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

CHEMISTRY

ATAR Course Examination 2016

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.

2016/64751

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

Question No.	Answer
1	c
2	a
3	b
4	b
5	b
6	d
7	b
8	a
9	a
10	b
11	d
12	d
13	d
14	a
15	c
16	c
17	a
18	b
19	d
20	c
21	d
22	a
23	b
24	c
25	a

Section Two: Short answer **35% (83 Marks)**

Question 26 **(6 marks)**

Galvanic cells and electrolytic cells are often constructed in the laboratory.

(a) List **four** characteristics or components that these two types of cells have in common with each other. (4 marks)

Description	Marks
Answers may include, but are not limited to the following:	
• both contain a cathode and an anode (whether on one line or two only one mark) • electrons flow through an external circuit (from anode to cathode) • an electrolyte/liquid/solution is needed • electrons flow from the anode to the cathode • both are redox reactions • oxidation occurs at the anode and reduction occurs at the cathode (only need to mention one to get the mark) • anions flow towards anode and cations flow towards cathode. • both require electrodes • both operate on a potential difference	1–4
Total	**4**

(b) List **two** characteristics or components that can be used to distinguish between the two types of cells. State the characteristic or component for each cell. (2 marks)

Description	Marks
One mark for each difference. Maximum two marks. Answers may include, but are not limited to the following:	
• there is only one cell in an electrolytic cell while two half cells (separated) for a galvanic cell • the galvanic cell has a salt bridge while the electrolytic cell does not have a salt bridge • the galvanic cell has a spontaneous reaction while an electrolytic cell requires an emf to be applied to force a reaction (non-spontaneous) • the electrolytic cell has an external emf applied (battery/power source) while the galvanic cell produces the emf. • galvanic cell is spontaneous (+ emf) while electrolytic cell reaction is non-spontaneous (- emf) • galvanic cell the anode is negative and cathode is positive while in an electrolytic cell, the anode is positive and the cathode is negative • in a galvanic cell, chemical energy is converted to electrical energy while in an electrolytic cell, electrical energy is converted to chemical energy.	1–2
Total	**2**

Question 27 **(9 marks)**

Write observations for the changes occurring when the substances below are mixed. In your answers include the appearance of the reactants and any product(s) that form.

(a) (i) methanol, pentanoic acid and sulfuric acid (2 marks)

Description	Marks
Description of initial reactants being combined – two (colourless) solutions (liquids) mix	1
Identification of main product observation/s – fruity smell produced	1
Total	**2**

(ii) powdered magnesium carbonate and excess methanoic acid (2 marks)

Description	Marks
Observation of reactants – white solid added to colourless liquid.	1
Observation of products (**at least one of each pair required for the mark**) - effervescence or fizzing or bubbling **or** - colourless, odourless gas - colourless solution **or** - white solid dissolves	1
Total	**2**
Note: Acceptable - no observable change (no visible reaction) or similar Not acceptable - Acronyms eg NOC, NVR	

(iii) acidified potassium permanganate solution and excess propan-2-ol (2 marks)

Description	Marks
Description of initial reactants being combined. - a purple solution is mixed with a colourless solution/liquid	1
Identification of main product observation/s - purple colour fades / the solution decolourises or turns pale pink / colourless	1
Total	**2**

(b) Name the organic product and write the equation for the reaction when pentanal is added to a solution containing acidified sodium dichromate. (3 marks)

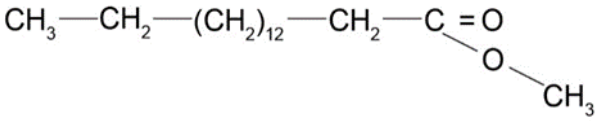
Description	Marks
Pentanoic acid	1
$Cr_2O_7^{2-} + 3\ C_5H_{10}O + 8\ H^+ \rightarrow 2\ Cr^{3+} + 3\ C_5H_{10}O_2 + 4\ H_2O$	2
One error or omission	1
Total	**3**
Note: If name incorrect, but equation is correct for pentanoic acid – 2 marks If reactant used is pentanol but balanced correctly for the alcohol – 1 mark	

Question 28 **(6 marks)**

(a) The condensed structure of a petroleum diesel is given here.

$$CH_3 - CH_2 - (CH_2)_{12} - CH_2 - CH_3$$

Draw the condensed structure of a biodiesel containing the same number of carbon atoms in the chain. (3 marks)

Description	Marks
Structure contain an methyl, ethyl, or propyl ester functional group	1
Structural diagram (methyl) - 16 or 17 carbon atoms in total (ethyl) - 16 or 18 carbon atoms in total (propyl) - 16 or 19 carbon atoms in total	2
Has one minor error or omission	1
Example: 	
Total	**3**

(b) Biodiesel can be synthesised using a base-catalysed method or a lipase-catalysed method. Outline briefly an argument to justify the use of a lipase-catalysed method rather than a base-catalysed method to produce biodiesel. (3 marks)

Description	Marks
One mark for each point of argument; up to a maximum of three marks. The point made must contrast between the two methods of catalysis clearly identifying to which method/s is being referred.	
Answers may include, but are not limited to the following: The lipase-catalysed method: • produces a higher yield as it does not produce the soaps that are formed using a base-catalysed method • produces a higher purity biodiesel than when the base-catalysed method is used • is safer as it does not: ◦ require the use of caustic materials such as sodium hydroxide used in the base-catalysed method ◦ produce the high temperatures, with its accompanying risks, which a strong base catalyst produces • has less negative environmental impact as lipase catalysts are: ◦ biodegradable while strong bases are not ◦ not caustic nor affect acidity of the environment as strong bases do • contributes to lower overall costs because: ◦ they are less subsequent processing problems than those caused by the presence of a strong base ◦ does not add to the expense in the purifying of glycerol as is in the case when in the presence of a strong base ◦ it makes for easier separation of biodiesel from the by-product glycerol.	1–3
Total	**3**

Question 29 **(9 marks)**

Select **one** addition polymer you have studied and use it to complete parts (a) to (c).

