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

CHEMISTRY

ATAR course examination 2023

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

Section Two: Short answer   **35% (79 Marks)**

Question 26   **(11 marks)**

(a)   Outline the difference between the terms 'monoprotic' and 'polyprotic'. Use equations to illustrate your answer.   (4 marks)

Description	Marks
monoprotic – one hydrogen ion available for ionisation	1
polyprotic – two or more hydrogen ions available for ionisation	1
minimum of two appropriate equations	1–2
Total	**4**
$HX + H_2O \rightarrow X^- + H_3O^+$	
$H_2X + H_2O \rightarrow HX^- + H_3O^+$ $HX^- + H_2O \leftrightharpoons X^{2-} + H_3O^+$	
Note: accept Arrhenius equations	

(b)   Using the Brønsted-Lowry model of acids and bases, write the ionisation equations for both acids.   (2 marks)

Description	Marks
Both equations correct	2
One equation correct	1
Total	**2**
$HNO_2 + H_2O \leftrightharpoons NO_2^- + H_3O^+$ $HCOOH + H_2O \leftrightharpoons HCOO^- + H_3O^+$	
Note: award a maximum of 1 mark if double arrows not present	

(c)   In the equations above, circle the Brønsted-Lowry bases.   (2 marks)

Description	Marks
All Brønsted-Lowry bases correctly circled	2
Two Brønsted-Lowry bases correctly circled	1
Total	**2**
H_2O, NO_2^-, $HCOO^-$	

(d)   Using one of the two acids as an example, describe how Arrhenius theory of acids and bases differs from Brønsted-Lowry theory. Include an appropriate Arrhenius theory equation in your answer.   (3 marks)

Description	Marks
Recognition that an Arrhenius acid is a substance that will (ionise and) produce H^+ in aqueous solution	1
Recognition that Brønsted-Lowry acid-base reaction involves proton transfer/acids donate protons	1
Appropriate equation	1
Total	**3**
$HNO_2 \leftrightharpoons H^+ + NO_2^-$ or $HCOOH \leftrightharpoons H^+ + HCOO^-$	

Question 27 **(10 marks)**

(a) Write an equation for the action of phosphoric acid on the rust. Assume rust is iron(III) oxide. Include state symbols in your answer. (3 marks)

Description	Marks
Correct species	1
Correct balancing	1
Correct state symbols	1
Total	**3**
$Fe_2O_3(s) + 2\ H_3PO_4(aq) \rightarrow 2\ FePO_4(s) + 3\ H_2O(\ell)$	
Note: if incorrect equation, equation must have merit for balancing and state symbol marks to be awarded. e.g. iron(II) oxide is used	

(b) Identify the best method that the carpenter could use to protect the pliers from rusting further. Explain how this method would be effective. (3 marks)

Description	Marks
oiling/greasing	1
Recognition that the method provides a barrier	1
Recognition that the barrier prevents water (and oxygen) from contacting the iron, (preventing oxidation of the iron)	1
Total	**3**

(c) State what a sacrificial anode is and explain how it is effective in preventing corrosion of the toolboxes. You should state which metal could be used for a sacrificial anode in your answer. (4 marks)

Description	Marks
Recognition that the sacrificial anode is a more reactive metal than the toolboxes (cathode)	1
Metals could include any one of: • zinc • magnesium • chromium • manganese • aluminium	1
Recognition that the two metals are touching/connected electrically	1
Recognition that the E° value of the anode is more negative compared to that of iron/is more readily oxidised/stronger reductant	1
Total	**4**
Note: do not accept reactive group 1 metals or Ca/Ba.	

Question 28 **(8 marks)**

(a) Define the term 'buffer' and identify the chemical species in this system responsible for its buffering capacity. Specify the role of each chemical species you identify in your answer. (3 marks)

Description	Marks
Recognition that a buffer resists changes to pH when small amounts of acid or base are added to the solution	1
Recognition that in this system H_2CO_3 (is the weak acid that) reacts with any added base	1
Recognition that in this system HCO_3^- (is the conjugate base that) reacts with any added acid	1
Total	**3**
Accept other relevant answers.	

