Units 3+4

ATAR CHEMISTRY

Sem 2 2017

CORPUS CHRISTI COLLEGE

SEQUERE DOMINUM

STUDENT NUMBER

mark CORRECT

Multiple Choice Answers

For each question, shade the box to indicate your answer.
Use only a blue or black pen to shade the boxes.

For example, if b is your answer: ☐ a ■ b ☐ c ☐ d

If you make a mistake, place a cross through that square, do not erase or use correction fluid and shade your new answer.

For example, if b is a mistake and d is your answer: ☐ a ☒ b ☐ c ■ d

In the event that you then change your mind back to your original answer, you then cross out the second selection and then circle the first choice.
For example, if b was the first choice and d your second, but you changed your mind back and b is your answer: ☐ a ◯ b ☐ c ☒ d

Marks are only awarded for correct answers. No answer, or an incorrect answer, scores no marks for that question.

No marks will be given if more than one answer is completed for any question.

Candidates who inadvertently use pencil when answering multiple choice questions will not be disadvantaged.

Questions 1-15

1	☐ a	☐ b	☐ c	■ d	6	■ a	☐ b	☐ c	☐ d	11	☐ a	☐ b	☐ c	■ d
2	■ a	☐ b	☐ c	☐ d	7	☐ a	☐ b	■ c	☐ d	12	☐ a	☐ b	☐ c	■ d
3	☐ a	☐ b	■ c	☐ d	8	■ a	☐ b	☐ c	☐ d	13	☐ a	☐ b	■ c	☐ d
4	☐ a	■ b	☐ c	☐ d	9	☐ a	☐ b	■ c	☐ d	14	☐ a	■ b	☐ c	☐ d
5	☐ a	☐ b	■ c	☐ d	10	☐ a	■ b	☐ c	☐ d	15	☐ a	☐ b	☐ c	■ d

Questions 16-25

16	■ a	☐ b	☐ c	☐ d	21	☐ a	☐ b	☐ c	■ d
17	☐ a	■ b	☐ c	☐ d	22	☐ a	■ b	☐ c	☐ d
18	☐ a	☐ b	■ c	☐ d	23	☐ a	■ b	☐ c	☐ d
19	☐ a	☐ b	☐ c	■ d	24	☐ a	☐ b	☐ c	■ d
20	☐ a	☐ b	☐ c	■ d	25	☐ a	■ b	☐ c	☐ d

SECTION TWO: Short answer **35% (70 Marks)**

This section has **8** questions. Answer **all** questions. Write your answers in the spaces provided.

Additional working space pages at the end of this Question/Answer booklet are for planning or continuing an answer. If you use these pages for planning, indicate at the original answer, the page number it is planned/continued on and write the question number being planned/continued on the additional working space page.

Suggested working time: 60 minutes.

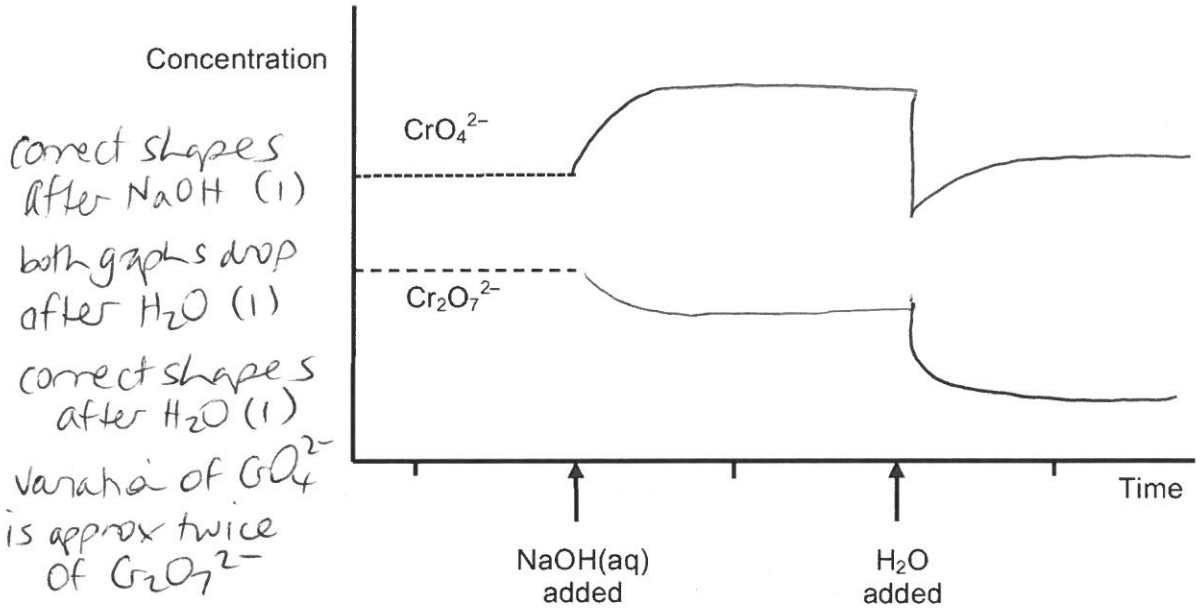
Question 26 **(6 marks)**

A student investigated changes to the following equilibrium.

$$2\ CrO_4^{2-}{}_{(aq)} + 2\ H^+{}_{(aq)} \rightleftharpoons Cr_2O_7^{2-}{}_{(aq)} + H_2O_{(\ell)}$$

She took 50 mL of a solution of sodium dichromate/chromate and added sodium hydroxide pellets to the solution. The solution was left to return to a state of equilibrium. She then added 50 mL of distilled water to the beaker and stirred.

(a) Complete the following graph showing the changes to the concentrations of the chromate and dichromate ions involved in the reaction until a new equilibrium is reached. (4 marks)



correct shapes after NaOH (1)
both graphs drop after H_2O (1)
correct shapes after H_2O (1)
Variation of CrO_4^{2-} is approx twice of $Cr_2O_7^{2-}$

(b) Describe the colour changes expected over the same time. (2 marks)

Solution goes from orange to yellow on addition of NaOH. (1) On addition of water yellow solution fades suddenly then becomes deeper yellow. (1)

Question 27 **(4 marks)**

In April 2017 carbon dioxide levels in the atmosphere reached 410 ppm, a level not reached for millions of years. The increase in levels of carbon dioxide is causing increased ocean acidification. Two symptoms of ocean acidification are the increase in concentration of hydrogen ions and the decrease in the concentration of carbonate ions.

