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

CHEMISTRY

ATAR course examination 2020

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.

2020/65375

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

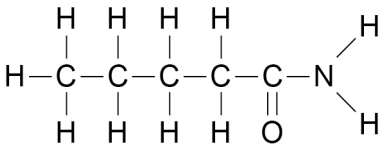
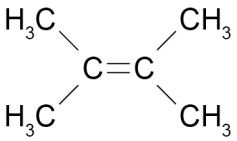
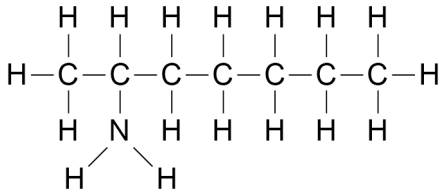
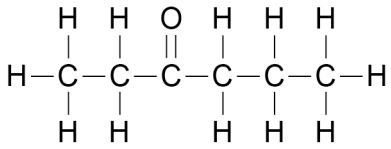
Question	Answer
1	c
2	b
3	b
4	c
5	a
6	d
7	a
8	c
9	a
10	d
11	b
12	c
13	a
14	d
15	b
16	a
17	d
18	b
19	d
20	a
21	c
22	b
23	c
24	d
25	b

Section Two: Short answer **35% (76 Marks)**

General Notes:
- Answers provided in brackets are desired but not essential for the relevant mark to be allocated.
- Clear and unambiguous demonstration of the candidate's understanding in their response is required rather than the exact wording in the marking key.
- Notes provided within the marking key will indicate which elements of the model answers are required for the allocated mark.

Question 26 **(4 marks)**

Complete this table by giving the IUPAC name or full structural formula of the indicated organic compounds. All hydrogen atoms must be shown.

Full structural formula	IUPAC name	Marks
	**Answer** pentanamide	1
	**Answer** 2,3-dimethylbut-2-ene Accept 2,3-dimethyl-2-butene dimethylbut-2-ene dimethyl-2-butene	1
Answer 	heptan-2-amine	1
Answer 	hexan-3-one	1
	Total	**4**

Note:
- Structural formula must have all hydrogen atoms for the mark to be allocated.
- Condensed structures are also accepted.
- All structures require numbers except those which would have a 1.

Question 27 **(8 marks)**

Write balanced equations for any reactions occurring between the following substances and describe the observation(s).

If there is no reaction, write 'no reaction' for the equation and if there is no change observed, write 'no visible reaction' for the observations. Where applicable, use the colours stated in the Chemistry Data Booklet.

Iron filings and dilute hydrochloric acid.

Description	Marks
Equation $Fe(s) + 2\ H^+(aq) \rightarrow Fe^{2+}(aq) + H_2(g)$ **or** $Fe(s) + 2\ HC\ell(aq) \rightarrow FeC\ell_2(aq) + H_2(g)$	
correct species	1
correct balancing	1
Observations Any two of the following: • colourless, (odourless) bubbles /effervescence/gas • silver/grey solid dissolves • (pale) green solution formed	1
Total	**3**
Note: • State symbols are not required for full marks. • The candidate must provide a minimum of two correct observations for the mark to be allocated. • Do not accept 'clear solution' without reference to colour. • Each observation requires a colour (or colourless) specified.	

Chromium(III) nitrate solution and magnesium ribbon.

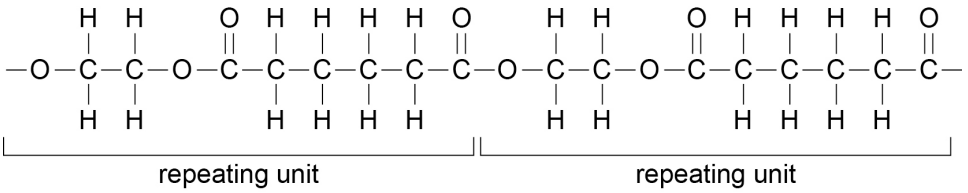
Description	Marks
Equation $2\ Cr^{3+}(aq) + 3\ Mg(s) \rightarrow 2\ Cr(s) + 3\ Mg^{2+}(aq)$ **or** $2\ Cr(NO_3)_3(aq) + 3\ Mg(s) \rightarrow 2\ Cr(s) + 3\ Mg(NO_3)_2(aq)$	
correct species	1
correct balancing	1
Observations Any two of the following: • silver/grey solid dissolves • blackish/grey/silver solid forms • solution becomes less green/colourless	1
Total	**3**
Note: • State symbols are not required for full marks. • The candidate must provide a minimum of two correct observations for the mark to be allocated. • Do not accept 'clear solution' without reference to colour. • Each observation requires a colour (or colourless) specified.	