(b) Explain what will happen in the blood when there is an elevated concentration of carbon dioxide. Predict how blood pH is affected. Include relevant equations in your answer. (5 marks)

Description	Marks
Recognition that elevated concentration of carbon dioxide in the blood increases the concentration of carbonic acid in the blood	1
Equation: $CO_2(aq) + H_2O(\ell) \rightleftharpoons H_2CO_3(aq)$	1
Recognition that the increase in blood carbonic acid concentration shifts the blood buffer equilibrium to the right, increasing H_3O^+ concentration	1
Recognition that the HCO_3^- will react with the additional H_3O^+, or equation: $HCO_3^-(aq) + H_3O^+(aq) \rightarrow H_2CO_3(aq) + H_2O(\ell)$	1
Recognition that there is a small decrease in pH	1
Total	**5**

Question 29 **(8 marks)**

Electrochemical cells are categorised as either galvanic cells or electrolytic cells. Identify **three** similarities and **three** differences with which to compare galvanic and electrolytic cells, using relevant examples of each cell type. You may choose to use diagrams to illustrate your answer.

Description	Marks
Similarities between galvanic and electrolytic cells	1–3
Differences between galvanic and electrolytic cells	1–3
Relevant examples	1–2
Total	8

Answers could include:

Similarities:
- oxidation occurs at the anode/reduction occurs at the cathode
- cations move towards the cathode/anions move towards the anode
- external circuit through which a current flows
- electrolyte for transfer of ions.

Differences (any three of the following):
- galvanic cell reactions are spontaneous while electrolytic cell reactions are not spontaneous
- galvanic cells generate a voltage/electric current while electrolytic cells require an external power source
- galvanic cells convert chemical energy to electrical energy while electrolytic cells convert electrical energy to chemical energy
- the charge on the anode of a galvanic cell is designated as negative while the charge on the anode of an electrolytic cell is designated as positive.

Examples could include:
- Galvanic cells:
  - Leclanché cell
  - lead-acid accumulator
  - fuel cells.
- Electrolytic cells:
  - recharging of cells
  - purification of copper cells
  - electroplating cells.

Note: similarities and differences may be provided on annotated diagrams.
Accept other relevant answers.

Question 30 **(12 marks)**

Write a balanced ionic equation for any reactions occurring 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 piece of iron wool is added to a 0.1 mol L^{-1} solution of copper(II) sulfate. (4 marks)

Description	Marks
Equation	
Equation $Fe(s) + Cu^{2+}(aq) \rightarrow Cu(s) + Fe^{2+}(aq)$	
Correct reactants	1
Correct products	1
Observed colour change/s	
a grey/silver solid and blue solution	1
form a salmon pink solid (solution decolourises/pale green)	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' without reference to colour.	

(b) Calcium hydrogencarbonate powder is added to excess 1 mol L^{-1} nitric acid. (4 marks)

Description	Marks
Equation	
$Ca(HCO_3)_2(s) + 2 H^+(aq) \rightarrow Ca^{2+}(aq) + 2 H_2O(\ell) + 2 CO_2(g)$	
Correct species	1
Correct balancing	1
Observed colour change/s	
white solid and colourless solution	1
solid dissolves/reacts and there is effervescence (bubbling)	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' without reference to colour.	

Question 30 (continued)

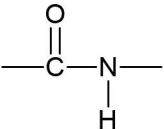(c)   Excess chlorine gas is bubbled through a 0.1 mol L^{-1} sodium bromide solution.   (4 marks)

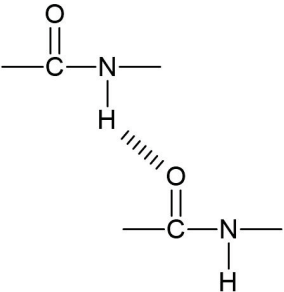| Description	Marks
Equation	
2 Br$^-$(aq) + Cℓ_2(g) → Br$_2$(aq) + 2 Cℓ^-(aq)	
Correct species	1
Correct balancing	1
Observed colour change/s	
greenish-yellow gas is bubbled through a colourless solution	1
forms an orange solution	1
Total	**4**
Note: • maximum 1 mark for correct and balanced molecular 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' without reference to colour.	