Using relevant equations, explain how increased levels of atmospheric carbon dioxide causes:

(i) an increase in concentration of hydrogen ions in the ocean. (2 marks)

Carbon dioxide dissolves in water to create (1)
carbonic acid which increases H^+/H_3O^+ concentration
$H_2O_{(l)} + CO_{2(g)} \rightleftharpoons H_2CO_{3(aq)} \rightleftharpoons 2H^+_{(aq)} + CO_3^{2-}{}_{(aq)}$
or $H_2CO_3 + H_2O \rightleftharpoons HCO_3^-{}_{(aq)} + H_3O^+_{(aq)}$ (1)

(ii) a decrease in the concentration of carbonate ions. (2 marks)

The increased level of hydrogen/hydronium
reacts with the carbonate ions
either $CO_3^{2-}{}_{(aq)} + H^+_{(aq)} \rightleftharpoons HCO_3^-{}_{(aq)}$
or $CO_3^{2-}{}_{(aq)} + H_3O^+_{(aq)} \rightleftharpoons HCO_3^-{}_{(aq)} + H_2O_{(l)}$

Question 28 **(7 marks)**

Aluminium is refined in a two-part process from the mineral 'bauxite' and extracted directly from alumina, (Al_2O_3) using electrorefining processes. Aluminium is used to make many different alloys due to its corrosion resistance, as well as finding application in the building industry and aviation, due to its light-weight and relatively strong properties.

A student was given the following sets of aqueous 1.00 mol L^{-1} solutions and asked to find out whether any of them could be safely stored in an aluminium cup.

The solutions were: $Fe(NO_3)_2$, $Mg(NO_3)_2$, $Cu(NO_3)_2$ and $Ni(NO_3)_2$

(a) Using relevant chemical equations, explain which of the solutions could be safely stored in a cup made of aluminium metal.

(4 marks)

The only solution that could be safely stored in the aluminium cup is $Mg(NO_3)_2$ (1)
This is because Al solid will not be oxidised by Mg^{2+} ions as (1)

(1) $Al \longrightarrow Al^{3+} + 3e^-$ $(E^\circ = +1.68V)$ } $E^\circ = -0.68V$
$Mg^{2+} + 2e^- \rightarrow Mg$ $(E^\circ = -2.36V)$ } no reaction

All the other cations Fe^{2+}, Cu^{2+}, Ni^{2+} in the other solutions have higher reduction potentials thus they will oxidise aluminium cup. (1)

When aluminium metal is placed in an acidified solution of sodium hydrogendichromate, (containing the weakly acidic ion, hydrogendichromate ($HCr_2O_7^-$), a deep green solution containing chromium (III) ions is formed, and the aluminium metal dissolves producing aluminium ions.

(b) In the space below, write separate oxidation and reduction half-equations, and then the overall redox equation for this reaction.

(3 marks)

$(Al_{(s)} \longrightarrow Al^{3+}_{(aq)} + 3e^-) \times 2$ (1)

$6e^- + HCr_2O_7^- + 13H^+ \longrightarrow 2Cr^{3+}_{(aq)} + 7H_2O$ (1)

$2Al_{(s)} + HCr_2O_{7(aq)}^- + 13H^+_{(aq)} \longrightarrow 2Al^{3+}_{(aq)} + 2Cr^{3+}_{(aq)} + 7H_2O_{(l)}$ (1)

Question 29 **(4 marks)**

Sodium hypochlorite (NaCℓO) is commonly used in the textile industry as a bleach. When added to water, hypochlorous acid (HCℓO) is formed. The solution can now be considered as an equilibrium system, where hypochlorite ions are converted into hypochlorous acid.

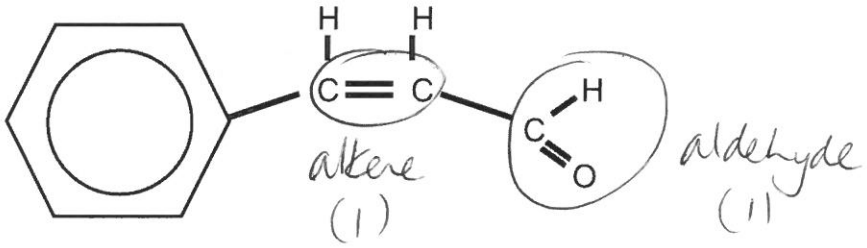
$$C\ell O^-(aq) + H_2O(\ell) \rightleftharpoons HC\ell O(aq) + OH^-(aq) + HEAT$$

Complete the following table by predicting, with reasoning, the effect that the following changes will have on the concentration of the hypochlorous acid (HCℓO) in the treated water. (4 marks)

Imposed change	Predicted effect to the concentration of HCℓO(aq)	Brief justification for your prediction
Addition of some hydrochloric acid to the water	Increase (1)	The addition of H^+ ions will neutralise the OH^- ions on product side thus favouring forward reaction due to higher rate of collisions
Increasing the temperature of the water	decrease (1)	Forward reaction is exothermic thus increasing the temperature the system will favour the reverse reaction to use up heat and decrease the concentration of HClO(aq)

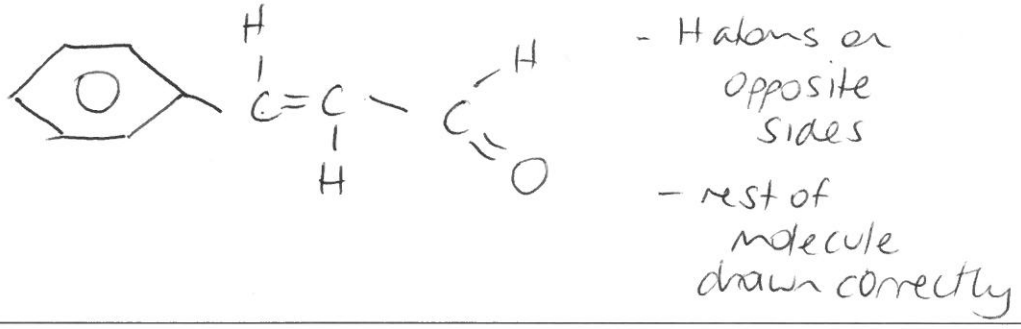
Question 30 **(8 marks)**

The compound shown below gives cinnamon its characteristic flavour and odour. It is a pale yellow liquid that occurs naturally in the bark of cinnamon trees.

