2010

HSC Half-Yearly Examination

Chemistry

General Instructions
Reading time – 5 minutes
Working time – 1.5 hours

Write using blue or black pen
Draw diagrams using pencil
Approved calculators may be used
Write your student number on each section of this booklet

Total marks 65
This examination has two parts, Part A and Part B.
Part A – 10 marks
Attempt Questions 1 – 10.
Allow about 15 minutes for this part.

Part B – 55 marks
Attempt Questions 11 – 19.
Allow about 1 hour and 15 minutes for this part.

Teacher-in-charge: S. Davis

Task Weighting: 20%

Chemistry 2010

Multiple choice answer sheet

This sheet may be separated from the rest of the paper for your convenience.

Part A

1. A ⬭ B ⬭ C ⬭ D ⬭
2. A ⬭ B ⬭ C ⬭ D ⬭
3. A ⬭ B ⬭ C ⬭ D ⬭
4. A ⬭ B ⬭ C ⬭ D ⬭
5. A ⬭ B ⬭ C ⬭ D ⬭
6. A ⬭ B ⬭ C ⬭ D ⬭
7. A ⬭ B ⬭ C ⬭ D ⬭
8. A ⬭ B ⬭ C ⬭ D ⬭
9. A ⬭ B ⬭ C ⬭ D ⬭
10. A ⬭ B ⬭ C ⬭ D ⬭

TOTAL _________ / 10

Part A.

10 marks

Attempt questions 1 - 10.

Allow about 15 minutes for this part.

Record your answers on the separate multiple-choice answer sheet that is on the back of the exam title page. You may DETACH this page for your convenience. Ensure your student number is written on it AND at the top of this page.

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample: 2 + 4 = (A) 2 (B) 6 (C) 8 (D) 9

A ○ B ● C ○ D ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ● B ⊗ C ○ D ○

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word *correct* and drawing an arrow as follows.

correct

A ⊗ B ⊗ C ○ D ○

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1. What is one use that ethyl ethanoate is known for?

(A) solvent
(B) flavouring
(C) hydrating agent
(D) leavening agent

2. The aqueous solution that is the most acidic is the one with:

(A) pH = 12
(B) pH = 4
(C) $[OH^-] = 1 \times 10^{-5}$ mol/L
(D) $[H^+] = 1 \times 10^{-6}$ mol/L

3. A buffer solution can be prepared by mixing approximately equal amounts of:

(A) a weak acid and a strong acid in water
(B) a weak acid and the salt of another weak acid in water
(C) a salt of a weak acid and water
(D) a weak acid and a salt of the weak acid in water

4. When an indicator is used in an acid base titration, its colour change:

(A) always identifies the equivalence point.
(B) occurs at pH of 7.
(C) needs to correspond to that point when the moles of acid and base present are identical.
(D) occurs at the end point.

5. Which of the following can act as a Bronsted-Lowry base when mixed with water?

(A) HCO_3^-
(B) Cl^-
(C) CH_3COOH
(D) $NaNO_3$

6. How much oxygen is required for the complete combustion of 1.0 mole of propene to form carbon dioxide and water?

(A) 100 L oxygen at 273K and 100 kPa
(B) 9.0 moles of oxygen
(C) 4.5 L oxygen at 273K and 100 kPa
(D) 72 g of oxygen

7. Given 0.10 mol/L aqueous solutions of each of the following listed compounds, which would be the most basic?

(A) NH_3
(B) $NaOH$
(C) $Ca(OH)_2$
(D) CH_3COONa

8. How should the conical flask being used in a titration be prepared?

(A) rinse with the solution in the burette.
(B) rinse with the solution to be added by the pipette.
(C) rinse with distilled water, with the flask being dried before use in a drying oven.
(D) rinse with distilled water and can be left wet.

9. Which action would result in an increase of 2 pH units?

(A) diluting 10 mL of a 0.1 mol L^{-1} HCl to 200 mL
(B) diluting 10 mL of a 0.1 mol L^{-1} NaOH to 200 mL
(C) diluting 10 mL of a 0.1 mol L^{-1} HCl to 1000 mL
(D) diluting 10 mL of a 0.1 mol L^{-1} NaOH to 1000 mL

10. Identify the formula for the conjugate acid of HS^-.

(A) H^+
(B) S^{2-}
(C) H_2S
(D) $HS(OH)^{2-}$

Part B.