(a) Draw and name the structure of the monomer used to produce this polymer. (2 marks)

Description	Marks
Structure contains a double bond	1
Name matches structure drawn	1
Answers may include, but are not limited to the following: • ethene • propene • chloroethene • tetrafluoroethene • styrene.	
Total	**2**

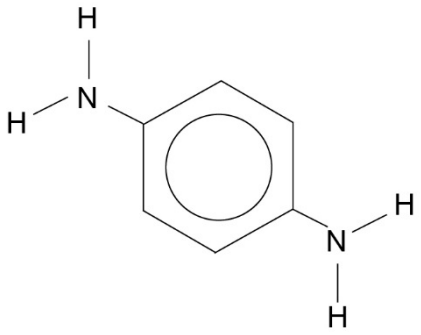
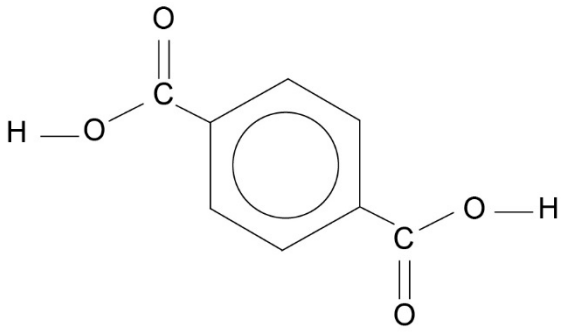
(b) Draw and name the polymer, including at least **three** repeating units. (2 marks)

Description	Marks
Structure contains at least three repeating units of monomer	1
Name matches structure drawn	1
Answers may include, but are not limited to the following: • polyethylene/polyethene • polypropylene • poly vinyl chloride (PVC accepted) • polytetrafluoroethene/Teflon • polystyrene.	
Total	**2**

(c) State **one** use for this polymer, making reference to its relevant property/ies. (2 marks)

Description	Marks
One mark for use	1
One mark for **relevent** property	1
Answers may include, but are not limited to the following: • Polyethylene/polyethene – packaging, bottles, cling wrap, insulation (strength, flexibility, transparency, heat resistance) • Polypropylene – packaging, textiles, laboratory containers (strength, flexibility) • Poly vinyl chloride – construction, piping, flooring (strength) • Polytetrafluoroethene/Teflon – non-stick coatings for cooking, clothing (heat resistance, low friction) • Polystyrene – containers, disposable cutlery and dinnerware, packing material (flexibility, heat resistance).	
Total	**2**
Note: If the property is not relevant to the use then a maximum of one mark may be allocated.	

(d) Draw the **two** monomers from which Kevlar is derived. (2 marks)

Description	Marks
di-amine structure correct 	1
di-carboxylic acid structure correct 	1
Total	**2**

(e) To what secondary structure of proteins does this refer? (1 mark)

Description	Marks
ß-pleated sheets	1
Total	**1**

Question 30 **(5 marks)**

(a) Use equations to show how ethyl ethanoate can be produced from ethene through the successive processes of hydrolysis and esterification. (4 marks)

Description	Marks
Step 1: Hydrolysis of ethene to ethanol	
$CH_2{=}CH_2(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g)$	2
One error or omission	1
Step 2: Esterification of ethanol to ethyl ethanoate	
$CH_3COOH(g) + CH_3CH_2OH(g) \rightleftharpoons CH_3COOCH_2CH_3(g) + H_2O(g)$	2
One error or omission	1
Total	**4**

(b) Write the overall equation for the process of synthesising ethyl ethanoate from ethene. (1 mark)

Description	Marks
$CH_2{=}CH_2(g) + CH_3COOH(g) \rightleftharpoons CH_3COOCH_2CH_3(g)$	1
Total	**1**

Question 31 **(6 marks)**

(a) Select **one** basic, **one** acidic and **one** neutral salt from the list below to complete the table. (3 marks)

Description	Marks
Acidic salt: $NH_4C\ell$	1
Neutral salt: $NaNO_3$, or $KC\ell$	1
Any one of the following basic salts:KCN, $Mg_3(PO_4)_2$, $KHCO_3$, $NaCH_3COO$	1
Total	**3**

(b) Use the Brønsted-Lowry model to explain why the pH of ammonia solution is greater than 7.0 at 25 °C. Incorporate at least **one** appropriate equation in your answer. (3 marks)

Description	Marks
Refers to the Brønsted-Lowry model specific to the equation: Water acts as an acid donating a proton to ammonia and ammonia acts as a base accepting a proton **or** Correctly labelling conjugate acid and base	1
$NH_3(g) + H_2O(\ell) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$	1
Recognises that the concentration of the OH^- is greater than the concentration of the H^+, therefore basic	1
Total	**3**

Question 32 **(6 marks)**

(a) A buffer of carbonic acid (H_2CO_3)/hydrogencarbonate (HCO_3^-) is present in blood plasma to maintain a pH between 7.35 and 7.45. Write an equation to show the relevant species present in a carbonic acid/hydrogencarbonate buffer solution. (2 marks)

Description	Marks
$H_2CO_3(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + HCO_3^-(aq)$ (or reverse)	2
One error or omission	1
Total	**2**

(b) Explain why 300.0 mL of 1.00 mol L^{-1} carbonic acid/hydrogencarbonate buffer does **not** change in pH significantly when 3 drops of 1.00 mol L^{-1} HCℓ are added to it, yet when 3 drops of 1.00 mol L^{-1} HCℓ are added to 300.0 mL of distilled water there is a significant change in pH? (4 marks)