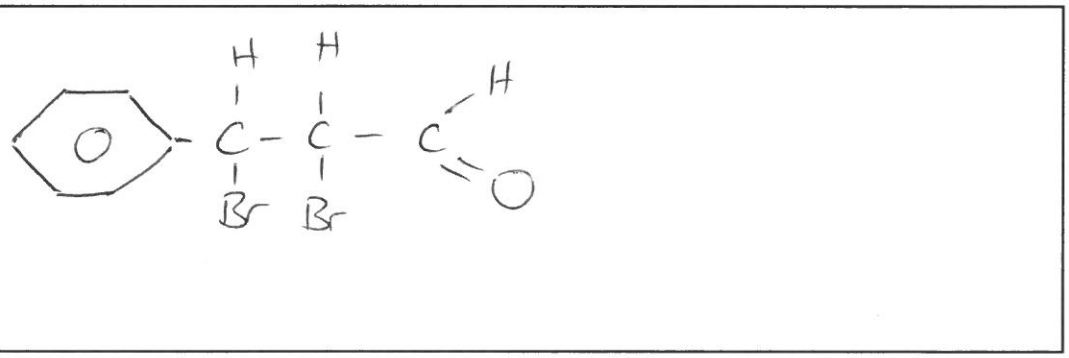


(a) On the diagram above, circle and label two functional groups present in the molecule. (2)

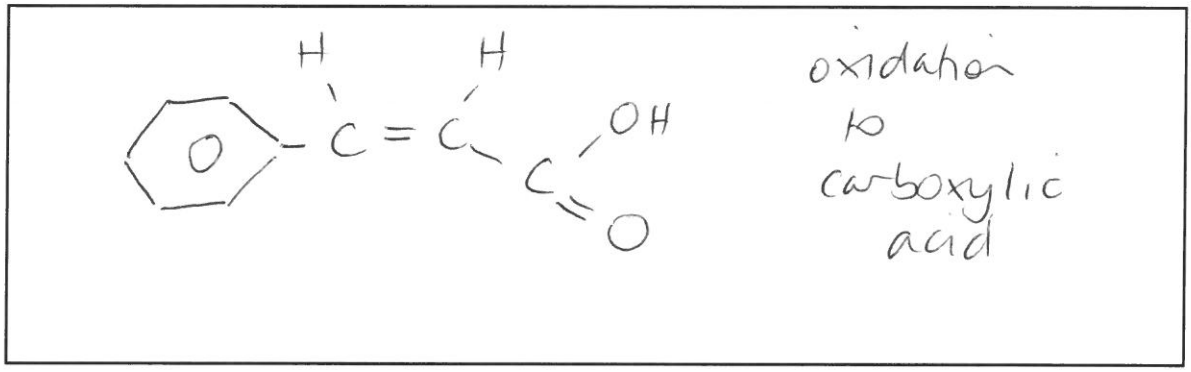
(b) Draw a geometric isomer of the compound presented above. (1)



(c) Draw the structure of the product that would be formed if the **original** compound was mixed with some aqueous bromine (bromine water). (1)

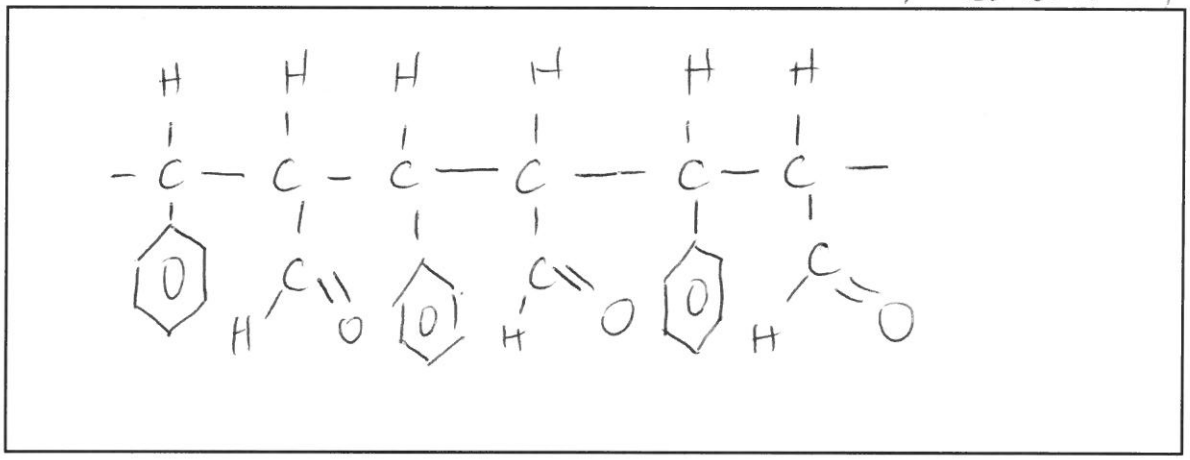


(d) Draw the structure of the product that would be formed if the **original** compound was mixed with an acidified solution of sodium dichromate. (1)



(e) Draw the structure of the product that would be formed if the **original** compound was polymerised in the presence of an appropriate catalyst (draw three repeating units in your answer) (2)

double C=C bond breaks, neighbouring molecules link up



(f) State the name given to the type of polymerisation described in part (e) above. (1)

addition polymerisation

Question 31 **(6 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.

If no change is observed, you should state this.

(a) Solid iodine is added to a solution of potassium chloride. (2 marks)

no change is observed.