Question 31 **(9 marks)**

(a) Define the primary structure of a protein, including a description and annotated diagram, to explain how the α-amino acid monomers are joined. (4 marks)

Description	Marks
Recognition that the primary structure of a protein is the sequence of α-amino acids	1
Recognition that the α-amino acids are joined by peptide or amide bonds	1
Diagram shows a correctly drawn peptide/amide bond O ‖ —C—N— | H	1
Peptide bond is labelled	1
Total	**4**

(b) Explain the difference between the secondary and tertiary structures of proteins. Include a description of each level of the structure and how it forms in your answer. (5 marks)

Description	Marks
Recognition that secondary structures result from hydrogen bonding between amide group hydrogen atoms and carbonyl group oxygen atoms. This may include a drawing with a dotted line to show the hydrogen bonding interaction. For example: O ‖ —C—N— | H ···· O ‖ —C—N— | H	1
Recognition that secondary structures are α-helixes and/or β-pleated sheets	1
Recognition that α-helix is a secondary structure that results from hydrogen bonding between amide and carbonyl functional groups within a peptide chain and/or Recognition that β-pleated sheet is a secondary structure resulting from hydrogen bonding between amide and carbonyl functional groups along adjacent polypeptide chains	1
Recognition that the tertiary structure of a protein is a result of folding of the polypeptide chain/overall shape of the protein	1
Recognition that tertiary structure forms due to interactions between side chains of α-amino acids in the polypeptide. Answer to include any one of the following interactions: disulfide bridges, hydrogen bonding, dipole-dipole interactions, dispersion forces and ionic interactions	1
Total	**5**

Question 32 **(5 marks)**

In the decaffeination process, the solvent used should only dissolve caffeine so it can be removed, leaving compounds that are responsible for the flavours of coffee. Using your understanding of intermolecular forces, explain why dichloromethane, $CH_2C\ell_2$, can act as a solvent to remove caffeine.

Description	Marks
Recognition that caffeine contains dipole-dipole and dispersion forces	1
Recognition that dichloromethane contains dipole-dipole and dispersion forces	1
Recognition that the predominant form of bonding between dichloromethane and caffeine is dipole-dipole and dispersion forces	1
Recognition that the energy released in the formation of the forces of attraction between the dichloromethane and caffeine molecules will be sufficient to overcome the forces of attraction between the molecules in caffeine and in dichloromethane	1–2
Total	**5**
Note: accept explanations relating to strength of intermolecular forces.	

Question 33 **(7 marks)**

A barium hydroxide solution is titrated against an ammonium chloride solution to produce barium chloride, ammonia and water.

(a)   Write a balanced ionic equation for this reaction. (2 marks)

Description	Marks
Equation $OH^-(aq) + NH_4^+(aq) \rightarrow NH_3(aq) + H_2O(\ell)$	
Correct species	1
Correct balancing	1
Total	**2**
Note: if molecular equation, award maximum of 1 mark.	

(b)   Identify the most appropriate indicator for this titration and justify your choice, using an equation to support your answer. (5 marks)

Description	Marks
Phenolphthalein	1
Recognition that (at the equivalence point) the ammonia hydrolyses to produce OH^-	1
Recognition that at (equivalence point) $[OH^-]>[H^+]$ (and solution is basic)	1
Recognition that indicator changes in the basic range/indicator colour change/end point is a similar pH to the equivalence point	1
Appropriate equation $NH_3(aq) + H_2O(\ell) \leftrightharpoons NH_4^+(aq) + OH^-(aq)$	1
Total	**5**

Question 34   **(9 marks)**

(a)   Write the equilibrium constant K expression for the ionisation of sorbic acid in water.