Potassium chloride solution and bromine water.

Description	Marks
Equation • a statement indicating 'no reaction'	1
Observations • a statement indicating 'no visible reaction'	1
Total	**2**
Note: • Accept colourless solution mixed with orange/brown/red solution and no further change observed (or similar). • Do not accept NVR or NR.	

Question 28 **(5 marks)**

(a) Draw the structural formula of poly(ethylene adipate). Show two repeating units. (2 marks)

Description	Marks
 (one minor error is 1 mark only)	1–2
Total	**2**

Note:
- If only one repeating unit is shown allocate a maximum of one mark only.
- Minor errors include missing hydrogens or terminating the ends of the polymer.
- Incorrect or missing ester links is a major error, allocate 0 marks.

(b) Classify poly(ethylene adipate) according to the:

(i) functional group or groups present in its structure. (1 mark)

Description	Marks
ester/polyester	1
Total	**1**

(ii) type of reaction resulting in its formation. (1 mark)

Description	Marks
condensation (polymerisation/reaction)/esterification)	1
Total	**1**

(c) Identify a different type of reaction that results in the formation of a polymer. (1 mark)

Description	Marks
addition (polymerisation/reaction)	1
Total	**1**

Question 29 **(11 marks)**

(a) Write the equilibrium constant expression (K) for this reaction. (2 marks)

Description	Marks
$K = \frac{[H_2]^4}{[H_2S]^2\,[CH_4]}$ (one minor error is 1 mark only)	1–2
Total	**2**
Note: • Minor errors include one superscript missing or K= missing. • Accept partial pressures.	

(b) Some methane was removed from the reaction vessel. What effect did this have on the position of the equilibrium? Use collision theory to justify your answer. (5 marks)

Description	Marks
Reduced concentration/pressure of CH_4 means a decrease in the frequency of collisions between CH_4 and H_2S molecules.	1
This decreases the rate of the forward reaction.	1
The rate of the reverse reaction is not affected initially.	1
The rate of the reverse reaction, therefore, is greater than the rate of the forward reaction.	1
The equilibrium position, therefore, shifts to the left/equilibrium favours the reverse reaction.	1
Total	**5**

(c) Using the graph and your answer to part (a), predict the effect of an increase in temperature on the numerical value of K. Justify your prediction. (4 marks)

Description	Marks
Value of K decreases	1
The graph shows that as the temperature increases the number of moles (yield) of H_2 present at equilibrium decreases.	1
Recognises any two of: • $[H_2S]$ and $[CH_4]$ increase • $[H_2]$ decreases • the reverse reaction has been favoured.	1–2
Total	**4**
Note: • A justification based on Le Châtelier's Principle is acceptable. For example: As temperature increases, an endothermic reaction is favoured. This is the reverse reaction in this case.	

Question 30 **(7 marks)**

(a) Identify the atom that is oxidised and the atom that is reduced in this reaction. (2 marks)

Description	Marks
The atom that is oxidised is sulfur (or S).	1
The atom that is reduced is hydrogen (or H).	1
Total	**2**
Note: • Must have the actual atom. No marks allocated for SO_2 being oxidised or H_2O being reduced. • H^+ and S^{2-} are not acceptable answers.	

(b) Explain how the $HPO_4^{2-}/H_2PO_4^-$ prevented any significant pH change when the SO_2 was bubbled into the solution. (5 marks)

Description	Marks
Recognition that SO_2 reaction results in increase in the $[H^+]$	1
Recognition $HPO_4^{2-}/H_2PO_4^-$ is a buffer (because it is a weak base/weak acid combination)	1
Produced H^+ reacts with the HPO_4^{2-} base in the buffer.	1
Recognition that this consumes the majority of the added H^+ in the solution (therefore overall minimal increase in $[H^+]$)	1
Recognition of how $[H^+]$ links to pH	1
Total	**5**

Question 31 **(9 marks)**

(a) Complete the following sequence of equations to show what happens to carbon dioxide when it dissolves in water. (3 marks)

Description	Marks
$CO_2(g) + H_2O(\ell) \rightleftharpoons$ **$H_2CO_3(aq)$**	1
$H_2CO_3(aq) + H_2O(\ell) \rightleftharpoons$ **$HCO_3^-(aq)$** $+ H_3O^+(aq)$	1
$HCO_3^-(aq) + H_2O(\ell) \rightleftharpoons$ **$CO_3^{2-}(aq)$** $+ H_3O^+(aq)$	1
Total	**3**

Note:
- Only allocate marks for the species in the boxes shown above.
- State symbols are desirable but not essential.