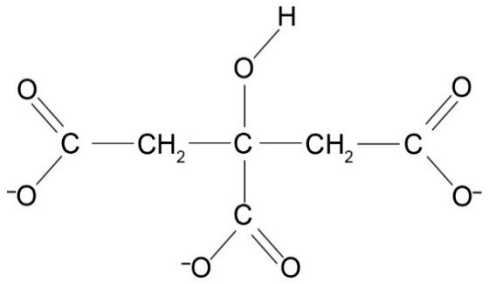
Description	Marks
Addition of HCℓ increases the concentration of H_3O^+	1
In the buffer there is sufficient HCO_3^- (or species appropriate to the student's equation above) to react and reduce the amount of added H_3O^+ **or** The additional H_3O^+ reacts with the HCO_3^- (or species appropriate to the student's equation above) and the equilibrium shifts to the left **or** The rate of the reverse reaction increases due to the additional H_3O^+ reacting with HCO_3^- more than the forward reaction resulting in a reduction in the amount of H_3O^+ present when equilibrium is re-established	1
As the concentration of H_3O^+ is reduced to close to before the addition of HCℓ, there is a minimal change in pH	1
(While an equilibrium system, water cannot act as a buffer system because) in water there is insufficient OH^- to react with added H_3O^+ so all of the added H_3O^+ contributes to the significant change in pH	1
Total	**4**
Note: It is not adequate to simply state that water is not a buffer to earn the mark.	

Question 33 **(5 marks)**

(a) Write a balanced chemical equation for this reaction, showing all state symbols. (2 marks)

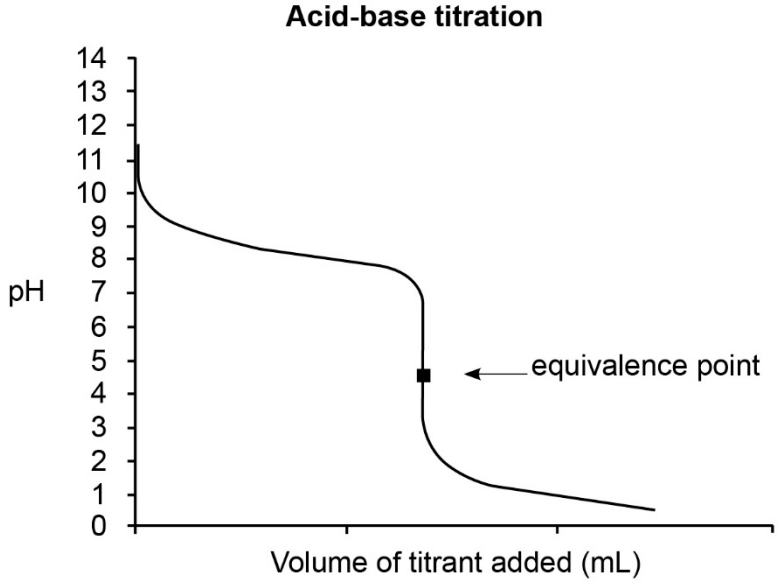
Description	Marks
Correct species	1
Balanced with state symbols $C_6H_8O_7(aq) + 3\ NaOH(s) \rightarrow Na_3C_6H_5O_7(aq) + 3\ H_2O(\ell)$ **or** $C_6H_8O_7(aq) + 3\ NaOH(s) \rightarrow 3\ Na^+ + C_6H_5O_7^{3-}(aq) + 3\ H_2O(\ell)$	1
Total	**2**

(b) In the spaces below, complete the structures, showing **each** successive ionisation of the acidic hydrogen atoms. (3 marks)

Description	Marks
One mark for each successive ionisation shown. Each structure must show negative charge on the particular oxygen atom	1–3
Example: 	
Total	**3**

Question 34 **(6 marks)**

(a) Label the equivalence point on the titration curve below using an arrow and record the pH value at his point. (2 marks)



Description	Marks
Label on Titration curve pointing to correct equivalence point pH 4.8 ± 0.5	1
pH stated within range of 4.8 ± 0.5 (pH 4.3 to 5.3)	1
Total	**2**

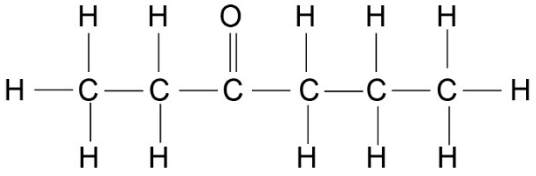
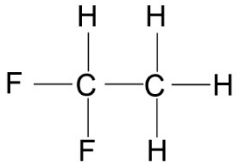
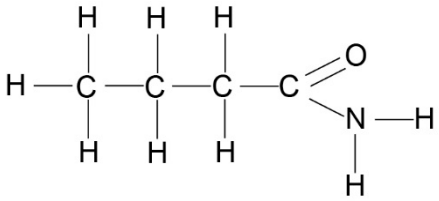
(b) Select an indicator from the table below that would be **best** for this titration and justify your choice. (4 marks)

Description	Marks
Bromocresol Green	1
Justification may include up to, but not be limited to, three of the following recognitions: • That a change in colour of the indicator (end point) indicates that the equivalence point has been reached • The (appropriate) indicator changes colour in the range of the equivalence point • Bromocresal Green is the only indicator that changes colour in the range of the equivalence point • Other indicators will change colour either before (Phenolphthalein, Alzarine Yellow R) or after the equivalence point (Methyl Yellow, Bromoscresol Blue) • The use of indicators other than Bromocresal Green will produce an incorrect titre (too large or too small) • The use of indicators other than Bromocresal Green will result in a systematic error or the use of Bromocresal Green will minimize experimental systematic error • This indicator provides an end point that is similar in pH to the equivalence point.	1-3
Total	**4**

Question 35 **(9 marks)**

For each of the three organic compounds identified in the table below:

- use a structural formula to show the arrangement of **all** the atoms and **all** the bonds
- state **all** the intermolecular forces that exist between its molecules.