54 marks

Attempt questions 11 – 19.
Read the whole of each question before commencing it.
Answer the questions in the spaces provided.
Show full working for questions requiring calculations.
Allow about 1 hour and 15 minutes for this part.

Question 11.

Outline the origin and effects of acid rain in industrial areas. 3M

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Question 12.

(a) A 285.3 g bottle of soda water was decarbonated by adding 14.7g of salt to it. The final mass was 296.2 g. Determine the volume of gas formed at 25°C and 100 kPa. 3M

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(b) Two identical bottles of soda water, one at room temperature (25°C) and one just out of the fridge (4ºC), had their pH determined using a probe and data logger. The results are tabulated below: 4M

Bottle	pH	Temperature (°C)
A	5.21	25
B	4.63	4

Account for the difference in pH in terms of Le Chatelier's principle.

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Question 13.

Describe what is meant by the term "amphiprotic species", using equations to illustrate your answer. 3M

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Question 14.

A clear solution was tested by a student by adding three drops of universal indicator and the resultant colour was red. The student was told the solution could be sodium chloride, ammonium chloride or sodium ethanoate.

(a) Predict the identity of the solution and justify your prediction with the aid of an appropriate chemical equation. 3M

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(b) Assess the reliability of the above investigation. 1M

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Question 15.

Analyse how knowledge of the composition and properties of acids has led to changes in the definition of acids.

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Question 16.

(a) Calculate the pH of a solution made by transferring 15 mL of 0.7 mol L^{-1} of sulfuric acid into a 250 mL volumetric flask and then filling it up to the graduation line. 3M

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(b) Calculate the pH of a solution made with dissolving 3.76 g of sodium hydroxide in water to make a 200 mL solution. 3M

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Question 17.

The equation to represent a reaction is as follows

$$CH_3-OH \;+\; CH_3-\underset{\underset{\displaystyle O}{\|}}{C}-OH \;\overset{H^+}{\leftrightarrow}\; CH_3-O-\overset{\overset{\displaystyle O}{\|}}{C}-CH_3 \;+\; H_2O$$

(a) Name the products of this reaction. 1M

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(b) Identify the functions of the H^+ written above the arrow. 2M

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(c) Of the two reactants, identify and justify the reactant with the higher boiling point. 2M

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(d) This reaction takes place with the addition of heat. Outline the precautions taken to prevent loss of volatile reactants. 2M

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(e) Draw a labelled scientific diagram of the equipment as it is set up to carry out esterification. 3M

Question 18.

A 500.0 mL sample of concentrated sulfuric acid (18 mol L^{-1}) was dropped in a laboratory accident. Solid sodium hydrogen carbonate was used to neutralise the spilled acid.

(a) Justify the choice of solid sodium hydrogen carbonate to clean up the spill. Include a relevant equation. 3M

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(b) Calculate the minimum mass of sodium hydrogen carbonate needed to neutralise the acid completely. 3M

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Question 19.

A solution of vinegar (ethanoic acid) was titrated against 0.22 mol L^{-1} sodium hydroxide to determine its concentration.
The 50.00 mL sample of vinegar was diluted to 500.00mL and 20.00mL aliquots of the diluted solution were titrated using an indicator.
The following table records the volumes of sodium hydroxide required to reach the endpoint.

Run number	Volume of sodium hydroxide added (mL)
1	23.50
2	23.10
3	23.00
4	24.00
5	22.90

(a) Make a scientific diagram of the piece of equipment used to measure out the 20.0 mL aliquot of diluted acid. 1M

(b) The sodium hydroxide used in the titration needed to be standardised. Explain why this step would be necessary. 2M

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(c) Identify one source of error for this experiment. 1M

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(d) The following indicators could be selected for this titration. 3M

Indicator	pH range	Colour range
Chlorophenol red	5.2 – 6.8	Yellow - red
Phenolphthalein	8.3 – 10.0	Colourless - crimson
Bromothymol blue	6.0 – 7.6	Yellow - blue
Methyl orange	3.1 – 4.4	Red - yellow

Identify the indicator that you would choose and justify your decision.

