = 13.81 mL	1
Total	**2**
Note: if only the table is completed – maximum 1 mark.	

Question 36 (continued)

(c) Calculate the mass of aspirin (in mg) in each tablet and comment on the accuracy of the packet label. (8 marks)

Description	Marks
Calculate n(OH^-) added initially n(OH^-) = 0.150 × 0.0842 = 0.01263 mol	1
Calculate n(H^+) added through titration with 25.00 mL aliquots n(H^+) = 0.01374 × 0.03033 = 4.167×10^{-4} mol	1
Calculate n(H^+) that would react with 250.0 mL of solution n(H^+) = $4.167 \times 10^{-4} \times 250/25$ = 4.167×10^{-3} mol	1
Calculate the n(OH^-) that reacted with aspirin in solution n(OH^-react) = n(OH^- initial) - n(H^+) = $0.01263 - 4.167 \times 10^{-3}$ = 8.463×10^{-3} mol = n(aspirin in 5 tablets)	1
Calculate the number of moles of aspirin in one tablet n(aspirin in 1 tablet) = $8.463 \times 10^{-3}/5$ = 1.693×10^{-3} mol	1
Calculate the mass of aspirin in one tablet m(aspirin) = $180.158 \times 1.693 \times 10^{-3}$ = 0.305 g	1
Convert the mass of mg m = 0.305 × 1000 = 305 mg	1
Comment on the labelling Recognition that tablets are incorrectly labelled as double strength/tablets are standard strength	1
Total	**8**
Note: different methods may be used to obtain the correct answer, steps must be logical.	
Note: If a 2:1 ratio used m = 152 mg.	