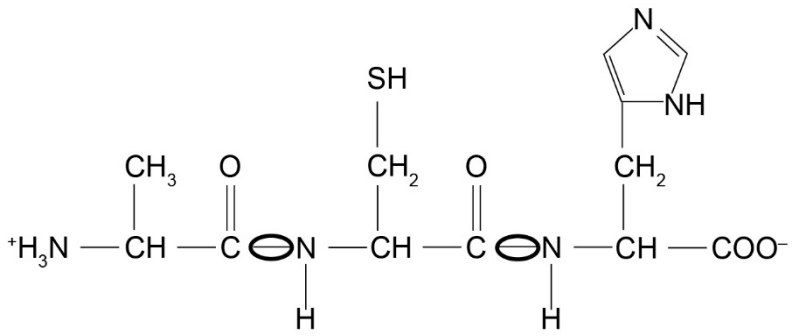
Organic compound	Full structural formula	All intermolecular forces
3-hexanone		dispersion dipole-dipole
1,1-difluoroethane		dispersion dipole-dipole
butanamide		dispersion hydrogen bonding dipole-dipole

Description	Marks
Two marks for each organic structure. Maximum six marks.	
Organic structure correctly drawn	2
Organic structure drawn with one minor error or omission	1
One mark for each structure's intermolecular forces. Maximum three marks.	
Correct intermolecular forces given	1
Total	**9**

Question 36 **(11 marks)**

(a) Below is the structure of a particular tripeptide.

(i) Circle the peptide bonds on the structure. (2 marks)

Description	Marks
Both peptide bonds correctly shown	2
One peptide bond correctly shown	1
	
Total	**2**

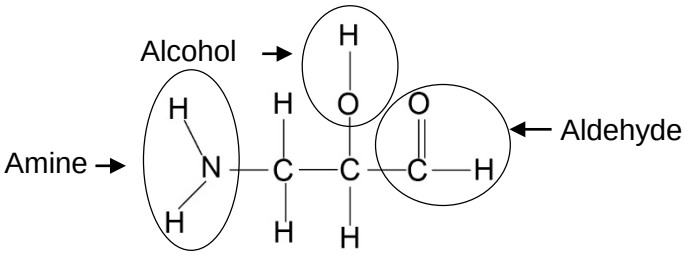
(ii) Name the **three** α-amino acids which reacted to form this tripeptide. (3 marks)

Description	Marks
alanine	1
cysteine	1
histidine	1
Total	**3**
Note: No penalty for incorrect order	

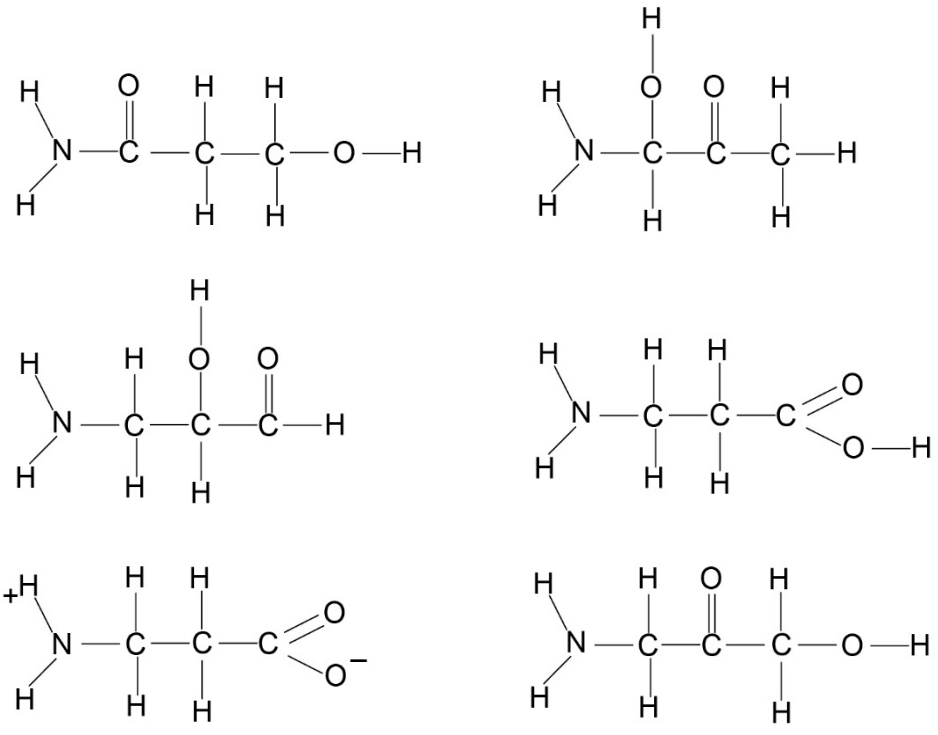
(b) Using the symbols (abbreviations) for these three α-amino acids, give **one** other polypeptide that can be formed from them. (1 mark)

Description	Marks
Answer must contain Ala, Cys and His. but not in this order	1
Answers may include, but are not limited to the following: • Ala-His-Cys • His-Ala-Cys • His-Cys-Ala	
Total	**1**

(c) Circle and name each of the **three** functional groups on the isomer of alanine drawn below. (3 marks)

Description	Marks
One mark for each functional group. Maximum three marks.	
Aldehyde	1
Alcohol (hydroxyl, hydroxy)	1
Amine (amino)	1
	
Total	**3**

(d) Draw a different isomer of alanine, showing clearly **all** atoms and **all** bonds. (2 marks)

Description	Marks
Isomer correctly drawn	2
Isomer drawn with one small error (e.g. missing one hydrogen atom)	1
Answers may include, but are not limited to the following: 	
Total	**2**
Note: Zwitterion of alanine also acceptable	

Question 37 **(5 marks)**

Account for the difference in boiling points of the three compounds.