(b) Other than death, state **two** consequences of the above sequence of equations on marine organisms with shells. (2 marks)

Description	Marks
States a plausible consequence	1
States another (different) plausible consequence	1
Total	**2**

Answers could include:
- building shells becomes harder
- weaker/thinner shells/poor quality shells
- makes organisms more vulnerable to predators
- less likely to grow large
- less likely to reproduce.

Note:
- Do not accept answers that refer to coral reefs or habitats.

Question 31 (continued)

(c) Use Le Châtelier's Principle and the sequence of equations in part (a) to predict what might happen, in relation to ocean acidification, if the United Nations Kyoto Protocol is discarded. Explain your reasoning. (4 marks)

Description	Marks
If the Kyoto Protocol is discarded then it is likely that there will be increased CO_2 emissions into the atmosphere that lead to increased amounts of CO_2 dissolved in the oceans.	1
Therefore, the forward reactions in the above sequence of reactions will be favoured.	1
The result is an increase in the concentration of H_3O^+ ions.	1
The prediction is, therefore, that the pH of oceans will decrease even more.	1
Total	**4**
Note: • Accept oceans become more acidic.	

Question 32 **(13 marks)**

(a) Identify the independent and dependent variables in the students' investigation. (2 marks)

Description	Marks
Independent variable = identity of the (cleaning) solvent	1
Dependent variable = the amount/extent to which the black spray paint is dissolved/removed	1
Total	**2**

(b) State **two** variables that the students needed to control in their investigation. (2 marks)

Description	Marks
Identification of one variable that needs to be controlled.	1
Identification of another (different) variable that needs to be controlled.	1
Total	**2**
Answers could include: • the brand of black spray paint • the concrete/wall the paint is sprayed on • thickness of paint • drying temperature • size of the painted areas • drying time • volume of cleaning solvent used • method used to apply the cleaning solvent.	

(c) What could the students do to ensure that their investigation was: (2 marks)

(i) valid?

Description	Marks
To make their investigation valid they will need to (either) • design/perform an investigation that compares the effectiveness of different cleaning solvents on the removal of black spray paint from concrete. • ensure the control variables are controlled.	1
Total	**1**

(ii) reliable?

Description	Marks
To make their investigation reliable they will need to repeat their investigation several times (if they obtain consistent/reproducible results then their investigation is reliable).	1
Total	**1**

Question 32 (continued)

(d) Identify **two** safety risks associated with the students' investigation and state how each risk could be minimised. (4 marks)

Description	Marks
Identification of one safety risk	1
States how to minimise that risk	1
Identification of another (different) safety risk	1
States how to minimise that risk	1
Total	**4**
Answers could include: • chemicals contacting the eyes, wear safety glasses • inhalation of fumes, wear suitable mask • chemicals contacting skin on hands, wear safety gloves • spilling chemicals on feet, wear enclosed shoes • spilling chemicals on exposed skin, wear enclosed shoes/gloves and/or lab coat.	
Note: • The risk must be a plausible risk for the investigation detailed in the question. • For full marks the minimising strategy must match the risk. • If only minimising risk box is filled in, 0 marks.	

(e) Paints contain, among other things, a pigment (which is the paint colour) and a solvent (which dissolves the pigment). When paint dries, the solvent evaporates, leaving the pigment behind.

Use this information, the students' results and your knowledge of chemistry to determine the predominant type of intermolecular force occurring between the pigment molecules in the black paint used by the students. Explain your reasoning. (3 marks)

Description	Marks
The paint's pigment molecules must have dispersion forces as their predominant intermolecular force because the best solvents have dispersion forces as their predominant intermolecular force.	1
• This is because for substances to be soluble in each other they must be able to disrupt the existing intermolecular forces and form new intermolecular forces with each other. • This can only be done if the intermolecular forces are of similar strength (hence they all need dispersion forces as their predominant intermolecular force).	1–2
Total	**3**

Question 33 **(9 marks)**

Describe the steps that will allow the chemist to synthesise ethyl pentanoate. Include balanced equations for all reactions that occur, using molecular formulae for organic compounds. Any inorganic compounds deemed necessary can be used in the procedure. It is not necessary to specify how the products of a particular reaction will be isolated before use in another reaction.