(b) Iron(III) chloride solution is added to solid copper. (2 marks)

Solution changes colour from pale brown to a pale blue/green colour - solid is salmon pink

from (1) to (1)

(c) Propene gas is bubbled through a solution of aqueous bromine. (2 marks)

Bubbles of gas (colourless) are passed through a yellow orange solution, the solution fades and turns colourless

from (1) to (1)

Question 32 **(8 marks)**

Describe how you could distinguish between the following pairs of compounds using chemical tests. For each test, write one equation for a reaction that occurred. (In (b) the test must not involve using an acid-base indicator*)

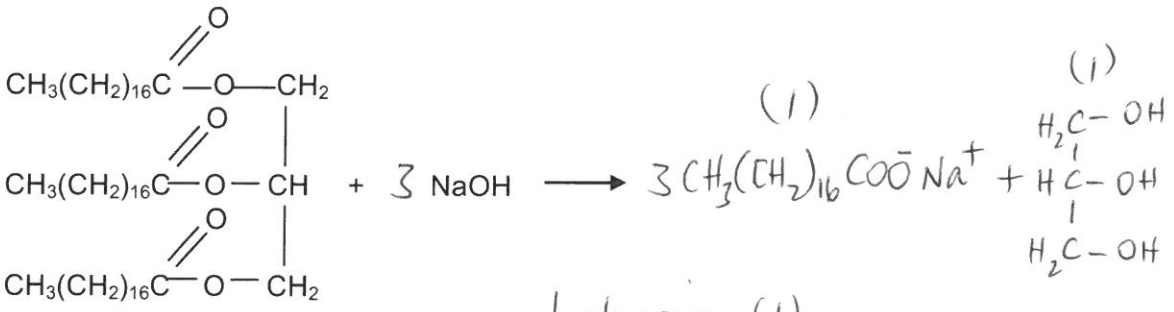
	Compounds	Description of Test	Observations
(a)	butan-1-ol	*either:* Add a solution of acidified potassium permanganate to both substances (~~and warm~~) (1) *or:* Add a solution of acidified sodium/potassium dichromate to both substances (and warm)	butan-1-ol either: purple colour fades (1) or: orange solution turns (deep) green
	methylpropan -2-ol		methylpropan-2-ol No visible change (1)
	either: $5\ CH_3CH_2CH_2CH_2OH + 4\ MnO_4^- + 12\ H^+ \rightarrow 5\ CH_3CH_2CH_2COOH + 4\ Mn^{2+} + 11\ H_2O$ *or:* $3\ CH_3CH_2CH_2CH_2OH + 2\ Cr_2O_7^{2-} + 16\ H^+ \rightarrow 3\ CH_3CH_2CH_2COOH + 4\ Cr^{3+} + 11\ H_2O$ *or accept equations to produce the aldehyde:* *either:* $5\ CH_3CH_2CH_2CH_2OH + 2\ MnO_4^- + 6\ H^+ \rightarrow 5\ CH_3CH_2CH_2CHO + 2\ Mn^{2+} + 8\ H_2O$ (1) *or:* $3\ CH_3CH_2CH_2CH_2OH + Cr_2O_7^{2-} + 8\ H^+ \rightarrow 3\ CH_3CH_2CH_2CHO + 2\ Cr^{3+} + 7\ H_2O$		
(b)	a solution of methylpropan -2-ol	Add a carbonate (solid or solution) to each of the solutions. (1)	methylpropan-2-ol No visible change (1)
	a solution of propanoic acid		propanoic acid Colourless gas produced (1)
	either (for solid): $CH_3CH_2COOH(aq) + Na_2CO_3(s) \rightarrow 2\ Na^+(aq) + 2\ CH_3CH_2COO^-(aq) + H_2O(\ell) + CO_2(aq)$ *or (for solution):* $CH_3CH_2COOH(aq) + CO_3^{2-}(aq) \rightarrow CH_3CH_2COO^-(aq) + H_2O(\ell) + CO_2(g)$ (1)		

need one equation for each test

Question 33 **(8 marks)**

Soaps and detergents are common organic substances widely used in our daily lives. While they both consist of a relatively long hydrocarbon chain which is attached to a 'polar end', there are also significant differences between the two substances, particularly in their applications as cleaning agents.

A typical soap like sodium stearate, $(CH_3(CH_2)_{16}COO^- Na^+)$, which can be produced from a reaction between tristearin and sodium hydroxide, is shown in the partially completed 'saponification' reaction below.



(1) (1)

balancing (1)

Tristearin

(a) Complete and balance the equation above, including any other organic products formed. (3 marks)

Soaps and detergents function to remove fats and grease from objects as they clean.

(b) Using a simplified general representation of a typical soap or detergent, explain in terms of their structure and polarity, how they are able to achieve their task as cleaners. (3 marks)

Both soap and detergent exhibit a polar (hydrophilic) end and a long hydrocarbon non-polar (hydrophobic) end (1) The hydrophobic 'tail' exhibits dispersion forces which interact and successfully embed in the grease or fat. The polar end can interact with the Hydrogen bonding in the water molecules. With agitation the soap/detergent molecules are able to break up sections of grease/fat into micelles and cleaning is achieved.

(c) Name these structures: (2 marks)

i) $CH_3CH_2COOCH_2CH_2\ CH_2CH_3$

butyl propanoate (1)

ii) $CH_3CH_2CH(NH_2)CH_2\ CH_2CH_3$

3-hexanamine (1)

Question 34 **(10 marks)**

(a) 20.0 mL of 0.0400 mol L^{-1} hydrochloric acid solution was added to 45.0 mL of 0.0200 mol L^{-1} sodium hydroxide solution. Calculate the pH of the resulting solution. (4 marks)

$$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O$$

$n(HCl) = CV$
$= 0.0400 \times 0.020$
$= 8.00 \times 10^{-4}$ moles (½)

$n(NaOH) = CV$
$= 0.0200 \times 0.0450$
$= 9.00 \times 10^{-4}$ moles (½)

LR is HCl (1)

$n(OH^-)_{excess} = 9.00 \times 10^{-4} - 8.00 \times 10^{-4} = 1.00 \times 10^{-4}$ moles

$c(OH^-) = \frac{n}{V}$
$= \frac{1.00 \times 10^{-4}}{(20+45) \times 10^{-3}}$
$= 1.54 \times 10^{-3}$ mol L^{-1} (½)

$c[H^+] = \frac{10^{-14}}{1.54 \times 10^{-3}}$
$= 6.50 \times 10^{-12}$ mol L^{-1} (½)

$pH = -\log[H^+]$
$= -\log 6.50 \times 10^{-12}$
$= 11.2$ (1)

See next page

(b) The experiment in (a) was repeated, but this time using 20.0 mL of 0.0400 mol L^{-1} ethanoic (acetic) acid solution instead of the hydrochloric acid. Would the pH of the final solution be the same or different from the answer calculated in part (a)? Explain your reasoning (no calculations are required). (3 marks)

- It would be the same (1)
- The ethanoic acid will totally ionise due to presence of the strong base (1) NaOH
- There will be same number of hydrogen ions present (1)