Description	Marks
Recognition that differences in boiling points is primarily due to the differences in **strength of the sum of the intermolecular forces** **or** Recognition that higher boiling points result from more energy being required to overcome the total intermolecular forces in the substance	1
Recognition that they will have similar dispersion forces (due to their size/structure)	1
Recognition that pentane **only** exhibits **dispersion forces**	1
Recognition that pentanal has **dipole-dipole** forces in **addition** to **dispersion forces**	1
Recognition that pentanoic acid has **hydrogen bonding** in **addition** to **dipole-dipole** and **dispersion forces**	1
Total	**5**
Note: If the cumulative effect of the intermolecular forces are not discussed a maximum of 4 marks	

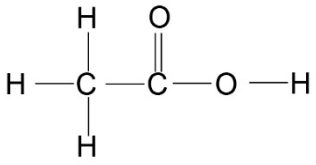
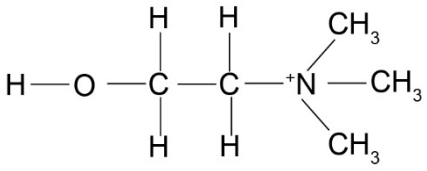
Section Three: Extended answer **40% (85 Marks)**

Question 38 **(14 marks)**

(a) What type of organic compound is an enzyme? (1 mark)

Description	Marks
Enzymes are protein molecules or polypeptides (which act as biological catalysts)	1
Total	**1**

(b) Two products are formed when acetylcholine undergoes hydrolysis in the presence of the enzyme acetylcholinesterase; one of these is a charged molecule called choline and the other is a carboxylic acid. Draw structures of these **two** products. (2 marks)

Description	Marks
Ethanoic acid structure correct 	1
Choline structure correct 	1
Total	**2**

(c) Calculate the empirical formula of the combusted sample. (9 marks)

Description	Marks
$n(c) = n(CO_2) = 9.020/44.01 = 0.20495$ mol	1
$n(H_2O) = 5.169/18.016 = 0.28691$ mol $n(H) = 2 \times n(H_2O)$ $= 0.57382$	1–2
$n(N) = n(NO_2) = 1.886/46.01 = 0.04099$ mol	1
$m(O) =$ mass sample - m(C) - m(H) - m(N) $= 4.270 - (0.20495 \times 12.01)$ $- (0.28691 \times 2 \times 1.008)$ $- (0.04099 \times 14.01)$ $= 4.270 - 2.4614 - 0.5784 - 0.5743$ $= 0.6559$ g	1–2
$n(O) = 0.6559/16 = 0.04099$ mol	1
C H O N n 0.20495 0.57382 0.04099 0.04099 ÷ n(O) 5 14 1 1	1
Correct EF stated as $C_5H_{14}ON$	1
Total	**9**

or

Description	Marks
$\%C = \frac{m(C)}{\text{mass sample}} \times 100 = \frac{9.020/44.01 \times 12.01}{4.27} \times 100 = 57.65\%$	1
$\%H = \frac{m(H)}{\text{mass sample}} \times 100 = \frac{5.169/18.016 \times 1.008 \times 2}{4.27} \times 100 = 13.55\%$	1–2
$\%N = \frac{m(N)}{\text{mass sample}} \times 100 = \frac{1.886/46.01 \times 14.01}{4.27} \times 100 = 13.45\%$	1
%O = 100 - %C - %H - %N = 15.35%	2
C H O N % 57.65 13.55 15.35 13.45 ÷ M 4.800 13.44 0.9594 0.9600 1 ÷ small 5 14 1 1 1	
Correct EF stated as $C_5H_{14}ON$	1
Total	**9**

(d) Use your calculated empirical formula to demonstrate that the enzyme is **active**.

(2 marks)

Description	Marks
Comparison made of determined empirical formula ($C_5H_{14}ON$) with the formula of the desired product (choline) which is $C_5H_{14}ON$	1
Recognition that the empirical formula matches that of the desired product (choline), not the initial reactant acetylcholine. Therefore the enzyme is working/active.	1
Total	**2**

Question 39 **(16 marks)**

(a) What is the volume of sulfur dioxide produced if 2.2 tonne of pentlandite is combusted in air? The process has a yield of 72.0%, and takes place at 300.0 °C and 165.0 kPa. Express your answer to the appropriate number of significant figures.

Molar mass $Fe_9Ni_9S_8$ = 1287.42 g mol^{-1}. (7 marks)

Description	Marks
Conversion of mass to moles For 100% = $m(Fe_9Ni_9S_8)/M(Fe_2Ni_9S_8)$ = 2.2 x 10^6 g/1287.42	1
Accurate figure; accounts for correct molar mass and calculation = 1.7089 x 10^3 mol	1
Recognition of 1:8 mol ratio $n(SO_2)$ = 8 x n ($Fe_9Ni_9S_8$) = 8 x 1.7089 x 10^3 = 1.3671 x 10^4	1
Recognition of efficiency conversion At 72% efficiency $n(SO_2)$ = 0.72 x 1.3671 x 10^4 = 9.84284 x 10^3 mol	1
Correct use of ideal gas equation $V(SO_2) = nRT/P = \frac{(9.843 \times 10^3 \times 8.314 \times 573.15)}{165.0}$	1
Correct answer (also accounts for use of temperature conversion) = 284262 L = 2.84262 x 10^5 L	1
Correct to **two** significant figures = 2.8 x 10^5 L	1
Total	**7**

(b) State **two** justifications for the use of catalysts in this process. (2 marks)