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(f) Calculate the concentration in grams per litre (g/L) of ethanoic acid in the original sample of vinegar. 4M

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Marking Guidelines HY Exam 2010
Year 12 CHEMISTRY

Part A – multiple choice.

1.	A	4.	D	8.	D
2.	B	5.	A	9.	C
3.	D	7.	C	10.	C

All students were awarded a mark for question 6 as a typo left the question less than perfect...

Part B.

11.

Marking criteria	*Marks*
* Using an equation, identifies the industrial origin and formation of the gas (SO_2, NO_2, CO_2, etc.). * Using an equation, shows the formation of the acid. * In general terms, outlines the effects of the acid rain on the environment or society	3
Completes two of the above	2
Completes one of the above	1

12 a.

Marking criteria	*Marks*
Correctly calculates → the mass of CO_2 lost as 3.8 g → the moles of CO_2 as 0.0863 mol, and → the volume of CO_2 as 2.14 L	3
Correctly calculates two of the above	2
Correctly calculates one of the above	1

12 b.

Marking criteria	*Marks*
* States Le Chatelier's principle. * Applies Le Chatelier's principle to the given data. * Using an equation, describes the exothermic nature of the equilibrium. * Accounts for the pH due to the change in temperature for both bottle A and B relating this to the acidity	4
Completes three of the above	3
Completes two of the above	2
Completes one of the above	1

13.

Marking criteria	*Marks*
* Correctly identifies an amphiprotic species * Defines amphiprotic species * Using two equations, describes the ability of the identified amphiprotic species to both act as an acid and a base	3
Completes two of the above	2
Completes one of the above	1

14 a.

Marking criteria	*Marks*
* Identifies the solution as NH_4Cl * States that the solution is acidic due to the universal indicator changing to a red colour which indicates acidity * Writes the correct equation that shows the formation of the H_3O^+ i.e. $NH_4^+ + H_20 \leftrightarrow NH_3 + H_3O^+$	3
Completes two of the above	2
Completes one of the above	1

14 b.

Marking criteria	*Marks*
States that the investigation is unreliable because it is not repeated	1

15.

Marking criteria	*Marks*
* Describes the correct chronological development of the theories of acids presented by Lavoisier, Davy, Arrhenius, Bronsted-Lowry. * Provides thorough definitions of acids presented by each theory. * Draws out implications of each development by relating the definition to examples of acids. * Outlines a different limitation of **each** of the **three** earlier definitions presented by Lavoisier, Davy and Arrhenius that is correct for the level of knowledge at that time.	5
* Describes the correct chronological development of the theories of acids presented by Lavoisier, Davy, Arrhenius, Bronsted-Lowry. * Provides thorough definitions of acids presented by each theory. * Draws out implications of each development by relating the definition to examples of acids. * Outlines a different limitation of **one** of the earlier definitions that is correct for the level of knowledge at that time. OR * Describes the correct chronological development of the theories of acids presented by Lavoisier, Davy, Arrhenius, Bronsted-Lowry. * Provides thorough definitions of acids presented by three of the scientists. * Draws out implications of each development by relating the definition to examples of acids. * Outlines a different limitation of each of the three earlier definitions (ie. Lavoisier, Davy, Arrhenius) that is correct for the level of knowledge at that time.	4
Outlines a sound definition for TWO or THREE of the theories of acids that have been developed, in correct chronological order. OR Outlines a definition for ONE or TWO of the theories of acids that have been developed, in correct chronological order, AND Identifies a limitation of ONE of the theories.	2 - 3
Outlines a definition for ONE of the theories of acids that have been developed.	1

16 a.

Marking criteria	*Marks*
Correctly calculates the pH of the acid as **1.1** (note – when writing a numerical value for pH, the number of decimal places given in the pH value are equal to the smallest number of significant figures given in the data – in this case, 1 significant figure in 0.7 mol/L) AND Shows full working as follows: ➔ Calculates the concentration of diluted acid in the 250 mL volumetric flask (0.042... mol/L) ➔ Uses an equation to show the mole/concentration ratio between H_2SO_4 and H^+ as 1:2 ➔ Determines the $[H^+]$ as 0.084.... mol/L ➔ Substitutes values into the equation for calculating pH and correctly processes the data to get an answer of 1.1	3
Calculates the pH of the acid as 1 (or 1.08 or 1.076) AND shows full working as detailed above **OR** Correctly carries out TWO of the four steps of working outlined above (and has an answer that is given to 1 decimal place)	2
Correctly carries out ONE of the four steps of working outlined above	1

16 b.