(c) The experiment in (a) was repeated again, but this time using 20.0 mL of 0.0400 mol L^{-1} sulfuric acid solution instead of the hydrochloric acid. Would the pH of the final solution be the same or different from the answer calculated in part (a)? Explain your reasoning. (3 marks)

It would be different (1)
Sulphuric acid (H_2SO_4) is a diprotic acid (1)
The number of moles of hydrogen ions provided to the solution will be more so there will be an excess

Question 35 **(9 marks)**

Carbon disulfide (CS_2) can be manufactured using an endothermic reaction between sulfur trioxide gas and carbon dioxide as shown below:

Heat + $2\,SO_3(g) + CO_2(g) \rightleftharpoons CS_2(g) + 4\,O_2(g)$

(a) Write an expression for the equilibrium constant of the reaction. (1 mark)

$$K = \frac{[CS_2][O_2]^4}{[SO_3]^2[CO_2]}$$

(b) Predict how each of the following changes to an equilibrium mixture would affect the yield of CS_2. (increase, decrease or no effect)

(i) addition of CO_2 (at constant total volume) (1 mark)

increase

(ii) increasing the temperature (1 mark)

increase

(iii) adding a catalyst (1 mark)

no change/effect

(iv) increasing the pressure by introducing argon gas into the reaction vessel (at constant volume) (1 mark)

no change/effect

(c) In the production plant, the carbon disulfide is removed from the reaction vessel on a regular basis. Using collision theory, explain how this technique will increase the yield of the reaction. (4 marks)

The concentration (1) of the carbon disulfide is continually reduced which reduces the rate of the reverse reaction due to less collisions (1) between the CS_2 and O_2. The rate of the forward reaction is not affected. There is a net forward reaction - favoured (1) increasing the products (↑yield) and I/m shift to right (1)

END OF SECTION TWO

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

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

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

Final answers to calculations should be expressed to **the appropriate number** of significant figures.

Additional working space pages at the end of this Question/Answer booklet are for planning or continuing an answer. If you use these pages for planning, indicate at the original answer, the page number it is planned/continued on and write the question number being planned/continued on the additional working space page.

Suggested working time: 70 minutes.

Question 36 **(18 marks)**

The opening of Perth Children's Hospital has been delayed due to lead contamination of the drinking water. Lead is a neurotoxin that is particularly harmful to children. One of the possible causes of the contamination was brass fittings. Brass is a metal alloy made of copper and zinc but lead is sometimes added to improve its malleability.

A recent large-scale study on water samples in New South Wales found that low-level lead contamination of water is widespread in Australian homes, with brass tap fittings the most likely source. In a subsequent experiment, the researchers tested water before and after it passed through brass taps and stainless-steel taps. Lead was only found in water that had passed through brass ones.

In 2014, the US government mandated a lead limit of 0.25 percent in plumbing fittings. Taps in Australia are typically made of brass that contains lead at a level of about 2 to 4 percent.

(a) Use evidence from the list of standard reduction potentials on your data sheet to explain why lead from brass is more likely than copper to corrode into drinking water. (2 marks)

The standard reduction potential for Pb^{2+}/Pb is $-0.13V$ and for Cu^{2+}/Cu $+0.34V$ (1)

Therefore lead metal is a stronger reducing agent than copper metal / so lead oxidises more easily than copper (1)

(b) Write an ionic equation, including state symbols, for the reaction of sulfuric acid with metallic lead. (2 marks)

$Pb_{(s)} + 2H^+_{(aq)} + SO_{4(aq)}^{2-} \rightarrow PbSO_{4(s)} + H_{2(g)}$

(c) In the experiment described in the passage above, identify the independent and dependent variable. (2 marks)

independent variable = material used to make tap (1)

dependent variable = level/concentration/amount of lead in water (1)

An experiment was carried out to calculate the percentage of lead in a sample of brass. A 45.13 g sample of brass was dissolved in excess 6.00 mol L^{-1} hydrochloric acid and any non-metallic insoluble solids were filtered out. Then an excess of 0.500 mol L^{-1} sodium sulfate solution was added to precipitate lead(II) sulfate. After washing and drying, this precipitate had a mass of 2.33 g.

(d) (i) Calculate the percentage, by mass, of lead in the sample. (4 marks)

$n(PbSO_4) = \frac{m}{MM}$

$= \frac{2.33}{303.27}$

$= 7.683 \times 10^{-3}$ moles (1)

$n(Pb) = n(PbSO_4)$ (1)

$m(Pb) = n \times MM$

$= 7.683 \times 10^{-3} \times 207.2$

$= 1.592$ g (1)

$\%\ Pb_{\text{in sample}} = \frac{\text{mass Pb}}{\text{mass sample}} \times \frac{100}{1}$

$= \frac{1.592}{45.13} \times \frac{100}{1}$

$= 3.53\%$ (1)

(ii) Write an ionic equation for the precipitation reaction used in this experiment and calculate the minimum volume of the 0.500 mol L^{-1} sodium sulfate solution required. (3 marks)

$Pb^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \rightarrow PbSO_4(s)$ (1)

$n(PbSO_4) = n(Pb) = 7.683 \times 10^{-3}$ moles (1)

$v(PbSO_4) = \frac{n}{c}$

$= 7.683 \times 10^{-3} / 0.500$ (1)

$= 0.0154\,L \Rightarrow 15.4\,mL$

Lead acts as a poison by displacing biologically-active metal cations, such as calcium and zinc, from their proteins that act as enzymes. Calmodulin, for example is an enzyme that regulates a number of body functions, including muscle contraction, metabolism and memory. Lead displaces one calcium atom from the enzyme molecule, thus reducing the enzyme's efficiency.

(e) Briefly describe how the enzymes catalyse chemical reactions occurring in the body. (2 marks)

Enzymes act as a catalyst for the reaction (1) providing an alternative reaction pathway with a lower activation energy (1)

(f) Using evidence from the periodic table, suggest why the replacement of calcium in an enzyme molecule by lead will significantly affect the function of the enzyme. (2 marks)

The lead atom/ion is significantly larger/heavier than the calcium atom/ion so the structure (1) of the enzyme will be distorted.
The lead atom has 4 valence electrons compared to calcium with 2 valence electrons - different bonding/structure

Question 37 **(15 marks)**

A diprotic amino acid, known to only contain carbon, hydrogen, oxygen and nitrogen underwent analysis to determine its formula. When a 12.50 g sample of the amino acid was combusted in oxygen, 18.60 g of carbon dioxide, 7.65 g of water, and 3.88 g of nitrogen dioxide was produced.