Description	Marks
One mark for each justification. Maximum two marks.	1–2
Answers may include, but are not limited to the following: • increases rate of formation of (the desired) product • better yield of at lower temperature, so catalysts make the rate viable • reusable making them cost effective • lowers operating temperature and pressure ◦ so saving fuel which is a major cost ◦ making it safer ◦ reducing thermal pollution.	
Total	**2**

(c) State the effect of raising the pressure of the system on both the rate and yield.
(2 marks)

Description	Marks
Rate – increases	1
Yield – increases	1
Total	**2**

(d) Use the Collision Theory to explain the effect of raising the total pressure on the yield.
(5 marks)

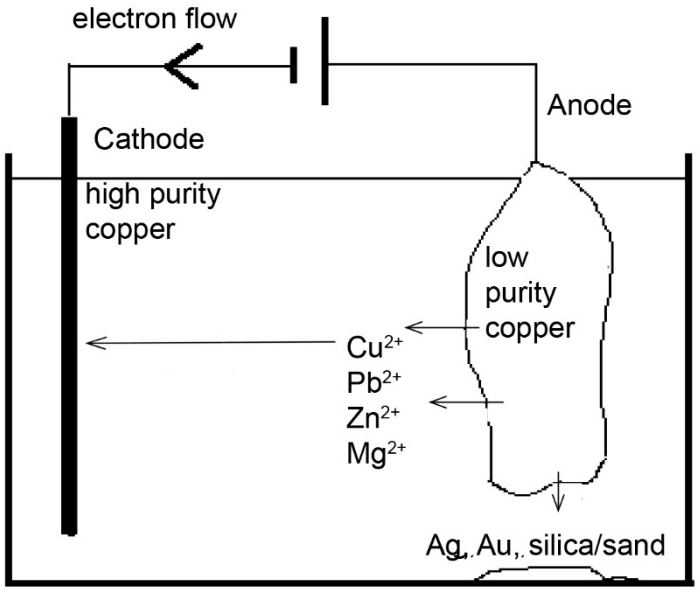
Description	Marks
When pressure is increased, (the reactant and product) particles are forced closer together increasing rate (frequency) of collision	1
Which in turn increases the rate of reaction of both the forward and reverse reactions	1
Ratio of gaseous particles of LHS to RHS as written is 3:2. The forward reaction as written has a greater proportion of gas particles hence	1
The forward reaction proceeds faster than the reverse reaction until the equilibrium conditions are re-established	1
This results in a greater proportion of products of the forward reaction (with a resultant shift in the equilibrium position)	1
Total	**5**

Question 40 **(11 marks)**

(a) Equation two can be represented as half equations. Write the reduction half equation. (1 mark)

Description	Marks
$Cu^+ + e^- \rightarrow Cu$ (No penalty for not including state symbols)	1
Total	**1**

(b) Explain the electrolytic process used to purify copper. Include:
- a brief overview of the process
- a labelled diagram of the electrolytic cell
- the relevant oxidation and reduction half equations
- discussion of impurities and how they are separated from the copper. (10 marks)

Description	Marks
	
Electrolytic cell drawn with: • the external emf/battery • with terminals or labelled arrow indicating the direction of electron flow • the anode being the impure copper (or stated in explanation) • cathode the pure copper (or stated in explanation)	 1 1 1 1
Recognition that impure copper (oxidises) and dissolves, releasing Cu^{2+} ions into solution	1
The Cu^{2+} ions released into the solution (migrate to the cathode) and are reduced to form pure copper metal on the cathode	1
Oxidation equation $Cu \rightarrow Cu^{2+} + 2e^-$	1
Reduction equation $Cu^{2+} + 2e^- \rightarrow Cu$	1
Recognition that the impurities within the copper are removed/separated from the impure copper because they are:	
• (sand, organic materials and) metals less reactive that copper, e.g. Ag, Au won't oxidise and remain on the anode or will fall to the bottom of the cell as a sludge	1
• not reduced, so stay in the solution; metals more reactive than copper will also oxidise, but at the cathode copper(II) will be preferentially reduced, leaving the other ions in solution.	1
Total	**10**

Question 41 **(18 marks)**

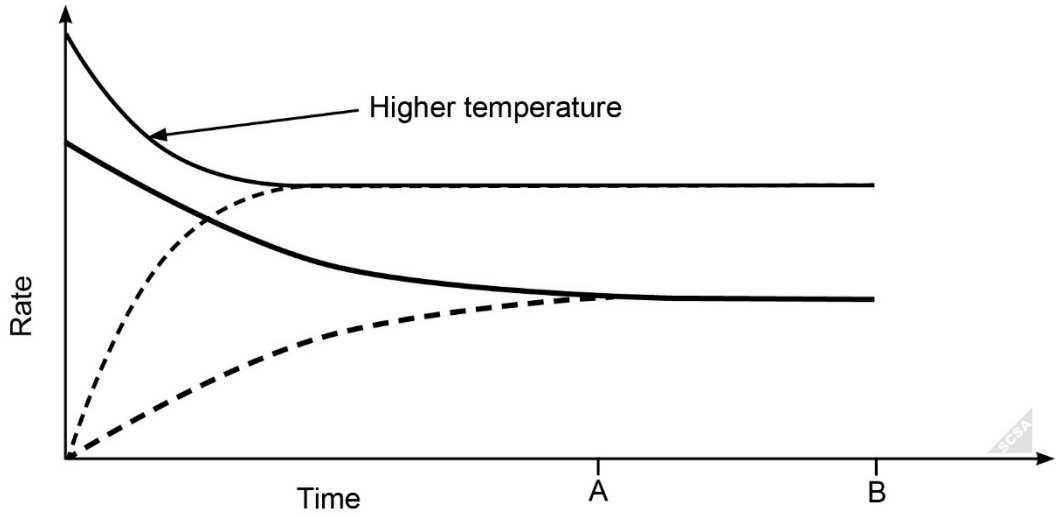
(a) Write the equilibrium expression for this reaction when it is in equilibrium. (2 marks)