                                                                                 (2 marks)

Description	Marks
$K = \dfrac{[CH_3(CH)_4COO^-][H_3O^+]}{[CH_3(CH)_4COOH]}$	1–2
Total	**2**

(b)   Under certain conditions, a 0.250 mol L^{-1} aqueous solution of sorbic acid has a pH of 2.23. Calculate the concentration of H_3O^+ to determine the percentage yield of the sorbate ion at equilibrium in 1.00 L of the solution.   (4 marks)

Description	Marks
$[H_3O^+] = 10^{-pH} = 10^{-2.23} = 5.89 \times 10^{-3}$ mol L^{-1}	1
for 1.00 L solution $n(H_3O^+) = n(CH_3(CH)_4COO^-) = 5.89 \times 10^{-3}$ mol	1
for 1.00 L solution $n(CH_3(CH)_4COOH) = 0.250$ mol	1
% yield sorbate ion $= n(CH_3CH(OH)COO^-) / n(CH_3CH(OH)COOH) \times 100$ $= (5.89 \times 10^{-3} / 0.250) \times 100$ $= 2.36$ %	1
Total	**4**

(c)   Explain the classification of sorbic acid as a weak acid with reference to **both** your answer to part (b) above and its acidity constant value $K_a = 1.73 \times 10^{-5}$ (20 °C).

                                                                                 (3 marks)

Description	Marks
Recognition that weak acids undergo partial/incomplete ionisation in water	1
Explanation that the answer to part (b) is numerically small, indicating that only a small percentage of sorbic acid in solution is ionised	1
Recognition that the value of K_a is less than one which indicates a greater proportion of reactants compared to products	1
Total	**3**
Note: accept answer based on the small value of K_a.	

Section Three: Extended answer 40% (86 Marks)

Question 35 **(14 marks)**

(a) The reaction in Equation 1 is carried out with a platinum-rhodium catalyst at approximately 850.0 ºC and 1500 kPa. Using collision theory, account for these conditions. (8 marks)

Description	Marks
Catalyst • Recognition that rate is increased as the platinum-rhodium catalyst provides an alternate reaction pathway with a lower activation energy • Recognition that there are an increased proportion of reacting particles colliding with energy greater than the activation energy (resulting in an increased frequency of successful collisions)	1–2
Temperature • Recognition that increased temperature increases the average kinetic energy of particles and they collide more frequently • Recognition that the increased proportion of collisions will have energy higher than the activation energy (which has been lowered due to the catalyst) • Recognition that a greater proportion of collisions are therefore successful (leading to an increased rate of reaction)	1–3
Pressure • Recognition that increased pressure reduces the space between reacting particles • Recognition that at high pressure particles collide more frequently • Recognition that this leads to a higher frequency of successful collisions	1–3
Total	**8**

(b) A nitric acid plant requires a production of 1095 tonnes of nitric acid by means of the Ostwald process each day. If the conversion of ammonia to nitric acid is 77.65% efficient, calculate the volume of ammonia at standard temperature and pressure (STP) that must be fed into the process each day. Give your answer to an appropriate number of significant figures. (6 marks)

Description	Marks
$m(HNO_3)$ required $= 1.095 \times 10^9$ g	1
$n(HNO_3)$ required $= \dfrac{1.095 \times 10^9}{63.018} = 1.738 \times 10^7$ mol	1
$n(NH_3)$ required 100% $= \dfrac{12}{8}\ 1.738 \times 10^7 = 2.606 \times 10^7$ mol	1
$n(NH_3)$ required 77.65% $= \dfrac{100}{77.65} \times 2.606 \times 10^7 = 3.356 \times 10^7$ mol	1
$v(NH_3)$ STP $= 3.356 \times 10^7 \times 22.71 = 7.621 \times 10^8$ L	1
Answer to 4 significant figures	1
Total	**6**
Accept other relevant answers.	