2.28 g of the acid was dissolved in 50.0 mL of water. 10.0 mL of this solution required 24.70 mL of 0.250 mol L^{-1} sodium hydroxide solution for complete neutralisation.

(a) Calculate the empirical formula of the amino acid. (7 marks)

$n(CO_2) = \frac{m}{MM}$

$= \frac{18.60}{44.01}$

$= 0.423$

$n(C) = n(CO_2)$

$m(C) = 0.423 \times 12.01$

$= 5.076g$ (1)

$n(H_2O) = \frac{m}{MM}$

$= \frac{7.65}{18.016}$

$= 0.425$

$n(H) = 2n(H_2O)$

$m(H) = 2 \times 0.425 \times 1.008$

$= 0.856g$ (1)

$n(NO_2) = \frac{m}{MM}$

$= \frac{3.88}{46.01}$

$= 0.0843$

$n(N) = n(NO_2)$

$m(N) = 0.0843 \times 14.01$

$= 1.181g$ (1)

$m(O) = 12.50 - 5.076 - 0.856 - 1.181$

$= 5.387g$ (1)

	C	H	N	O
mass	5.076	0.856	1.181	5.387
mole ratio	$\frac{5.076}{12.01}$	$\frac{0.856}{1.008}$	$\frac{1.181}{14.01}$	$\frac{5.387}{16.00}$ (1)
	$\frac{0.423}{0.0843}$	$\frac{0.849}{0.0843}$	$\frac{0.0843}{0.0843}$	$\frac{0.337}{0.0843}$
	~5	~10	~1	~4 (1)

EF $C_5H_{10}NO_4$ (1)

See next page

(b) Calculate the molecular mass of the amino acid. (4 marks)

$n(NaOH) = CV$

n in 10mL $= 0.250 \times 0.02470$

$= 6.175 \times 10^{-3}$ moles

$n(NaOH)$ in 50mL $= \frac{50}{10} \times 6.175 \times 10^{-3} = 0.03087$ moles

$n(\text{diprotic amino acid}) = \frac{1}{2} n(NaOH) = 0.01544$ moles

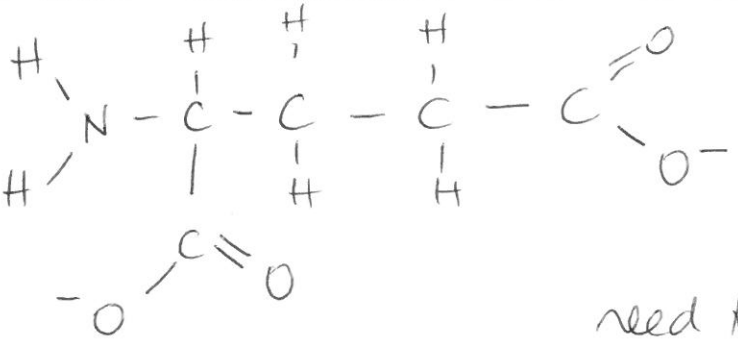
$MM(\text{diprotic aa}) = \frac{m}{n} = \frac{2.28}{0.01544} = 147.7 \text{ gmol}^{-1}$

(c) Use your data booklet to name the amino acid. (1 mark)

glutamic acid

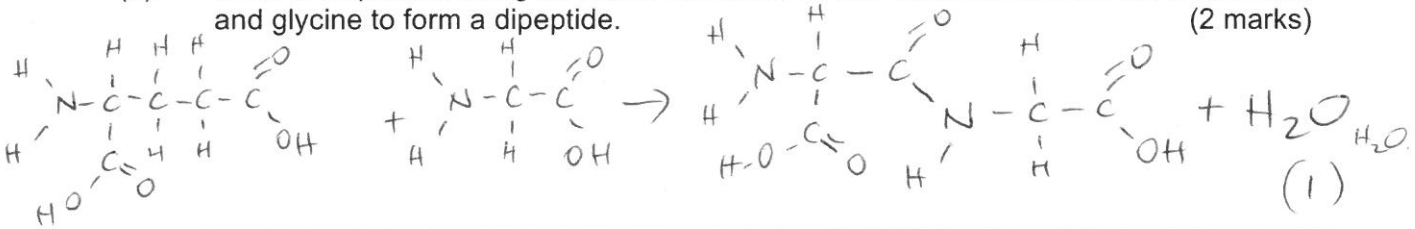
Note: If you were unable to determine an answer to part (c), use aspartic acid for the remainder of this question

(d) Draw the structure of the amino acid that would exist in a solution with a pH of 10. (1 mark)



need to have negative charges on both carboxyl groups

(e) Write an equation, using structural formulae, for the reaction between the amino acid and glycine to form a dipeptide. (2 marks)

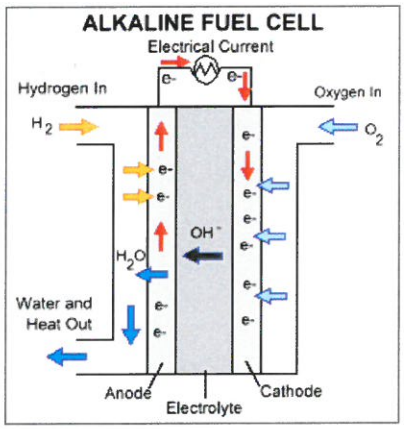


(1)

(1) correct

Question 38 **(17 marks)**

An alkaline version of a typical fuel cell is shown below. It utilises the oxidation of hydrogen gas (H_2) and the reduction of oxygen gas (O_2). Both reactants are continuously 'fed into' the cell during normal operation. The major product from the overall redox reaction is water, (H_2O).



(a) During the normal operation of this cell, write the appropriate reactions that will occur:

(i) at the cathode. (1 mark)

$O_{2(g)} + 2H_2O_{(l)} + 4e^- \rightarrow 4OH^-_{(aq)}$ $E^\circ = +0.40V$

(ii) at the anode. (1 mark)

$H_{2(g)} + 2OH^-_{(aq)} \rightarrow 2H_2O_{(l)} + 2e^-$ $E^\circ = +0.83V$

(iii) for the cell. (1 mark)

$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)}$

(a) What is the maximum EMF that this fuel cell can generate under standard conditions? (1 mark)

EMF = (+0.40) + (0.83) = +1.23V

(b) State one advantage and one disadvantage of a typical fuel cell when compared to a dry cell. (2 marks)

Advantage:

more reliable, consistent EMF, no toxic emissions or products

Disadvantage:

much more expensive, reactants need to be consistently fed into cells

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Another type of electrochemical cell utilises the following standard half-cell reactions.