Description	Marks
Ethanol Synthesis	
• Add steam (or water and heat) and a	1
• suitable catalyst (e.g. sulfuric acid) (to some gas from the cylinder (which has already been transferred to a suitable reaction vessel)).	1
• Equation: $C_2H_4 + H_2O \rightarrow C_2H_6O$	1
Pentanoic Acid Synthesis	
• Add permanganate solution or dichromate solution or another suitable oxidising agent, plus a suitable catalyst (e.g. concentrated sulfuric acid) to some pentanal or pentan-1-ol (which has already been transferred to another suitable reaction vessel).	1
• Equation using species identified in candidate's procedure: Pentanal and permanganate: $5\ C_5H_{10}O + 2\ MnO_4^- + 6\ H^+ \rightarrow 5\ C_5H_{10}O_2 + 2\ Mn^{2+} + 3\ H_2O$ **or** Pentanal and dichromate $3\ C_5H_{10}O + Cr_2O_7^{2-} + 8\ H^+ \rightarrow 3\ C_5H_{10}O_2 + 2\ Cr^{3+} + 4\ H_2O$ **or** pentan-1-ol and permanganate $5\ C_5H_{12}O + 4\ MnO_4^- + 12\ H^+ \rightarrow 5\ C_5H_{10}O_2 + 4\ Mn^{2+} + 11\ H_2O$ **or** pentan-1-ol and dichromate $3\ C_5H_{12}O + 2\ Cr_2O_7^{2-} + 16\ H^+ \rightarrow 3\ C_5H_{10}O_2 + 4\ Cr^{3+} + 11\ H_2O$	1–2
• Combine the substances in the two reaction vessels, add some more concentrated sulfuric acid (and heat) to produce ethyl pentanoate	1
• Equation: $C_2H_6O + C_5H_{10}O_2 \rightarrow C_7H_{14}O_2 + H_2O$	1–2
Total	**9**

Note:
- Equations must be balanced but state symbols are not required.
- Equations, where two marks are allocated for each, there is one mark for correct species and one mark for correct balancing (equation must have merit).
- Accept equations written with full structural or condensed molecular formulae without any penalty.

Question 34 **(10 marks)**

(a) State whether you agree with the claims about the effects of temperature on the yield of ammonia. Justify your statement using Le Châtelier's Principle. (4 marks)

Description	Marks
Applying Le Châtelier's Principle to this system, if the temperature is raised (goes from low to high temperature) then the reverse reaction is favoured **or** Applying Le Châtelier's Principle to this system, if the temperature is reduced (goes from high to low temperature) the forward reaction is favoured.	1
This is because the reverse reaction uses heat (it is endothermic) decreasing the temperature of the system **or** This is because the forward reaction produces heat (it is exothermic) increasing the temperature of the system.	1
The result is that less ammonia is made (yield decreases) at higher temperatures **or** The result is that more ammonia is made (yield increases) at lower temperatures.	1
The quote's claims about the effect of temperature on the yield of ammonia are, therefore, correct.	1
Total	**4**
Note: • Agreement/disagreement without any justification is not worth any marks.	

(b) State whether you agree with the claims about the effects of temperature on the rate of the Haber process. Justify your statement using collision theory. (6 marks)

Description	Marks
Option One (from the perspective of low temperature): • lower temperatures decrease the average kinetic energy of the particles • fewer collisions will have energy higher than the activation energy. • a smaller <u>proportion</u> of the collisions are, therefore, successful • particles are also moving slower so collide less <u>frequently</u> • the result is that the reaction rate decreases as the temperature decreases • the quote's claim about the effect of temperature on the rate of the reaction is thus correct. **or** **Option Two** (from the perspective of high temperature): • higher temperatures increase the average kinetic energy of the particles • more collisions have energy higher than the activation energy • a greater <u>proportion</u> of the collisions are, therefore, successful • particles are also moving faster so collide more <u>frequently</u> • the result is that the reaction rate increases as the temperature increases • the quote's claim about the effect of temperature on the rate of the reaction is thus correct.	1–6
Total	**6**
Note: • Agreement/disagreement without any justification is not worth any marks. • For both approaches, allocate one mark for each dot point.	

Section Three: Extended answer **40% (88 Marks)**

Question 35 **(11 marks)**

(a) What protein structure level does the α-amino acid sequence represent? (1 mark)

Description	Marks
primary	1
Total	**1**

(b) Identify **one** similarity and **one** difference between the given α-amino acid sequences of human and grey whale Cytochrome C. (2 marks)

Description	Marks
Accept anything reasonable, e.g. There are five α-amino acids that are common to both types of Cytochrome C. They both contain lysine.	1
The third amino acid is different. The only difference is that in the position where human Cytochrome C has serine, grey whale Cytochrome C has alanine (the third amino acid in their respective sequences).	1
Total	**2**

(c) Complete the following table by identifying the predominant side chain interaction for each α-amino acid pair. (3 marks)