Question 36 **(18 marks)**

(a) Describe the procedure for transferring the sample to the volumetric flask and diluting it for this analysis. (4 marks)

Description	Marks
Recognition that the entire sample of liquid toilet cleaner must be transferred from the beaker to the volumetric flask	1
Recognition that the complete transfer of the liquid sample occurs by thoroughly rinsing the beaker with (distilled) water and all the rinsing liquid is transferred to the volumetric flask	1
Recognition that the volumetric flask is filled to the mark	1
Recognition that the solution should be mixed thoroughly in the volumetric flask	1
Total	4

(b) Calculate the concentration of lactic acid in the toilet cleaner, in g L^{-1}. (5 marks)
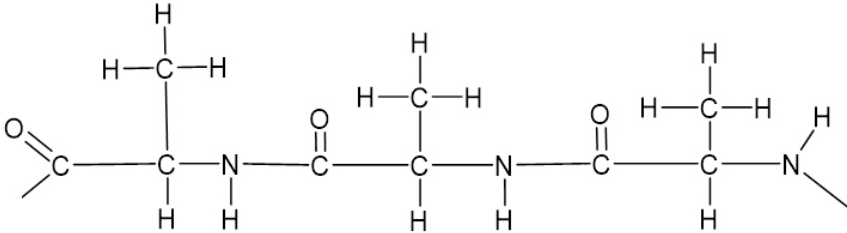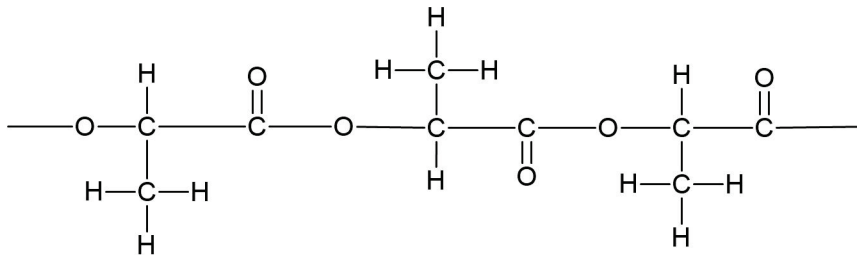
Description	Marks
$n(NaOH) = 9.861 \times 10^{-3} \times 2.274 \times 10^{-2} = 2.242 \times 10^{-4}$ mol	1
Recognition that $n(NaOH) = n(CH_3CH(OH)COOH) = 2.242 \times 10^{-4}$ mol	1
$m(CH_3CH(OH)COOH)$ acid in 10 mL aliquot $= 2.242 \times 10^{-4}$ mol $\times 90.078 = 2.020 \times 10^{-2}$ g	1
$m(CH_3CH(OH)COOH)$ acid in 100 mL solution $= 2.020 \times 10^{-2} \times 10 = 0.202$ g	1
$c(CH_3CH(OH)COOH) = \dfrac{0.202}{0.01} = 20.20$ g L^{-1}	1
Total	5

(c) Account for the large difference in melting points between alanine and lactic acid. (4 marks)

Description	Marks
Recognition that alanine is an amino acid which exists as a zwitterion in the solid state (alanine zwitterion structure may be drawn)	1
Recognition that the predominant force of attraction for lactic acid is hydrogen bonding and forces of attraction for alanine are ionic bonds	1
Recognition that the strength of attractive forces between alanine zwitterions are much stronger than those between lactic acid molecules	1
Recognition that the much higher melting point for alanine is because greater energy is required to overcome the attractive forces between the zwitterions to melt the solid	1
Total	4

Question 36 (continued)

(d) Under certain conditions, both alanine and lactic acid form condensation polymers which produce water molecules. Draw the structures of each polymer showing all atoms and bonds. Each polymer should contain three repeating units. (5 marks)

Description	Marks
Correct structure for polymer formed from alanine	1–2
Correct structure for polylactic acid	1–2
Each contains three repeating units	1
Total	5

Polymer formed from alanine

Polymer formed from lactic acid

Note: award 1 mark for structures with minor errors, including:
• terminating ends
• missing atoms
• incorrect linkage of monomers.