Marking criteria	*Marks*
Correctly calculates the pH value as 1 X 10[1] (13.67) (nb. number of decimal places in the pH was not looked at in this question) **AND** Shows full working as follows: ➔ Calculates the moles of sodium hydroxide in the 3.76 g (0.094... mol) ➔ Calculates the concentration of sodium hydroxide in the 200 mL (0.47... mol/L) ➔ Uses an equation to show the mole/concentration ratio between NaOH and OH^- as 1:1 and hence determines the $[OH^-]$ as 0.47… mol/L ➔ Substitutes values into the equation for calculating pH and correctly processes the data to get an answer of 1 X 10[1] (13.67) **AND** Shows the correct **symbol** equations for each of the 3 steps of calculations ($n = m/M$; $c = n/V$; $pH = 14 - (-\log_{10}[OH^-])$)	3
Correctly carries out TWO of the four steps of working outlined above	2
Correctly carries out ONE of the four steps of working outlined above	1

17 a.

Marking criteria	*Marks*
Identifies the TWO products as methyl ethanoate and water	1

17 b.

Marking criteria	*Marks*
Identifies H^+ as →a catalyst (lowering activation energy required for the reaction to occur) AND → as dehydrating agent (forcing the equilibrium to the right and favouring the production of the ester)	2
Identifies one of the above	1

17 c.

Marking criteria	*Marks*
Identifies ethanoic acid as the reactant with the higher boiling point **AND** justifies this choice with reference to greater dispersion points and an additional H bond requiring more energy to break the bonds than in methanol	2
Identifies ethanoic acid as the reactant with the higher b.p.	1

17 d.

Marking criteria	*Marks*
Outlines the precautions required to deal with TWO of the following hazards: refluxing procedure, water bath, boiling chips	2
Outlines ONE of the above	1

17 e.

Marking criteria	*Marks*
Scientific drawing included:	
- Use of pencil	0.5
- Use of ruler	0.5
- Correct drawing of :	
o Bunsen burner/hot plate and water bath, pear shaped flask, condenser, reactants	1
o 2-3 of the items above	0.5
- Labels for:	
o Bunsen burner/hot plate and water bath, pear shaped flask, condenser, reactants	1
o 2-3 of the items above	0.5

18 a.

Marking criteria	*Marks*
Includes a correct relevant equation AND outlines two reasons for its choice.	3
Includes a relevant equation and outlines one reason for its choice OR outlines two reasons.	2
Includes one reason OR a correct balanced equation.	1

18 b.

Marking criteria	*Marks*
Calculates the number of moles of H_2SO_4 as 9 mol **AND** Using the stoichiometric ratio, determines the moles of $NaHCO_3$ to be 18 mol **AND** Calculates the mass of $NaHCO_3$ as being 1512 g	3
Correctly proceeds through two steps in the calculations.	2
Calculates the number of moles of H_2SO_4 as 9 mol	1

19 a.

Marking criteria	*Marks*
Diagram of a piece of equipment that resembles a volumetric pipette.	1

19 b.

Marking criteria	*Marks*
Explains that sodium hydroxide is unsuitable as a primary standard and therefore needs to have its concentration checked for accurate titrations **OR** gives a reason for its concentration being uncertain.	2
States that standardisation is necessary to check its concentration (without a cause) or required for accurate titration.	1

19 c.

Marking criteria	*Marks*
States a reasonable error (as opposed to a procedure) that may occur in this practical.	1

19 d.

Marking criteria	*Marks*
Identifies phenolphthalein as the best choice **AND** Identifies the titration as a titration between a weak acid (ethanoic) and a strong base (sodium hydroxide) **AND** Identifies that the salt produced is basic and produces a solution with a pH > 7 **AND** States that phenolphthalein will create an endpoint that corresponds to the equivalence point which is signified by a colour change.	3
Identifies phenolphthalein as the best choice **AND** Identifies that the salt produced is basic (or the pH > 7)	2
Identifies phenolphthalein as the best choice.	1

19 f.