Description	Marks
$K = \frac{pNO_2(g)^2}{pN_2(g)\ pO_2(g)^2}$ or $\frac{[NO_2]^2}{[N_2][O_2]^2}$	2
One superscript incorrect or missing	1
Total	**2**

(b) Assuming all other conditions remain constant, what happens to the equilibrium constant after the pressure of the system, is lowered and equilibrium is re-established? (1 mark)

Description	Marks
No change in K	1
Total	**1**

(c) (i) On the axes below, draw the forward (——) and reverse (- - -) reaction rates, starting at the moment the oxygen and nitrogen gases begin to react with each other until after equilibrium has been established at time A. Continue the graph until time B. (3 marks)



Description	Marks
Both curves have the correct shape & orientation	1
Both curves meeting at point A	1
Straight line between point A and B	1
Total	**3**

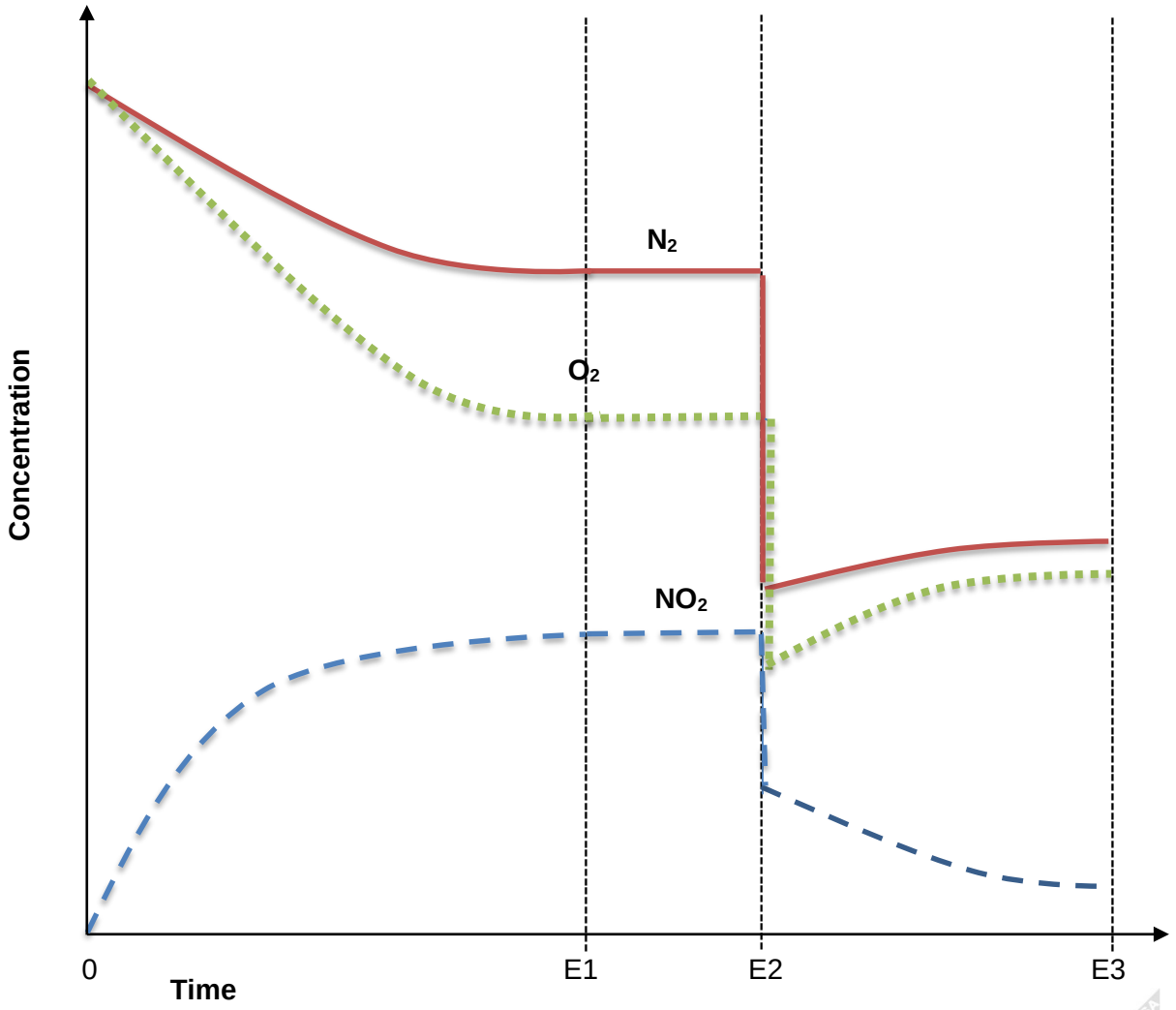
(ii) On the same axes, draw and label clearly the effect of conducting the same reaction at a higher temperature. (2 marks)

Description	Marks
The added curves show:	
Equilibrium reached sooner	1
Reaction rates are higher	1
Total	**2**

Question 41 (continued)

(d) On the axes below, draw separate curves to show how the concentrations of the **three** gases change with time, starting at the moment the oxygen and nitrogen gases begin to react with each other until the system reaches equilibrium at Time E1. Continue the graph from Time E1 to Time E2. Assume that the initial concentrations of oxygen and nitrogen are identical.