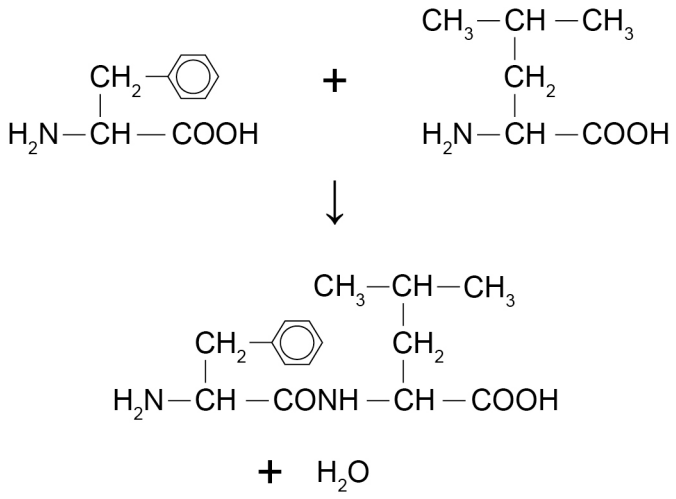
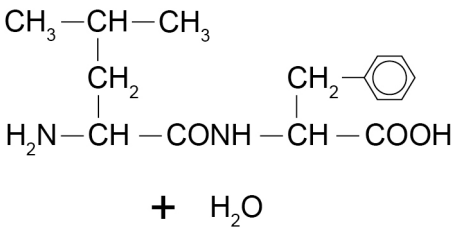
Description	Marks
Ala and Val = dispersion forces	1
Gln and His = hydrogen bonding	1
Cys and Cys = disulfide bridge (disulfide bond/covalent bond and dipole-dipole also acceptable)	1
Total	**3**

(d) The biochemist found that both human and grey whale Cytochrome C contain several alpha helices but no beta-pleated sheets. What protein structure level do alpha helices and beta-pleated sheets represent? (1 mark)

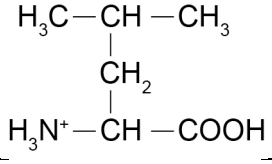
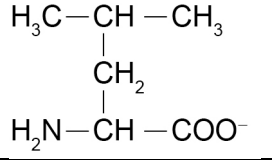
Description	Marks
secondary	1
Total	**1**

Question 35 (continued)

(e) Write a balanced equation, using condensed structural formulae, for a reaction that occurs between phenylalanine and leucine. (2 marks)

Description	Marks
 **Or** 	1–2
Total	**2**
Note: • One minor error maximum one mark e.g. no water, single transcription error. • Out of two possible organic products, only one is required. • Zwitterion form is also accepted.	

(f) The biochemist decided to examine how the structure of leucine changes with solution pH. Complete the following table by drawing the structural formula of leucine at the indicated pH. (2 marks)

Description		Marks
Structural formula of leucine	**pH**	
	acidic	1
	alkaline	1
	Total	**2**
Note: Wrong amino acid, maximum 1 mark.		

Question 36 **(16 marks)**

(a) A partially-labelled diagram of the galvanic cell built by the student is shown below. What substances should the student have used in the parts labelled (i) to (iv) to build a functioning galvanic cell? Write the names of these substances in the boxes provided. (4 marks)

Description	Marks
Option One	
(i) magnesium	1
(ii) copper or graphite	1
(iii) (1.0 mol L^{-1}) magnesium sulfate (solution)	1
(iv) (1.0 mol L^{-1}) copper(II) sulfate (solution)	1
or	
Option Two	
(i) Copper or graphite	1
(ii) magnesium	1
(iii) (1.0 mol L^{-1}) copper(II) sulfate (solution)	1
(iv) (1.0 mol L^{-1}) magnesium sulfate (solution)	1
Total	**4**
Note: • Accept formulae instead of names.	

(b) Add arrows to the diagram in part (a) to show the direction of movement of electrons through the external circuit. (1 mark)

Description	Marks
arrow on/near the wire pointing from Mg to Cu/C	1
Total	**1**

(c) Write the half-equations for the reactions occurring at the anode and the cathode in the student's galvanic cell. (4 marks)

Description	Marks
Anode half-equation $Mg(s) \rightarrow Mg^{2+}(aq) + 2e^-$	1–2
Cathode half-equation $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	1–2
Total	**4**
Note: • Anode and cathode reactions in wrong boxes – maximum of 3 marks. • Negative charge missing from electrons – maximum of 3 marks. • State symbols are not required.	

Question 36 (continued)

(d) Calculate the electrical potential difference of the student's galvanic cell. Assume standard conditions. Include appropriate units in your answer. (2 marks)

Description	Marks
+2.70	1
V or Volts	1
Total	**2**
Note: • Must have correct value, with or without the '+' sign. • Working out is not necessary (e.g. +2.36 + 0.34).	

(e) Galvanic cells, such as the one shown in the diagram, need a salt bridge.