$Cr^{3+}(aq) + 3e^- \longrightarrow Cr(s)$ $\quad E^\circ = -0.74\ V$

$Cl_2(g) + 2e^- \longrightarrow 2Cl^-(aq)$ $\quad E^\circ = +1.36\ V$

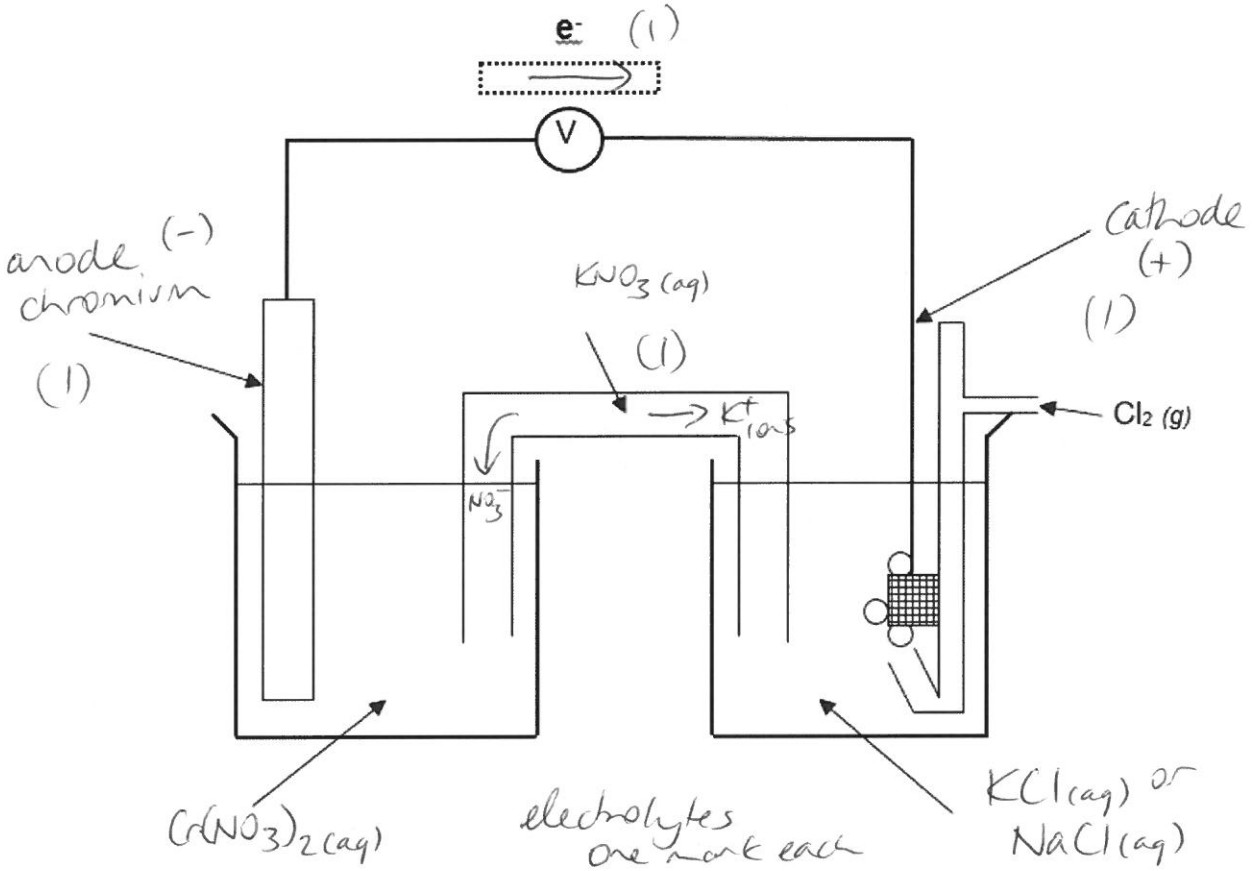
Complete the diagram below to show the construction and operation of this cell. Ensure that you fully label the cell to include:

(c) the anode and cathode, including their respective polarities. (2 marks)

(d) the electrolytes used. (2 marks)

(e) the direction of movement of cations and anions in the salt bridge. (1 mark)

(f) the direction of movement of electrons. (1 mark)



Write the overall cell reaction and calculate the cell EMF under standard conditions for this cell. (2 marks)

$3Cl_{2(g)} + 2Cr_{(s)} \rightarrow 6Cl^-_{(aq)} + 2Cr^{3+}_{(aq)}$ (1)

Cell EMF = $+2.10\ V$ (1)

(g) With reference to the cell you constructed above, and using relevant chemical theory, explain whether a solution of sodium carbonate would be a good choice for use as a salt bridge electrolyte. (Include a balanced chemical equation in your explanation).
(3 marks)

Using sodium carbonate as a salt bridge electrolyte would be a POOR choice. (1)
This is because any carbonate ions that came in contact with chromium ions would (1) precipitate 'blocking' the salt bridge + restricting ion movement.

$2Cr^{3+}_{(aq)} + 3CO_3^{2-}{}_{(aq)} \rightarrow Cr_2(CO_3)_{3(s)}$ (1)

Question 39 **(13 marks)**

The reaction for the production of ethanol from ethene is shown below.

$$CH_2CH_2(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g) \qquad \Delta H = -45 \text{ kJ mol}^{-1}$$

(a) Use green chemistry principles to explain why it is beneficial to achieve a high yield of ethanol. (2 marks)

Achieving a high yield means there are less wasted reactants (1)

Any: saves money + resources
more sustainable use of resources
less disposal issues

(b) Use sustainability principles to explain why it may be beneficial to source ethanol through a fermentation process rather than the reaction shown above. (2 marks)

fermentation uses biomass to produce ethanol
Biomass is renewable whereas ethene is sourced from non renewable crude oil
so fermentation methods are more sustainable

(c) It was found that 170.8 kg of ethanol was produced from 200.0 kg of ethene gas. Calculate the percentage yield of this reaction. (4 marks)

$n(CH_2CH_2) = \frac{m}{MM}$
$= \frac{200000}{28.02}$
$= 7129$ moles (1)

$n(CH_2CH_2) = n(CH_3CH_2OH)$ expected (1)
$7129 = n(CH_3CH_2OH)$ expected.