Marking criteria	*Marks*
* Correctly calculates the concentration of the ethanoic acid in the vinegar as 151.93 g/L *The following four steps need to be covered :-* (1) correctly balanced chemical equation (2) calculates the average titre as 23 mL (using titres 2,3 and 5; the first is the rough run and the fourth is an outlier) (3) calculates the moles of NaOH to be 0.00506 mol (4) Calculates the concentration of the diluted vinegar to be 0.253 mol/L (5) considering the dilution factor, the concentration of the undiluted vinegar was 2.53 mol/L (6) correct conversion to g/L * ALL calculations are well set out, logical and fully detailed.	4
Correctly completes first five steps (leaving the concentration in mol/L) **OR** All six steps are complete for an incorrect titre.	3
Correctly calculates the moles of NaOH and the concentration of the dilute ethanoic acid.	2
Correctly calculates the moles of NaOH	1

HAHS Half-Yearly Examination

2010 – Chemistry

Exemplar answers

1	2	3	4	5	6	7	8	9	10
A	B	D	D	A	—	C	D	C	C

Question 11.

Outline the origin and effects of acid rain in industrial areas. 3M

~~&~~ There have been an increase in the amount of acid rain in industrial ~~ke~~ areas caused by the increase in concentration of oxides of sulfur and nitrogen in the atmosphere.

→ ~~sulfur~~ sulfur oxides have been increasing due to the increase in the burning of fossil fuels, especially coal containing 0.5 – 0.6% of sulfur, ~~coal~~ $S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$, as well as the extraction of metals ~~ores~~ from metal sulfides, for example, $2ZnS_{(s)} + 3O_{2(g)} \rightarrow 2ZnO_{(s)}$ ...

3

– nitrogen oxides have been increasing due to the increase in the ~~coal~~ burning of fuels in high temperature combustion chambers, such as those in car engines. $N_{2(g)} + O_{2(g)} \rightarrow 2NO_{(g)}$

$2NO + O_2 \rightarrow 2NO_{2(g)}$

These oxides of sulfur and nitrogen is then dissolved in the water droplets in the atmosphere causing acid rain to form.

$SO_{2(g)} + H_2O_{(l)} \rightleftharpoons H_2SO_{3(aq)}$ ← weak acid

$2H_2SO_{3(aq)} + O_2 \rightleftharpoons 2H_2SO_{4(aq)}$ ← strong acid

The effects of acid rain can be seen on the environment, humans, and animals:

→ increasing the ~~pH~~ acidity of the water ways, lakes, and rivers which damages the animal cycle.

→ cause the deterioration of buildings and man-made structures.

→ increasing the acidity of soil, potentially leading to the destruction of an entire forest.

Question 11.

Outline the origin and effects of acid rain in industrial areas. 3M

- In industrial areas, the release of SO_2 and oxides of nitrogen contrimute to acid rain.
- SO_2 is produced through the burning of fossil fuel such as coal and petroleum that contains sulfur.

$$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$$

3

$$SO_{2(g)} + H_2O_{(l)} \rightarrow H_2SO_{3(aq)}$$

$$\cancel{H_2SO_{3(aq)} + H_2O_{(l)} \rightarrow H_2SO_{4(aq)}}$$

$$2H_2SO_{3(aq)} + O_{2(g)} \rightarrow 2H_2SO_{4(aq)}$$ (sulfuric acid)

- sulfur dioxide combines with water and thus produce sulfurous which oxdises to produce sulfuric acid.
- oxides of nitrogen are form from combustion chambers in cars, gas stoves, power stations.

$$2N_{(g)} + O_{2(g)} \rightarrow 2NO_{(g)}$$

$$2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)}$$

$$2NO_2 + H_2O_{(l)} \rightarrow HNO_{3(aq)} + HNO_{2(aq)}$$

$$\cancel{2HNO_{2(aq)} + H_2O_{(l)} \rightarrow HNO_3}$$

$$2HNO_{2(aq)} + O_{2(g)} \rightarrow 2\underline{HNO_3}_{(aq)}$$ (nitric acid)

- acid rain would affect buildings - causing corrosion to buildings around that area especially - metal structures (weakening them) and limestone buildings.
- acid rain would cause the surrounding environment - eg. dying of plants / ~~forrest~~ due to destruction of leaves thus effect logging industry and the environment as a whole.