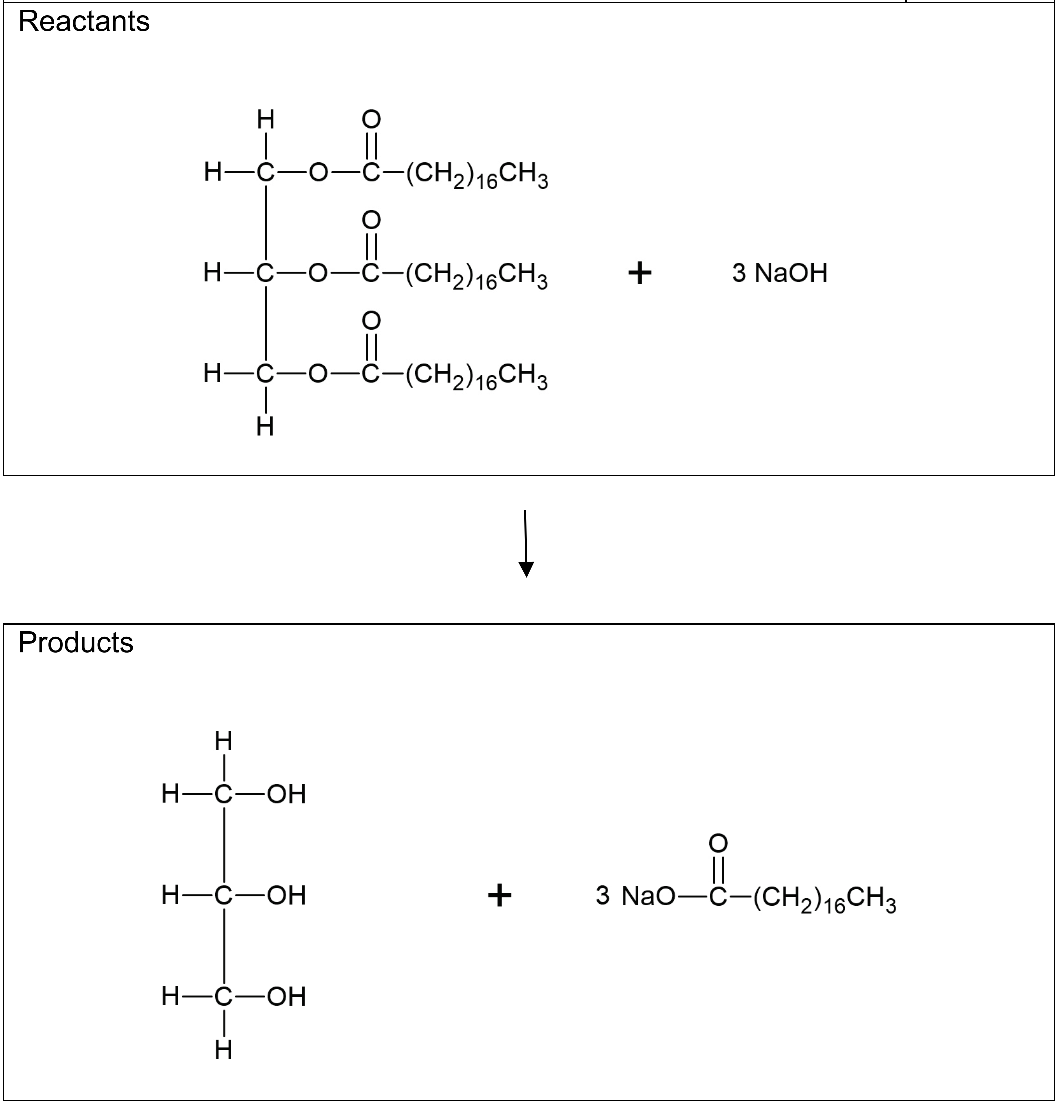
Question 37 **(22 marks)**

Triglycerides may be used in chemical synthesis processes to manufacture both soaps and biodiesel.

(a) Write balanced equations to show the reagents required and all products formed in the synthesis of soap in saponification of tristearin, and the synthesis of biodiesel in base-catalysed transesterification of tristearin. The structural formula of the reactant tristearin, a common triglyceride, and the product glycerol are given. There are separate boxes for reactants and products to help structure your answers.

(i) Balanced equation for the formation of soap from tristearin. (3 marks)

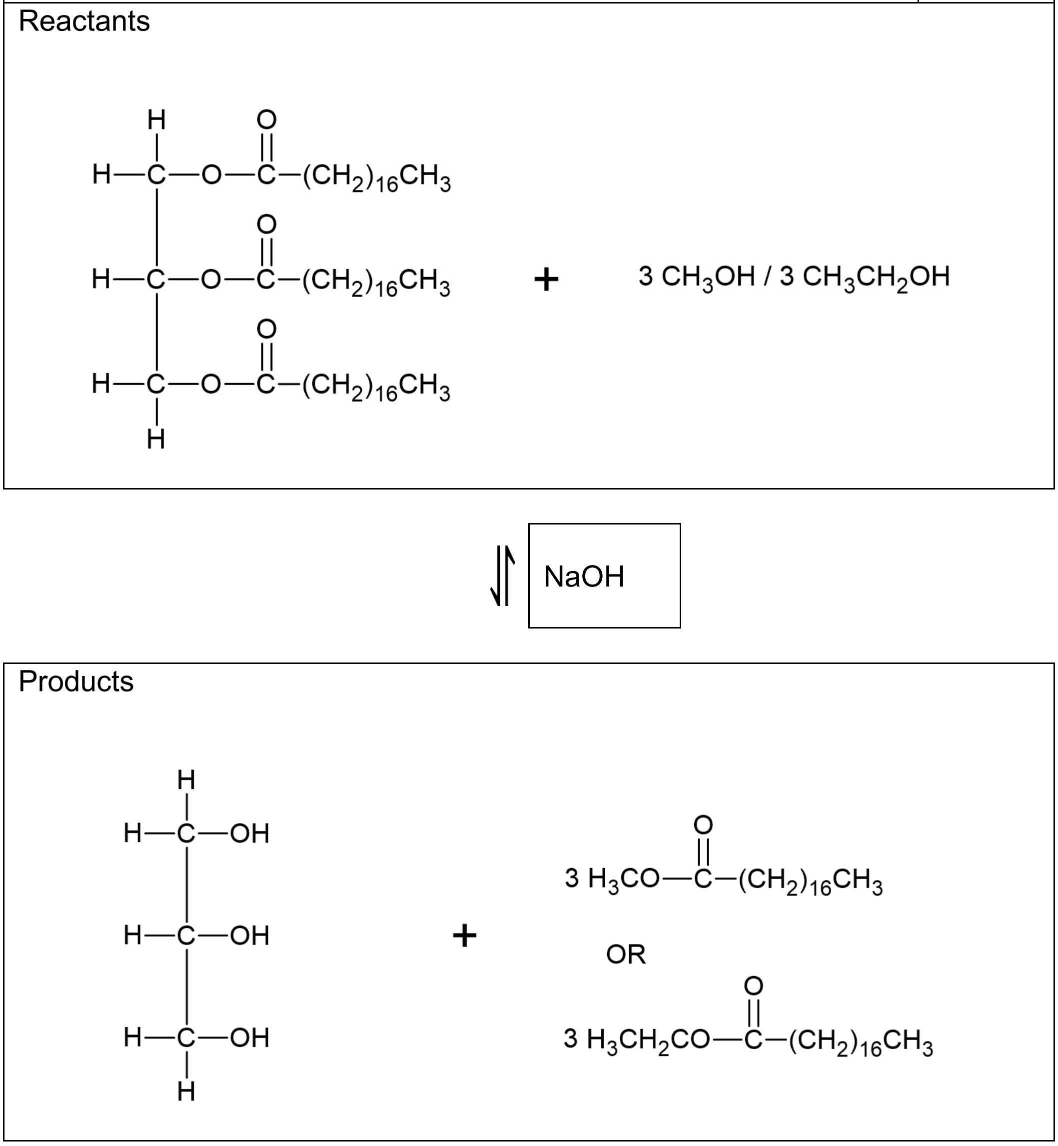
Description	Marks
Correct missing reactant (NaOH) and product (sodium stearate)	1–2
Correct balancing	1
Total	**3**