Question 37 **(29 marks)**

(a) Determine the empirical formula of the hydrocarbon. (4 marks)

Description			Marks
$n(C) = n(CO_2) = 7.25/44.01$ $= 0.165$ mol			1
$n(H) = 2 \times n(H_2O) = 2 \times 2.97/18.016$ $= 0.3297$			1
	C	H	
	0.165	0.3297	
Ratio ÷ 0.165	0.165/0.165	0.3297/0.165	1–2
	1	2	
EF = CH_2			
		Total	**4**

(b) A second 4.67 g sample of the hydrocarbon was vaporised and found to occupy 1.42 L at 150 ºC and 205 kPa. Calculate the molar mass of the compound and determine its molecular formula. (5 marks)
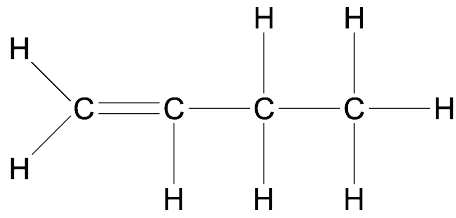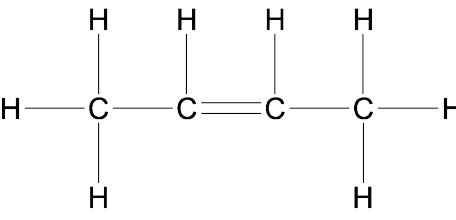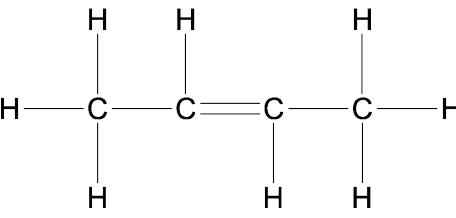
Description	Marks
$n(sample) = 1.42 \times 205/(8.314 \times 423.15)$ $= 8.27 \times 10^{-2}$ mol	1
$M = 4.67/8.27 \times 10^{-2}$ $= 56.4$	1
$EFM = 12.01 + (2 \times 1.008)$ $= 14.016$	1
Ratio M/EFM = 56.4/14.016 = 4	1
MF = C_4H_8	1
Total	**5**

Question 37 (continued)

*See alternative marking key after Question 37(f)(ii) if C_5H_{10} is used.

(c)   The hydrocarbon has three straight-chain isomers (no branching). Complete the table below by drawing the structure of and naming the three isomers. Show all atoms and bonds in each structure.   (9 marks)

If you were unable to determine an answer to part (b) use C_5H_{10} as the molecular formula for the remaining parts of this question.

Description	Marks
	1–2
But-1-ene	1
	1–2
Cis but-2-ene	1
	1–2
Trans but-2-ene	1
Total	9

(d) State which isomer reacts with water to produce a primary alcohol. Write an equation for this reaction. (3 marks)

Description	Marks
But-1-ene	1
Correct reactants	1
Correct products	1
Total	**3**
$C_4H_8 + H_2O \rightarrow CH_3CH_2CH_2CH_2OH$	
Note: equation must show primary alcohol.	

(e) The alcohol produced in part (d) on page 26 can be fully oxidised by acidified potassium dichromate solution.

(i) Write an ionic equation for this reaction. (3 marks)

Description	Marks
Correct reactants	1
Correct products	1
Correctly balanced	1
Total	**3**
$2\ Cr_2O_7^{2-} + 16\ H^+ + 3\ CH_3(CH_2)_2CH_2OH \rightarrow 4\ Cr^{3+} + 3\ CH_3(CH_2)_2COOH + 11\ H_2O$	
Note: award maximum 1 mark, if only correct ½ equations are given.	

(ii) Describe fully the observations for this reaction. (2 marks)

Description	Marks
orange solution added to colourless solution/liquid	1
(deep) green solution formed	1
Total	**2**

(f) (i) Write an equation for the reaction between the organic products from parts (d) and (e). (2 marks)