(waxy cuticle is dissolved and broken by the acid rain)

(destroying the industry in which acid rain occurs at).

3

Question 11.

Outline the origin and effects of acid rain in industrial areas. 3M

In industrial areas, there are production of many acidic oxides such as sulfur dioxide and nitrogen dioxide that leads to the production of acid rain. Acidic oxides like SO_2 is produced from the smelting of sulfide ores: $ZnS_{(s)} + O_{2(g)} \rightarrow ZnO_{(s)} + SO_2$ and the combustion of fossil fuels such as coal reacts sulfur with oxygen to produce SO_2: $S_{(g)} + O_{2(g)} \rightarrow SO_{2(g)}$. When this acidic gas is released into the atmosphere it can react with moisture in the air to form sulfurous acid which can oxidise to form sulfuric acid:

$$SO_{2(g)} + H_2O_{(l)} \rightarrow H_2SO_{3(aq)}$$

3

$$2H_2SO_{3(aq)} + O_{2(g)} \rightarrow 2H_2SO_4$$

Acid rain due to sulfuric acid etc has a major impact on the environment as it can cause damage to carbonate buildings, corrode metal structures, and lower the pH of water systems which in turn can kill aquatic organism which can't survive at low pH.

$$CaCO_{3(s)} + H_2SO_{4(aq)} \rightarrow CaSO_{4(s)} + H_2O_{(l)} + CO_{2(g)}$$

Question 12.

(a) A 285.3 g bottle of soda water was decarbonated by adding 14.7g of salt to it. The final mass was 296.2 g. Determine the volume of gas formed at 25°C and 100 kPa. 3M

Mass of soda + salt = 285.3 + 14.7g = 300g

Final mass = ~~262.2g~~ 296.2

∴ Mass change = 300 − ~~262.2~~ 296.2 = 3.8g

$n_{CO_2} = \frac{m}{M} = \frac{3.8g}{12.01 + 16\times2} = 0.086... \text{ mol}$

3

$V_{CO_2} = n \cdot V_{RTP} = 0.086... \times 24.79L = \underline{2.14L}$ (3 sig fig)

m_{CO_2} lost = 285.3 + 14.7 − 296.2 = 3.8g

$n_{CO_2} = \frac{m}{M} = \frac{3.8}{12.01 + 2(16)} = 0.086.... \text{ mol}$

3

$V_{CO_2} = n \times V_M = (0.086....)(24.79) = 2.14L$

(b) Two identical bottles of soda water, one at room temperature (25°C) and one just out of the fridge (4°C), had their pH determined using a probe and data logger. The results are tabulated below: 4M

Bottle	pH	Temperature (°C)
A	5.21	25
B	4.63	4

4

reaction 1
reaction 2

Account for the difference in pH in terms of Le Chatelier's principle. $\Delta H = -ve$

pH is determined by ~~this~~ these reactions $CO_{2(g)} + H_2O_{(l)} \rightleftharpoons H_2CO_{3(aq)}$ and $H_2CO_{3(aq)} \rightleftharpoons H^+_{(aq)} + HCO^-_{3(aq)}$
Le chatelier's principle states that if a system at equilibrium is disturbed then the position of equilibrium will shift until a new equilibrium is established.
Since dissolution is exothermic, according to Le chatelier's principle then the increased temperature will shift equilibrium to the left in 1 decreasing solubility of $CO_{2(g)}$ to minimize temperature increase. But to minimize decrease in $[H_2CO_3]$ caused by temperature increase H^+ is consumed in 2 to produce H_2CO_3 to compensate decrease in $[H_2CO_3]$. So the higher temperature in bottle A reduce the number of H^+ relative to B and then has a higher pH than A.

4

Account for the difference in pH in terms of Le Chatelier's principle.