Question 37 (continued)

(ii) Write the balanced equation for the formation of biodiesel from tristearin. (4 marks)

Description	Marks
Correct missing reactant (methanol or ethanol) and product (methyl or ethyl stearate)	1–2
Correct catalyst (NaOH) next to equilibrium arrow	1
Correct balancing	1
Total	**4**



An alternative method for biodiesel synthesis is lipase-catalysed transesterification of triglycerides. Lipases are enzymes that may be isolated from many biological sources.

(b) Biodiesel production would not be viable in the absence of a base or lipase catalyst. Use collision theory to explain how the presence of catalysts makes the production of biodiesel viable in these processes. (3 marks)

Description	Marks
Recognition that catalysts improve the viability of processes by increasing reaction rates	1
Recognition that catalysts provide an alternative reaction pathway with lower activation energy	1
Recognition that with reduced activation energy there will be a greater proportion of successful collisions occurring with sufficient energy (and a higher frequency of successful collisions)	1
Total	**3**

(c) Lipase-catalysed transesterification occurs under milder conditions of temperature and pH compared to the base-catalysed process. Explain why these conditions are a requirement and state **one** advantage for this biodiesel production. (3 marks)

Description	Marks
Requirement for mild temperature and pH	
Recognition that lipases are enzymes/biological catalysts that function in a narrow range of temperature and pH	1
Recognition that enzymes/biological catalysts lose their function/denature at high temperature and high or low pH/outside of the range	1
Advantage for biodiesel production, any one of	
• lower energy requirement • less chance of side reactions such as soap formation • easier purification of final products • more sustainable • reduces environmental impacts	1
Total	**3**
Accept other valid advantages.	

Information about the structure of a lipase B enzyme (Chain A) from the yeast species *Candida antarctica* is freely available through the Protein Data Bank (PDB). Use this information to answer part (d).

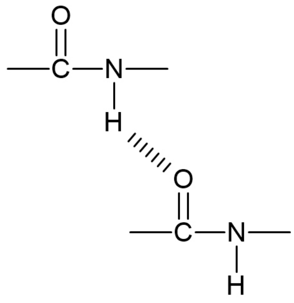
(d) A portion of this lipase B structure is highlighted in a box on the image above. Identify this structural feature of the protein and state the level of protein structure. (2 marks)

Description	Marks
Structure feature: α-helix	1
Level of protein structure: secondary	1
Total	**2**

Question 37 (continued)

Another example of this level of protein structure visible in the image are β-pleated sheets.

(e) The formation of β-pleated sheets and the structure identified in part (d), on page 26, form through the same type of intermolecular force. Name and describe this intermolecular force, including a diagram that shows which atoms of the protein structure are involved.
(4 marks)

Description	Marks
Intermolecular force is named – hydrogen bonding	1
Recognition that the hydrogen bonding forms due to the attraction between the (slightly positive) hydrogen on one part of the structure and the lone pair of an oxygen on an adjoining part of the structure	1
Diagram shows amide groups	1
Diagram shows a dotted line correctly showing the hydrogen bonding	1
Total	**4**
Diagram: 	

The sequence of 317 amino acids of this lipase B protein chain is given in the PDB. The presence of three disulfide bridges is clearly represented in the data.