Description	Marks
Correct reactants	1
Correct products	1
Total	**2**
$CH_3(CH_2)_2CH_2OH + CH_3(CH_2)_2COOH \leftrightharpoons CH_3(CH_2)_2COOCH_2(CH_2)_2CH_3 + H_2O$	
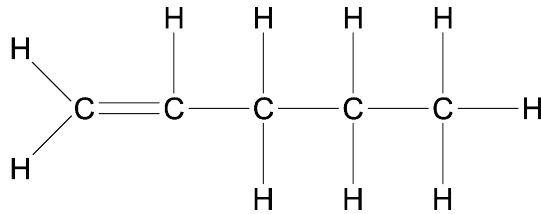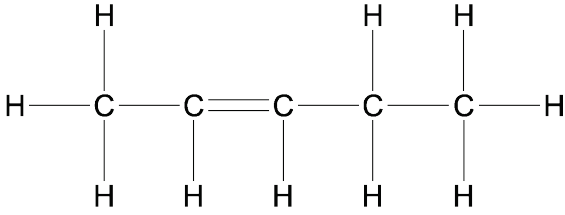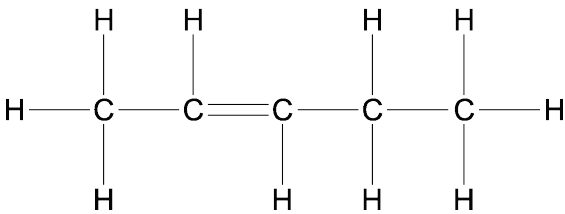
(ii) Name the organic product of this reaction. (1 mark)

Description	Marks
Butyl butanoate	1
Total	**1**

*Alternative marking key for Question 37(c)–(f)(ii) if C_5H_{10} is used.

(c)   The hydrocarbon has three straight-chain isomers (no branching). Complete the table below by drawing the structure of and naming the three isomers. Show all atoms and bonds in each structure.   (9 marks)

If you were unable to determine an answer to part (b) use C_5H_{10} as the molecular formula for the remaining parts of this question.

Description	Marks
	1–2
Pent-1-ene	1
	1–2
Cis pent-2-ene	1
	1–2
Trans pent-2-ene	1
Total	9

(d) State which isomer reacts with water to produce a primary alcohol. Write an equation for this reaction. (3 marks)

Description	Marks
Pent-1-ene	1
Correct reactants	1
Correct products	1
Total	**3**
$C_5H_{10} + H_2O \rightarrow CH_3CH_2CH_2CH_2CH_2OH$	
Note: equation must show primary alcohol.	

(e) The alcohol produced in part (d) on page 26 can be fully oxidised by acidified potassium dichromate solution.

(i) Write an ionic equation for this reaction. (3 marks)

Description	Marks
Correct reactants	1
Correct products	1
Correctly balanced	1
Total	**3**
$2\ Cr_2O_7^{2-} + 16\ H^+ + 3\ CH_3(CH_2)_3CH_2OH \rightarrow 4\ Cr^{3+} + 3\ CH_3(CH_2)_3COOH + 11\ H_2O$	
Note: award maximum 1 mark, if only correct ½ equations are given.	

(ii) Describe fully the observations for this reaction. (2 marks)

Description	Marks
orange solution added to colourless solution/liquid	1
green solution formed	1
Total	**2**

(f) (i) Write an equation for the reaction between the organic products from parts (d) and (e). (2 marks)

Description	Marks
Correct reactants	1
Correct products	1
Total	**2**
$CH_3(CH_2)_3CH_2OH + CH_3(CH_2)_3COOH \leftrightharpoons CH_3(CH_2)_3COOCH_2(CH_2)_3CH_3 + H_2O$	

(ii) Name the organic product of this reaction. (1 mark)

Description	Marks
Pentyl pentanoate	1
Total	**1**

Question 38 **(10 marks)**

(a) 7.00 g of chlorine gas is bubbled through 30 000 L of groundwater containing 39 010 mg of iron(II) hydrogencarbonate to which 16.22 g of calcium hydrogencarbonate has been added. Calculate the mass of iron(III) hydroxide that will be precipitated? (8 marks)