Label clearly the line for each gas. (5 marks)



Description	Marks
Correct shape and orientation for curves depicting $N_2(aq)$ and $O_2(g)$	1
Correct shape and orientation for curve depicting $NO_2(g)$	1
Curve for $NO_2(g)$ starting at zero	1
Ratio of change 2:1 for $O_2(g)$ compared with $N_2(g)$	1
Straight horizontal lines between E1 and E2	1
Total	**5**

(e) At Time E2 shown on the axis, the reaction vessel is doubled in volume, and the system is then again allowed to reach equilibrium at Time E3. On the same graph above, show how the concentrations of the three gases would change in response to the change in volume, from Time E2 until equilibrium is re-established at Time E3. (3 marks)

Description	Marks
Immediate reduction (halving) of concentration for all gases	1
Correct shape and orientation for curve for $N_2(g)$ and $O_2(g)$	1
Correct shape and orientation for curve for $NO_2(g)$	1
Total	**3**

(f) What does the stability of this composition indicate about the equilibrium constant and energy requirements of the reaction between nitrogen and oxygen gases? (2 marks)

Description	Marks
(Reactants favoured), the equilibrium constant would be small	1
Energy requirements would be large **or** Activation energy would be large	1
Total	**2**

Question 42 **(26 marks)**

(a) Demonstrate, by means of calculation, that the concentration of HCℓ(aq) solution is 3.76×10^{-6} mol L^{-1}. (5 marks)

Description	Marks
$n(Na_2CO_3) = m/M = 5.74 \times 10^{-6}$ mol	1
$c(Na_2CO_3) = n/2 = 2.868 \times 10^{-6}$ mol L^{-1}	1
$n(Na_2CO_3) = c \times 0.0164$ (mL to L conversion) $= 4.7038 \times 10^{-8}$ mol	1
$n(HCl) = 2 \times n(Na_2CO_3) = 9.4077 \times 10^{-8}$ mol	1
$c(HCl) = n/0.025$ (mL to L conversion) $= 3.76 \times 10^{-6}$ mol L^{-1}	1
Total	**5**

(b) Outline **two** reasons why sodium hydroxide, NaOH(s) is **not** a suitable primary standard for this titration. (2 marks)

Description	Marks
One mark for each reason. Two marks maximum.	1–2
Answers may include, but are not limited to the following: • difficult to obtain in a very pure form • readily absorbs moisture, H_2O from air (deliquescent) **or** hydroscopic • readily absorbs carbon dioxide, CO_2 from air • mass varies over time • has a relatively low molar mass.	
Total	**2**

(c) Calculate the concentration of the NaOH(aq) solution. (3 marks)

Description	Marks
$n(HCl) = cV = 8.02 \times 10^{-8}$ mol	1
$n(HCl) = n(NaOH)$	1
$c(NaOH) = 8.02 \times 10^{-8}/0.025$ (mL to L conversion) $= 3.21 \times 10^{-6}$ mol L^{-1}	1
Total	**3**

(d) Complete the table below to state with what the following pieces of glassware should be rinsed for this titration. (3 marks)

Description			Marks
Burette	–	NaOH solution	1
Conical flask	–	distilled or deionised water (H_2O)	1
Pipette	–	diluted rainwater	1
Total			**3**

(e) Calculate the average titre volume and record it in the table above. (1 mark)

Description	Marks
19.66	1
Total	**1**
Note: Units (mL) stated in table heading and first titre is not used in average	

(f) Calculate the pH of the undiluted rainwater sample. Determine if it would be classified as acid rain or not. (6 marks)

Description	Marks
$n(NaOH)$ = conc. and titre volume from part c and e $= 3.21 \times 10^{-6} \times 1.966 \times 10^{-2}$ $= 6.31 \times 10^{-8}$ mol	1
$n(H^+) = n(NaOH)$ $c(H^+)_{25mL} = 6.31 \times 10^{-8}/0.025$ $= 2.52 \times 10^{-6}$ mol L^{-1}	1
$n(H^+)_{250mL} = 2.52 \times 10^{-6} \times 0.250$ $= 6.30 \times 10^{-7}$ mol	1
$c(H^+)_{100mL} = 6.30 \times 10^{-7}/0.100$ $= 6.30 \times 10^{-6}$ mol L^{-1}	1
$pH = -\log(6.30 \times 10^{-6}) = 5.20$	1
The rain water sample would not be classified as acid rain (No marks awarded unless accompanied by supporting working.)	1
Total	**6**

(g) If carbon dioxide, $CO_2(g)$ alone accounts for rain with a pH of 5.60, then calculate the volume of sulfur dioxide, $SO_2(g)$ at 16.0 °C and 97.2 kPa, that would also need to be dissolved to produce 0.100 L of an acid rain sample with a pH of 4.0. Use the equation below.

$$SO_2(g) + H_2O(\ell) \rightleftharpoons H_2SO_3(aq)$$

For this calculation, assume the complete ionisation of $H_2SO_3(aq)$. (6 marks)

Description	Marks
$pH = 4.0 \quad c(H^+)_{total} = 1 \times 10^{-4}$ mol L^{-1}	
$pH = 5.6$ $c(H^+)_{CO2} = 2.51 \times 10^{-6}$ mol L^{-1}	1
$c(H^+)_{SO2} = c(H^+)_{total} - c(H^+)_{CO2}$ $= 100.0 \times 10^{-6} - 2.51 \times 10^{-6}$ $= 9.75 \times 10^{-5}$ mol L^{-1}	1
$n(H^+)_{SO2} = 9.75 \times 10^{-5} \times 0.100$ $= 9.75 \times 10^{-6}$ mol	1
$n(H_2SO_3) = n(H^+)/2$ $= 9.75 \times 10^{-6}/2$ $= 4.88 \times 10^{-6}$ mol	1
1:1 ratio between SO_2 and H_2SO_3	1
$V(SO_2) = nRT/P$ $= 4.88 \times 10^{-6} \times 8.314 \times 289.15/97.2$ $= 1.21 \times 10^{-4}$ L	1
Total	**6**

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