(f) Identify the amino acid where disulfide bridges can form. (1 mark)

Description	Marks
cysteine	1
Total	**1**

(g) Disulfide bridges are an example of a protein tertiary structure. Define 'tertiary structure' and outline how it forms. (2 marks)

Description	Marks
Recognition that tertiary structure of a protein is the overall shape/3-D structure of the protein and is a result of the polypeptide folding	1
Recognition that this tertiary structure forms due to interactions between side chains of the α-amino acids in the polypeptide	1
Total	**2**

Question 38 **(15 marks)**

Doxylamine succinate is an antihistamine, which is used to treat hay fever, and, as one of its side-effects is drowsiness, it is also used as a sleep aid. Doxylamine succinate contains carbon, hydrogen, oxygen and nitrogen.

(a) A 2.500 g sample of the compound was combusted, and 5.94 g of carbon dioxide and 1.63 g of water were produced. All of the nitrogen from a second 2.500 g sample was converted to ammonia and reacted with a 0.823 mol L^{-1} solution of hydrochloric acid. 15.6 mL of the acid was required to react completely with the ammonia.

Determine the empirical formula for doxylamine succinate. (11 marks)

Description	Marks
Calculate n(C) $n(C) = n(CO_2) = 5.94/44.01$ $= 0.135$ mol	1
Calculate m(C) $m(C) = 0.135 \times 12.01$ $= 1.62$ g	1
Calculate n(H) $n(H) = 2 \times n(H_2O) = 2 \times 1.63/18.016$ $= 0.181$ mol	1
Calculate m(H) $m(H) = 0.181 \times 1.008$ $=0.1824$ g	1
Calculate n(N) $n(N) = n(H^+) = 0.823 \times 0.0156$ $=0.01284$ mol	1
Calculate m(N) $m(N) = 0.01284 \times 14.01$ $= 0.1799$ g	1
Calculate m(O) $m(O) = 2.50 – (1.62 + 0.1824 + 0.1799)$ $= 0.518$ g	1
Calculate n(O) $n(O) = 0.518/16.00$ $= 3.235 \times 10^{-2}$ mol	1
Calculate ratio of number of moles Determine lowest whole number formula	1–2
State empirical formula $C_{21}H_{28}N_2O_5$	1
Total	**11**

	C	H	N	O
n	0.135	0.181	0.01284	3.235×10^{-2}
÷ 0.01284	10.5	14	1	2.5
× 2	21	28	2	5

Note: accept alternative methods, e.g. using percentage composition.
%C = 64.84
%H = 7.296
%N = 7.188
%O = 20.68

Question 38 (continued)

(b) Doxylamine succinate is also a weak base. A 19.42 mg sample of doxylamine succinate required 1.00 mL of a 0.100 mol L^{-1} $HC\ell O_4$ acid solution for neutralisation.

Using a calculation, identify how many protons (hydrogen ions) a doxylamine succinate molecule can accept. The molar mass of doxylamine succinate is 388.46 g mol^{-1}.

(4 marks)

Description	Marks
Calculate n($HC\ell O_4$) n($HC\ell O_4$) = 0.00100 × 0.100 = 1×10^{-4} mol	1
Calculate the number of moles of doxylamine succinate n(doxylamine succinate) = 0.01942/388.46 5×10^{-5} mol	1
Determine ratio of $HC\ell O_4$ to doxylamine succinate Ratio n($HC\ell O_4$):n(doxylamine succinate) = 1×10^{-4}:5×10^{-5} = 2:1	1
Therefore, doxylamine succinate accepts 2 protons per molecule	1
Total	**4**

Question 39 **(17 marks)**

Steel poles are used as 'power poles' to hold streetlights and carry electricity to businesses and houses. While being stronger than timber poles and not prone to rotting, they do have the capacity to rust.

A steel pole was treated to inhibit rusting but when soil was removed at its base, significant rusting could be observed.