(i) State why galvanic cells need a salt bridge. (1 mark)

Description	Marks
Any one of the following: A salt bridge • maintains charge neutrality • completes the circuit • allows transfer of ions between two half-cells • prevents polarisation.	1
Total	**1**

(ii) Describe, with reference to ion movement, how the salt bridge in a galvanic cell works. Also state why ion movement occurs as you have described. (4 marks)

Description	Marks
Negative ions travel through the salt bridge and move (migrate) into the anode half-cell	1
Due to an increase in positive ions/charge (as a result of the oxidation of magnesium producing positive ions that enter the electrolyte)	1
Positive ions travel through the salt bridge and move (migrate) into the cathode half-cell	1
Due to a removal of positive ions/charge (as a result of the reduction of copper ions from the electrolyte)	1
Total	**4**

Question 37 **(17 marks)**

(a) Below is a table of the student's results. Determine the average titre. (1 mark)

Titration number	Burette readings (mL)		
	Initial	Final	Titre
Rough	1.35	22.45	21.10
1	21.45	41.50	20.05
2	3.50	23.65	20.15
3	23.65	43.05	19.40
4	2.75	22.85	20.10
		Average titre	

Description	Marks
Average titre = (20.05 + 20.15 + 20.10)/3 = 20.10 mL	1
Total	**1**
Note: • Also accept 20.1 mL as the average titre.	

(b) Show that the concentration of the sodium hydroxide solution is 0.0963 mol L^{-1}, correct to three significant figures. (3 marks)

Description	Marks
n(HCℓ) = cV = 0.0958 × 0.0201 = 0.00193 mol	1
1 mol NaOH reacts with 1 mol HCℓ	1
c(NaOH) = 0.00193/0.020 = 0.0963 mol L^{-1}	1
Total	**3**

Question 37 (continued)

(c) Calculate the percentage, by mass, of phosphoric acid in the original, undiluted rust remover. Express your answer to the appropriate number of significant figures. Assume that the rust remover contains no other substances that react with sodium hydroxide.

(8 marks)

Description	Marks
$n(NaOH) = 0.0963 \times 0.0245 = 0.00235$ mol	1
Stoichiometry: $3\ NaOH + H_3PO_4 \rightarrow Na_3PO_4 + 3\ H_2O$ So, $3\ NaOH : 1 H_3PO_4$	1
$n(H_3PO_4$ reacting in the titration$) = (1 \times 0.00235)/3$ $= 0.000785$ mol in 10 mL	1
$n(H_3PO_4$ in 250 mL volumetric flask$) = (0.000785 \times 250)/10$ $= 0.0196$ mol in 10.05 g	1
$M(H_3PO_4) = 97.994$ g mol^{-1}	1
$m(H_3PO_4$ in rust cleaner sample$) = 0.0196 \times 97.994 = 1.92$ g	1
$\%\ H_3PO_4$ in the rust cleaner $= (1.92/10.05) \times 100 = 19.1\%$	1
3 significant figures = 19.1%	1
Total	**8**

or

Description	Marks
$n(NaOH) = 0.0963 \times 0.0245 = 0.00235$ mol	1
Stoichiometry: $2\ NaOH + H_3PO_4 \rightarrow Na_2HPO_4 + 2\ H_2O$ So, $2\ NaOH : 1\ H_3PO_4$	1
$n(H_3PO_4$ reacting in the titration$) = (1 \times 0.00235)/2$ $= 0.00118$ mol in 10 mL	1
$n(H_3PO_4$ in 250 mL volumetric flask$) = (0.\ 00118 \times 250)/10$ $= 0.0294$ mol in 10.05 g	1
$M(H_3PO_4) = 97.994$ g mol^{-1}	1
$m(H_3PO_4$ in rust cleaner sample$) = 0.0294 \times 97.994 = 2.88$ g	1
$\%\ H_3PO_4$ in the rust cleaner $= (2.88/10.05) \times 100 = 28.7\%$	1
3 significant figures = 28.7%	1
Total	**8**

Note:

- Phosphoric acid is a weak acid with only two of its three hydrogen atoms reacting with hydroxide to give the 2:1 ratio of $NaOH:H_3PO_4$. This is beyond the scope of the syllabus, and was not expected of students.