In the soda water, an equilibrium exists:
$CO_{2(g)} + H_2O_{(l)} \rightleftharpoons H_2CO_{3(aq)} \rightleftharpoons H^+_{(aq)} + HCO^-_{3(aq)}$
The forward reaction is exothermic. As Le Chatelier's principle states, when a change is made to a system at equilibrium, it shifts to minimise the change, reaching a new equilibrium. Therefore if temperature is increased, the endothermic (reverse) reaction will be favoured to decrease it. This will decrease ~~solubility~~ concentration of H_2CO_3, thereby decreasing the H^+ ions. Thus increasing temperature ~~decreases~~ increases pH (less H^+) and decreasing will do the opposite. This is why bottle A has a higher pH than bottle B. (it is at a higher temperature)

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(b) Two identical bottles of soda water, one at room temperature (25°C) and one just out of the fridge (4°C), had their pH determined using a probe and data logger. The results are tabulated below: 4M

Bottle	pH	Temperature (°C)
A	5.21	25
B	4.63	4

$CO_{2(aq)} \rightleftharpoons CO_{2(g)}$
$CO_{2(aq)} + H_2O \rightleftharpoons H_2CO_3$.
$CO_{2(g)} \rightleftharpoons CO_{2(aq)}$
$CO_{2(aq)} + H_2O \rightleftharpoons H_2CO_3$.

Account for the difference in pH in terms of Le Chatelier's principle.

$CO_2(g) \rightleftharpoons CO_2(aq)$
$CO_2(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$ 4

- The reaction above is an exothermic reaction
- By Le Chatelier's prinicple when a change is imposed to a system at equilibrium the ~~system~~ equilibrium would shift to minimise disturbance until a new equilibrium is established
- When the temperature is decreased (from room temperature -25 to 4°C), the system would want to increase the temperature (thus exothermic reaction is favoured - reaction shifts to right,
- More $CO_2(g)$ will convert to $CO_2(aq)$ in which increases $H_2CO_3(aq)$ and thus $[H^+]$ will increase.
- the bottle at 4°C will be more acidic and thus lower pH.

4

Account for the difference in pH in terms of Le Chatelier's principle.

Soda water contains the equilibrium system:
$CO_{2(g)} \rightleftharpoons CO_{2(aq)} + H_2O_{(l)} \rightleftharpoons H_2CO_{3(aq)} \rightleftharpoons 2H^+_{(aq)} + CO_3^{2-}{}_{(aq)}$
This forward reaction is exothemic, Lechatelier principle states when a system at equilibrium is disturbed, the system will respond in a way to counteract this change, eventually establishing a new equilibrium. The bottle out of the fridge, the temperature was reduced, therefore causing a disturbance, so the system counteracts this by shifting to the right (exothemic) to produce more heat. This in turn with also increase $[H^+]$, thus increasing the pH of soda water. In case at room temperature, the soda water being quite warm will shift to the left (endothemic) to reduce temperature. But this in turn will reduce $[H^+]$ and therefore increasing the pH of water. Hence the difference in pH of the 2 bottles

Question 13.
Describe what is meant by the term "amphiprotic species", using equations to illustrate your answer. 3M

An amphiprotic species refers to ~~a~~ a substance which can act as both a B-L acid and a B-L base, either accepting or donating a proton. HCO_3^- is an example of this, it can act as a base; accepting a H^+:

$$HCO_3^-{}_{(aq)} + H_3O^+ \rightleftharpoons H_2CO_{3(aq)} + H_2O_{(l)}$$

or ~~as~~ as an acid, donating a H^+:

$$HCO_3^-{}_{(aq)} + OH^- \rightleftharpoons CO_3^{2-}{}_{(aq)} + H_2O_{(l)}$$

3

Question 13.
Describe what is meant by the term "amphiprotic species", using equations to illustrate your answer. 3M

Amphiprotic species are substances that can donate and accept protons.

For example, the amphiprotic substance HCO_3^-.

Here the HCO_3^- is acting as an acid and donate a proton. 3

$$HCO_3^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+{}_{(aq)} + CO_3^-{}_{(aq)}$$

Here, the HCO_3^- is acting as a base and accepts a proton.

$$HCO_3^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons OH^-{}_{(aq)} + H_2CO_{3(aq)}$$

Question 14.
A clear solution was tested by a student by adding three drops of universal indicator and the resultant colour was red. The student was told the solution could be sodium chloride, ammonium chloride or sodium ethanoate.