Description	Marks
$n(Cl_2) = 7.00/70.9$ $= 0.0987$ mol	1
$n(Fe(HCO_3)_2) = 39010/1000/177.886$ $= 0.2193$ mol	1
$n(Ca(HCO_3)_2) = 16.22/162.116$ $= 0.100$ mol	1
1 mole of Cl_2 reacts with 2 moles of $Fe(HCO_3)_2$ and 1 mole of $Ca(HCO_3)_2$ 0.0987 mol of Cl_2 will react with 0.197 mol $Fe(HCO_3)_2$ and 0.0987 mol of $Ca(HCO_3)_2$ Since $n(Fe(HCO_3)_2)$ required is less than $n(Fe(HCO_3)_2)$ available and the $n(Ca(HCO_3)_2)$ required is less than the $n(Ca(HCO_3)_2)$ available Cl_2 is limiting reagent (or similar explicit statement)	1–3
$n(Fe(OH)_3) = 2n(Cl_2)$ $= 0.197$ mol	1
$m(Fe(OH)_3) = 0.197 \times 106.874$ $= 21.1$ g	1
Total	**8**

(b) Calculate the concentration of calcium chloride in the final solution? (2 marks)

Description	Marks
$n(CaCl_2) = n(Cl_2)$ $= 0.0987$ mole	1
$c(CaCl_2) = 0.0987/30000$ $= 3.29 \times 10^{-6}$ mol L^{-1}	1
Total	**2**

Question 39 **(15 marks)**

(a) (i) Justify the conditions used for fermentation. (2 marks)

Description	Marks
Recognition that yeast/zymase are enzymes	1
Recognition that enzymes are only effective in a narrow pH band and temperature band or Recognition that without the enzymes, reaction either does not proceed or is too slow to be viable	1
Total	2

(ii) Write an equation for the fermentation process, using $C_6H_{12}O_6$ as the sugar. Use condensed structures in your equation. (2 marks)

Description	Marks
Correct reactants and products	1
Correct balancing	1
Total	2
$C_6H_{12}O_6 \rightarrow 2\ CH_3CH_2OH + 2\ CO_2$	

Ethanol can also be produced by the endothermic hydration of ethene. This is carried out at 250 to 300 ºC and 6000 to 7000 kPa in the presence of an acid catalyst.

(b) (i) Write an equation for the hydration of ethene. Use condensed structures in your equation. (3 marks)

Description	Marks
Correct reactants	1
Correct products	1
Uses condensed structures in equation	1
Total	3
$CH_2CH_2 + H_2O \leftrightharpoons CH_3CH_2OH$	

Question 39 (continued)

(ii) Justify the temperature and pressure used for the hydration of ethene. (5 marks)

Response for the reaction being endothermic.

Description	Marks
Recognition that high pressure increases rate of reaction as there are more particles per unit volume, therefore a greater frequency of collisions	1
Recognition that high pressure also increases yield due to it favouring the direction with the fewer number of gas particles which is the product side of the reaction	1
Recognition that high temperature will increase rate as the particles are moving more rapidly and collide more often, as well as more particles having sufficient energy for successful collision, so greater proportion of collisions will be successful	1
Recognition that because hydration of ethene is endothermic, high temperature will favour the formation of the products	1
Recognition that, although high temperature favours both rate and yield, a moderate temperature will produce economical/safe yield	1
Total	5

Alternative response for the reaction being exothermic.

Description	Marks
Recognition that high pressure increases rate of reaction as there are more particles per unit volume, therefore a greater frequency of collisions	1
Recognition that high pressure also increases yield due to it favouring the direction with the fewer number of gas particles which is the product side of the reaction	1
Recognition that high temperature will increase rate as the particles are moving more rapidly and collide more often, as well as more particles having sufficient energy for successful collision, so greater proportion of collisions will be successful	1
Recognition that because hydration of ethene is exothermic, high temperature will favour the formation of the reactants	1
Recognition that, high temperature favours rate and a low temperature favours yield, a moderate temperature will be an appropriate compromise.	1
Total	5

(c) State **three** reasons why the fermentation process to produce ethanol is more common than the hydration of ethene. (3 marks)

Description	Marks
Any three of	
• fermentation requires less energy input than hydration of ethene • fermentation costs less than hydration of ethene • fermentation is a 'greener' process than hydration of ethene • fermentation uses a renewable feedstock while hydration of ethene does not.	1–3
Total	3
Accept other relevant answers.	