(d) Which of these indicators should the student use when titrating phosphoric acid with sodium hydroxide? Justify your choice with the aid of a relevant balanced chemical equation. (5 marks)

Description	Marks
Phenolphthalein	1
Recognition that PO_4^{3-} present in the solution at equivalence point. $(3\ OH^-(aq) + H_3PO_4(aq) \rightarrow PO_4^{3-}(aq) + 3\ H_2O(\ell))$	1
The phosphate ion undergoes hydrolysis to form hydroxide ions. $PO_4^{3-} + H_2O \rightleftharpoons HPO_4^{2-} + OH^-$	1
The solution at the equivalence point will be (slightly) basic (with a pH of approximately 9) due to the excess of hydroxide ions ($[OH^-] > [H^+]$)	1
The pH at which the indicator changes colour approximates the pH of the equivalence point.	1
Total	**5**

Note:
- No hydrolysis equation – maximum 4 marks
- Do not accept a statement about strong base is added to weak acid, gives a weakly basic solution as part of the explanation.

Alternative responses that some students may provide
Methyl orange
The pH of the first equivalence point is around 4.7. If students identify this and supply appropriate logic with equations, up to full marks may be awarded.

If a student recognises that the third equivalence point is beyond the end point of phenolphthalein and explains why none of the indicators would be appropriate with sufficient reasoning, up to full marks may be awarded.

Question 38 **(16 marks)**

(a) Determine the empirical formula of the compound. (12 marks)

Description	Marks
Carbon • $n(CO_2) = n(C) = 6.46/44.01 = 0.147$ mol carbon in 5.00 g • $m(C) = 0.147 \times 12.01 = 1.76$ g in 5.00 g	 1 1
Hydrogen • $n(H_2O) = 2.68/18.016 = 0.149$ mol • $n(H) = 2 \times 0.149 = 0.298$ mol • $m(H) = 0.296 \times 1.008 = 0.300$ g in 5.00 g	 1 1 1
Sulfur • $n(H_2SO_4) = cV = 10 \times 0.00371 = 0.0371$ mol • $n(S) = 0.0371$ mol • $m(S) = 0.0371 \times 32.06 = 1.19$ g in 5.00 g	 1 1 1
Oxygen • $5.00 – 1.76 – 0.300 – 1.19 = 1.75$ g of oxygen • $n(O) = 1.75/16.00 = 0.109$ mol	 1 1
Atom ratio • carbon hydrogen sulfur oxygen 0.147 0.300 0.0371 0.109 • Divide all by 0.0371 to get atom ratio 3.96 8.02 1.00 2.94 4 8 1 3	 1
Empirical formula = $\mathbf{C_4H_8SO_3}$	1
Total	**12**
Accept any other methods that have consistent logic to achieve a correct answer.	

(b) Determine the molecular formula of the compound. (4 marks)

Description	Marks
Empirical formula mass = 136.164	1
Actual molar mass • PV = nRT • $150 \times 0.637 = n \times 8.314 \times 313.15$ • $n = 0.0367$ • $n = m/M$, so $M = m/n = 5.00/0.036700 = 136$	 1 1
• (Molar mass = empirical mass) • Thus, the molecular formula is $C_4H_8SO_3$	 1
Total	**4**
Note: • If Empirical formula mass is not calculated – maximum of 2 marks.	

Question 39 **(12 marks)**

(a) At the completion of Step 2, the mass of the mixture had decreased by 11.3 g. Calculate the mass of sodium carbonate that reacted with the rare earth metal phosphates.

(3 marks)

Description	Marks
$n(CO_2) = 11.3/44.01 = 0.257$ mol	1
$n(CO_2) = n(C) = n(Na_2CO_3) = 0.257$ mol	1
$m(Na_2CO_3) = 0.257 \times 105.99 = 27.2$ g	1
Total	**3**
Note: • Mass loss is due to $CO_2(g)$.	

(b) Calculate the percentage, by mass, of lanthanum in the fluorescent light coating chemical, given that the leaching efficiency for lanthanum was 86%.

Note that the balanced equation for the leaching of lanthanum with hydrochloric acid is:

$$La_2O_3(s) + 6\ HC\ell(aq) \rightarrow 2\ LaC\ell_3(aq) + 3\ H_2O(\ell)$$ (5 marks)

Description	Marks
Volume of $HC\ell$ used: 1160/150 = 7.73 L	1
$n(La) = cV = 8.65 \times 10^{-3} \times 7.73 = 0.0669$ mol La in solution	1
Taking into account the leaching efficiency, n(La in the solid that was leached) = 0.0669/0.86 = 0.0778	1
m(La in the solid that was leached) = 0.0778 × 138.9 = 10.8 g	1
% La in the coating chemical = (10.8/1200) × 100 = 0.900%	1
Total	**5**

(c) Did the chemist add enough oxalic acid solution to precipitate all of the cerium? Use calculations to support your answer. (4 marks)

Description	Marks
n(cerium) = 0.146 × 0.424 = 0.0619 mol	1
n(oxalic acid needed to react with cerium) = 2 × 0.0619 = 0.124 mol	1
n(oxalic acid available) = 0.110 × 1.15 = 0.127 mol	1
comparison of the moles of oxalic acid shows that enough oxalic acid was added	1
Total	**4**