(a) Refer to one or more equations below, representing the various parts of the rusting process, and explain why the steel pole rusts below ground level but there were no signs of rusting above ground level. (5 marks)

Equation 1 $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$
Equation 2 $O_2(g) + 2\,H_2O(\ell) + 4\,e^- \rightarrow 4\,OH^-(aq)$
Equation 3 $4\,Fe^{2+}(aq) + 4\,H^+(aq) + O_2(aq) \rightarrow 4\,Fe^{3+}(aq) + 2\,H_2O(\ell)$
Equation 4 $Fe^{3+}(aq) + 3\,OH^-(aq) \rightarrow Fe(OH)_3(s)$
Equation 5 $4\,Fe(OH)_2(s) + O_2(g) + x\,H_2O(\ell) \rightarrow 2\,Fe_2O_3.(x+4)H_2O(s)$

Description	Marks
Recognition that rusting requires oxidation of iron (reference equation 1) and reduction of oxygen in the presence of water (equation 2)	1
Any two of	
• recognition that oxidation and reduction processes do not need to occur at the same place • recognition that iron acts as a conductor of electrons from the site of oxidation to the site of reduction • recognition that the soil may be acidic (reference equation 3)	1–2
Any one of	
• recognition of the effect of differential aeration in reduction occurring above the surface of the soil and oxidation can occur below the surface of the soil • recognition that moisture retention in the soil means that water is more commonly present below the surface	1
Reference to at least one equation in appropriate context	1
Total	**5**

Question 39 (continued)

After the surrounding soil was dug away to expose the pole, two different attempts were made to protect it from rusting any further. One was to paint the pole and the other was to connect a wire from it to a piece of metal in the ground. Neither attempt was successful in preventing further rusting.

(b) Explain why these two methods did **not** work as intended. If appropriate, include an equation in your answer.

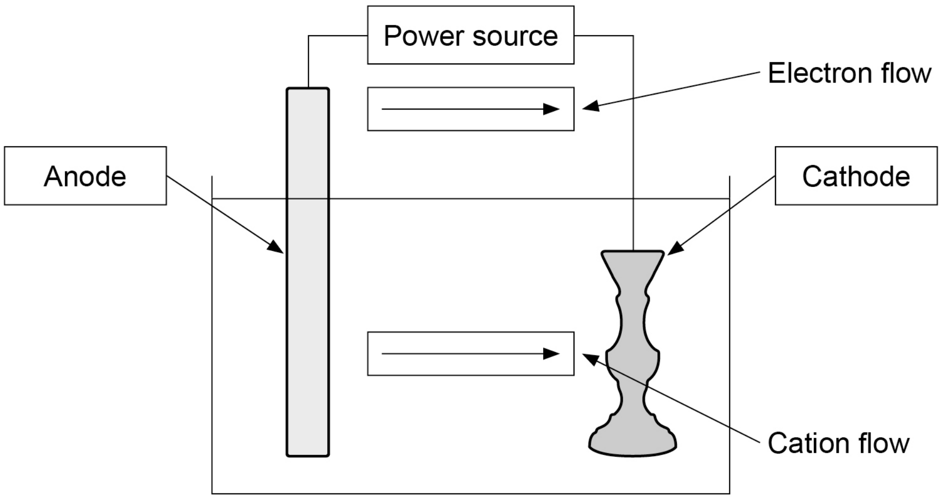
(i) Painting the pole. (2 marks)

Description	Marks
Recognition that painting produces a barrier between the iron and (oxygen) and water	1
Recognition that given the method is not successful, the barrier is not complete	1
Total	**2**

(ii) Attaching a wire to a second metal. (3 marks)

Description	Marks
Recognition that the wire acts as a conductor between the iron and second metal	1
Recognition that the second metal should oxidise instead/preferentially of the iron	1
Recognition that, given the method is unsuccessful, that the second metal is (one of the following): • less reactive than iron • less likely to oxidise than iron • has a higher reduction potential/lower oxidation potential than iron	1
Total	**3**

(c) Consider the following electrolytic cell used for the chrome plating of a candlestick. The cell consists of a lead electrode, the item to be plated and a chromium(III) chloride solution. Another chemical is added to prevent the Cr^{3+} from oxidising.



In the spaces above, label the above diagram to show the:

- anode and cathode
- direction of cation flow
- direction of electron flow. (3 marks)

Description	Marks
Anode and cathode correctly labelled	1
Direction of cation flow correctly labelled	1
Direction of electron flow from anode to cathode	1
Total	**3**

(d) Write ionic half-equations for the reactions occurring at the anode and the cathode. (2 marks)

Description	Marks
Anode half-equation	
Correct species and balancing $Pb \rightarrow Pb^{2+} + 2e^-$	1
Cathode half-equation	
Correct species and balancing $Cr^{3+} + 3e^- \rightarrow Cr$	1
Total	**2**

(e) State **two** reasons why the actual voltage required to run this cell is higher than the value that would be calculated using the standard reduction potentials. (2 marks)

Description	Marks
Any two of	
• concentrations may not be at standard conditions • temperature not at standard conditions • additional voltage required to overcome activation energy of reaction (overvoltage) • impurities may be present which result in competing reactions or impede the required reaction • internal resistance in the circuit	1–2
Total	**2**
Accept other relevant answers.	