$m(CH_3CH_2OH)$ expected $= n \times MM$
$= 7129 \times 46.068$
$= 328447$ g (1)

% yield $= \frac{\text{pure}}{\text{impure}} \times 100$
$= \frac{170.8 \times 10^3}{328447} \times 100$
$= 52.0\%$

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The ethanol in this reaction can be used to make ethyl ethanoate.

(d) Write an equation for this reaction, and state the conditions required. (2 marks)

$$CH_3CH_2OH + CH_3COOH \xrightarrow[\text{heat}]{H_2SO_4 \text{ catalyst}} CH_3COOCH_2CH_3 + H_2O \quad (1)$$

(1)

(e) If this reaction has a yield (efficiency) of 67.0%, calculate the mass of ethanol required to produce 1.00 tonne (1.00×10^6 g) of the ethyl ethanoate. (3 marks)

$$n(CH_3COOCH_2CH_3) = \frac{m}{MM}$$
$$= \frac{1.00 \times 10^6}{88.104}$$
$$= 11350 \text{ moles} \quad (1)$$

$$n(CH_3CH_2OH)_{required} = n(CH_3COOCH_2CH_3)$$
$$= \frac{100}{67} \quad (1) \times 11350$$
$$= 16940 \text{ moles} \quad (1)$$

$$m(CH_3CH_2OH) = n \times MM$$
$$= 16940 \times 46.068$$
$$= 780392 \text{ g} \quad (1)$$
$$\Rightarrow 7.80 \times 10^2 \text{ kg}$$

Question 40 **(17 marks)**

Standard solutions of sodium hydroxide, NaOH, must be kept in airtight containers. This is because NaOH is a strong base and absorbs acidic oxides, such as carbon dioxide, CO_2, from the air and reacts with them. As a result, the concentration of NaOH is changed to an unknown extent.

Carbon dioxide in the air reacts with water to form carbonic acid. This acid can then react with sodium hydroxide to form sodium carbonate.

(a) Write two molecular equations to illustrate the chemical process described in this reaction sequence. (2 marks)

$CO_{2(g)} + H_2O_{(\ell)} \rightleftharpoons H_2CO_{3(aq)}$ (1)

$H_2CO_{3(aq)} + 2NaOH_{(aq)} \rightleftharpoons Na_2CO_{3(aq)} + 2H_2O_{(\ell)}$ (1)

(b) A freshly prepared solution of sodium hydroxide was titrated against a previously standardised solution of ethanoic acid, using standard laboratory volumetric glassware. What would be a suitable indicator for this titration?

Circle your choice from the list below. (1 mark)

Methyl orange **Phenolphthalein** **Universal indicator**

The freshly prepared sodium hydroxide solution, as described in (b) above, was found to have a concentration of 0.1150 mol L^{-1}. A 250.0 mL batch of the solution was left in a storage bottle on the laboratory bench over-night but a careless student forgot to replace the lid on the bottle. The next day, the chemistry teacher noticed this and thought it would be a good exercise for the students to determine the mass of carbon dioxide that was absorbed in the solution of sodium hydroxide so she gave the students the task of carrying out a titration to determine this, by using a previously standardised sulfuric acid solution.

(c) Write a balanced chemical equation for the reaction between sulfuric acid and sodium hydroxide. (2 marks)

$H_2SO_{4(aq)} + 2NaOH_{(aq)} \rightarrow Na_2SO_{4(aq)} + 2H_2O_{(\ell)}$

(1) correct formula

(1) balanced correctly

20.00 mL aliquots of the sodium hydroxide solution were taken and titrated using a suitable indicator with the standardised 0.0565 mol L^{-1} sulfuric acid solution from the burette. The results of the titration are tabulated below.

(d) Complete the table and calculate the average titre of H_2SO_4 (2 marks)

Final reading (mL)	20.60	19.65	21.10	20.80	19.05
Initial reading (mL)	4.50	4.45	5.25	5.00	3.20
Titration volume (mL)	16.10	~~15.20~~	15.85	15.80	15.85

(1)

Average titre 15.83 mL (1) need to remove outly

(e) Calculate the moles of acid titrated and thus the moles of sodium hydroxide in the 20.00 mL aliquots. (3 marks)

$n(H_2SO_4) = CV$
$= 0.0565 \times 0.01583$
$= 8.944 \times 10^{-4}$ moles (1)
$n(NaOH) = 2n(H_2SO_4)$ (1)
$= 2 \times 8.944 \times 10^{-4} = 0.00179$ moles (1)

(f) Thus calculate the concentration of the sodium hydroxide solution. (1 mark)

$c(NaOH) = \frac{n}{V}$
$= \frac{0.001789}{0.020} = 0.0894$ mol L^{-1} * need correct sig figs

(g) In view of your results in (f) above and considering the original concentration of the sodium hydroxide solution:

Calculate the number of moles of sodium hydroxide that were originally present in the freshly made 250.0 mL solution. (1 mark)

$n(NaOH)_{original} = CV$
$= 0.115 \times 0.250$
$= 0.0288$ moles (1)

(i) Calculate the actual number of moles of sodium hydroxide in the 250.0 mL solution using the results of the students' titration. (2 marks)

$n(NaOH)$ from titration $= \frac{250}{20} \times 0.00179 = 0.0224$ moles (1) (1)

(ii) Using the results of (i) and (ii) above, calculate the moles of sodium hydroxide that reacted with the carbon dioxide as a consequence of the student leaving the storage bottle open over-night. (1 mark)

$n(NaOH)$ difference $= 0.0288 - 0.0224$
$= 0.00640$ moles (1)

(iii) Use the balanced chemical equations in part (a) on the previous pages as well as the titration data, to calculate the mass of carbon dioxide absorbed by the sodium hydroxide solution. (2 marks)

From reaction in (a)

$n(CO_2) = \frac{1}{2} n(NaOH) \left(\frac{1}{2}\right)$
$= \frac{1}{2} \times 0.00640$
$= 0.00320$ moles $\left(\frac{1}{2}\right)$

$m(CO_2) = n \times MM$
$= 0.00320 \times 44.01$
$= 0.141\,g$

End of questions

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