Question 40 **(16 marks)**

(a) Write a balanced equation, using condensed structural formulae, to show the formation of biodiesel from triolein and ethanol. Assume that a suitable catalyst is present. (3 marks)

Description	Marks
$CH_2O-C(=O)-C_{17}H_{33}$ $\vert$ $CHO-C(=O)-C_{17}H_{33}$ $\vert$ $CH_2O-C(=O)-C_{17}H_{33}$ + 3 CH_3CH_2OH → 3 $C_{17}H_{33}COOCH_2CH_3$ + $CH_2(OH)CH(OH)CH_2OH$	
glycerol (glycerin) is shown as a reaction product	1
biodiesel formula is correct and shown as a reaction product	1
equation balanced correctly	1
Total	**3**
Note: • Do not deduct marks if full structural formulae are drawn for any or all substances involved in the reaction.	

(b) Lipase is a protein that can be used to catalyse the reaction between triolein and ethanol. To which class of biological chemicals (other than proteins) does lipase belong? (1 mark)

Description	Marks
enzyme	1
Total	**1**

(c) Complete the following equation to show the equilibrium that is established between oleic acid and ethanol. Represent all organic substances as condensed structural formulae and assume acidic conditions. (2 marks)

Description	Marks
Reaction products: $CH_3(CH_2)_7CH{=}CH(CH_2)_7COOCH_2CH_3 + H_2O$	
the ester product formula is correct	1
water is shown as a reaction product	1
Total	**2**
Note: • Do not deduct marks if full structural formulae are drawn for any or all substances involved in the reaction.	

(d) Identify **two** different actions that can be carried out to favour the forward direction of this equilibrium. (2 marks)

Description	Marks
Removing the biodiesel/ester as it forms	1
Removing water as it forms	1
Total	**2**

Note:
Also accept
- decrease the temperature of the reaction
- increase concentration of ethanol
- increase the concentration of oleic acid.

(e) (i) Write a balanced equation showing the reaction of oleic acid with sodium hydroxide. Represent all organic substances as condensed structural formulae. (2 marks)

Description	Marks
$CH_3(CH_2)_7CH=CH(CH_2)_7COOH + NaOH \rightarrow CH_3(CH_2)_7CH=CH(CH_2)_7COO^-Na^+ + H_2O$	
the formula of the soap product is correct	1
water is shown as a reaction product	1
Total	**2**

Note:
- Do not deduct marks if full structural formulae are drawn for any or all substances involved in the reaction.
- Na is not required for full marks i.e. accept ionic equation.
- +/– on soap product is not required for full marks.

(ii) To which class of compounds does the organic product of this reaction belong? (1 mark)

Description	Marks
soaps/salts/carboxylate/alkene	1
Total	**1**

Question 40 (continued)

(f) Which of the catalysts, lipase or sodium hydroxide, is more likely to be the industrially preferred catalyst when using vegetable oil waste to make biodiesel? Justify your answer. (3 marks)

No mark is allocated for the choice of catalyst.

Description	Marks
Sodium hydroxide is most likely preferred in industrial settings	
Any three of the following: • can operate at high temperatures making conversion quicker • cost effective • sodium hydroxide cheaper • higher yield • more readily available • not pH or temperature sensitive.	1–3
Total	**3**
Accept other relevant answers.	

or

Description	Marks
Lipase is most likely preferred in industrial settings	
Any three of the following: • this is to avoid contaminating the biodiesel with soap • requires less energy • can be reused many times • operates at a lower temperature • catalyst less harmful.	1–3
Total	**3**
Accept other relevant answers.	
Note: • Stating only 'environmentally friendly' without reasoning is too vague.	

(g) Other than the recycling of vegetable oil waste, give **two** different reasons why the production of biodiesel from vegetable oil waste is an example of green chemistry but the production of diesel from fossil fuels is not. Each of your reasons needs to contrast biodiesel and fossil fuel diesel. (2 marks)

Description	Marks
Any two of the following: • it uses a renewable feed stock (plants, as the ultimate source of its raw materials) but fossil fuel diesel (uses resources that take millions of years to form/) are non-renewable • the synthesis of biodiesel from vegetable oil waste does not require as much expensive/complex equipment as is the case for using fossil fuels • the synthesis of biodiesel from vegetable oil waste does not require the use of high temperatures, unlike the production from fossil fuels. This means that the carbon footprint of biodiesel is less.	1–2
Total	**2**
Accept other relevant reasons.	
Note: • To be awarded the mark, each reason must mention biodiesel vs fossil fuel diesel.	

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