Question 40 **(17 marks)**

Step 1
Nickel(II) oxide is reacted with hydrogen to produce nickel metal and water at 200 °C, according to the equation:

$$NiO(s) + H_2(g) \rightarrow Ni(s) + H_2O(g)$$

The nickel produced is impure and must be further purified.

Step 2
The impure nickel is reacted with carbon monoxide to produce nickel carbonyl ($Ni(CO)_4$).

$$Ni(s) + 4\ CO(g) \leftrightharpoons Ni(CO)_4(g)$$

The impurities in the nickel are left as solids and separated.

Step 3
The nickel carbonyl gas is then passed over a platinum catalyst, causing the compound to decompose.

$$Ni(CO)_4(g) \leftrightharpoons Ni(s) + 4\ CO(g)$$

(a) If the nickel produced in Step 1 is 95.7% pure, calculate the mass of nickel(II) oxide that would be required to produce 2245 tonne of the impure nickel. (5 marks)

Description	Marks
Convert the mass of nickel from tonnes to grams m(Ni) = 2245 × (1 x 10^6) = 2.245 × 10^9 g	1
Calculate the mass of nickel in the impure sample m(Ni) = (2.245 × 10^9) × 95.7/100 = 2.148 × 10^9 g	1
Calculate the n(Ni) n(Ni) = (2.148 × 10^9)/58.69 = 3.661 × 10^7 mol	1
Calculate the n(NiO) n(Ni) = n(NiO) = 3.661 × 10^7 mol	1
Calculate the mass of NiO m(NiO) = (3.661 × 10^7) × 74.69 = 2.73 × 10^9 g (2730 tonne)	1
Total	**5**

(b) In Step 2, if the impure nickel mixture contains 521 tonne of pure nickel and produces 1025 tonne of $Ni(CO)_4$, calculate the percentage yield of this reaction. (4 marks)

Description	Marks
Calculate n(Ni) $= (5.21 \times 10^8)/58.69$ $= 8.877 \times 10^6$ mol	1
Calculate the theoretical $n(Ni(CO)_4)$ $n(Ni(CO)_4) = n(Ni)$ $= 8.877 \times 10^6$ mol	1
Calculate the theoretical mass $= 170.73 \times (8.877 \times 10^6$ mol) $= 1.516 \times 10^9$ g	1
Calculate the percentage yield $= (1.025 \times 10^9)/(1.516 \times 10^9) \times 100$ $= 67.6\%$	1
Total	**4**

(c) A 19.22 g sample of the impure nickel from Step 1, on page 34, was reacted with 90.00 mL of a 5.02 mol L^{-1} solution of nitric acid. This reaction can be represented by the following equation:

$$3\ Ni(s) + 8\ HNO_3(aq) \rightarrow 3\ Ni(NO_3)_2(aq) + 2\ NO(g) + 4\ H_2O(\ell)$$

Calculate the volume of nitrogen monoxide produced measured at standard temperature and pressure (STP). (8 marks)

Description	Marks
Calculate the number of moles of Ni $= 19.22 \times 0.957/58.69$ $= 0.3134$ mol	1–2
Calculate the number of moles nitric acid $n(HNO_3) = 0.0900 \times 5.02$ $= 0.4518$ mol	1
Determine the limiting reagent $n(Ni) = 3/8\ n(HNO_3)$ From 0.4518 mol of HNO_3 $n(Ni) = 3/8(0.4518)$ $= 0.1694$ mol is produced $n(HNO_3$ required) < $n(HNO_3$ available) Therefore, HNO_3 is limiting reagent	1–3
Calculate the number of moles of NO $n(NO) = 2/8n(HNO_3)$ $= 0.4518/4$ $= 0.1129$	1
Calculate the volume of NO $V(NO) = 22.71 \times 0.1129$ $= 2.57$ L	1
Total	**8**

Published by the School Curriculum and Standards Authority of Western Australia
303 Sevenoaks Street
CANNINGTON WA 6107