(a) Predict the identity of the solution and justify your prediction with the aid of an appropriate chemical equation. 3M

The solution is an ammonium chloride, as the red ~~[illegible]~~ colour of the indicator suggests that the solution is acidic, and NH_4Cl is an acidic solution. ~~NH_4Cl~~ 3

* NH_4Cl is an ionic substance that fully dissociates in aqueous solution

$$NH_4Cl_{(aq)} \rightarrow NH_4^+{}_{(aq)} + Cl^-{}_{(aq)}$$

* NH_4^+ → can not act as a B-L base as it cannot accept a proton.
  → can act as a B-L acid as it can donate a proton.
* Cl^- → cannot act as a B-L acid as it doesn't contain a proton.
  → will not act as a B-L base as it is a weak conjugate of a strong acid.

7,

∴ the NH_4^+ hydrolyses water to form H_3O^+ ions, which adds to the acidity. $NH_4^+{}_{(aq)} + H_2O_{(l)} \rightleftharpoons NH_{3(aq)} + H_3O^+{}_{(aq)}$.

Question 14.
A clear solution was tested by a student by adding three drops of universal indicator and the resultant colour was red. The student was told the solution could be sodium chloride, ammonium chloride or sodium ethanoate. acid. NaCl neutral acidic.
basic.

(a) Predict the identity of the solution and justify your prediction with the aid of an appropriate chemical equation. 3M

3

• the ~~solution~~ that was predicted by the student was ammonium chloride since it is acidic salt - as indicated by red colour in UI
• NH_4Cl is a soluble ionic salt which fully dissociates in aqueous solution. $NH_4Cl_{(aq)} \rightarrow NH_4^+{}_{(aq)} + Cl^-{}_{(aq)}$
• NH_4^+ can act as a B-L acid since it can donate a proton. It cannot act as a B-L base because it cannot accept a proton.
• Cl^- can not act as a B-L acid since it does not contain a proton. It will not act as a B-L base since it is the weak conjugate base of strong acid (HCl). Thus it is neutral.
• NH_4^+ will hydrolyse water to produce hydronium ions - showing it is acidic. 1M
$NH_4^+{}_{(aq)} + H_2O_{(l)} \rightarrow NH_{3(aq)} + H_3O^+{}_{(aq)}$

(b) Assess the reliability of the above investigation. 1M

The investigation is not reliable as it has not been repeated and checked for consistency.

1

(b) Assess the reliability of the above investigation. 1M

The investigation is unreliable as it hasn't been repeated under the same conditions to show the same result.

1

Question 15.
Analyse how knowledge of the composition and properties of acids has led to changes in the definition of acids.

5M

Throughout time the definition of acids has changed as new knowledge of the composition and properties of acid increased. In the 17th century scientists were first discovering the properties of acids. Lavoisier was one of the first scientists to attempt to systematically classify acids, saying that it was oxygen which gave acids their acidic properties, looking at how many nonmetal oxides formed acids. However this

1

was shown to later incorrect, and didn't account for why ~~the~~ basic oxides did not produce acids. Humphry ~~Davies~~ Davy was another scientist who, through experiments using HCl, showed that it was ② hydrogen that gave acids their acidic properties, however it did not account for the reasons why compounds containing hydrogen, such as CH_4, did not produce acids. ①

5 Arrhenius, later stated that substances, when ionised in water, that gave H^+ ions ③ were acids, with substances giving OH^- ions were bases. Although this did show why neutralisation reactions occurred, and did describe the way hydrogen and ~~hydronium~~ hydroxide ions interacted to form water, this only classified substances dissolved in water, and did not account for the bases that did not contain OH^- (eg ③ Na_2CO_3). The modern theory of acids and bases however, the Bronsted-Lowry theory, describes acids as 'proton donors' (with bases 'proton acceptors'), as they showed the way that acids 'donated' protons (hydrogen ions) to bases, and that this what gives acids their distinct properties, giving a modern definition of acids.

Question 15.

Analyse how knowledge of the composition and properties of acids has led to changes in the definition of acids.

5M

The knowledge ~~of acids~~ and the definition of acids has changed over time with the theories of ~~Ar~~ Lavoisier, Davy, Arrhenius and Bronsted-Lowry, being the most well known definition of acids.

1776s · Lavoisie: He stated that acids were substances that contain oxygen ① as he observed that the nonmetal compounds of oxygen produced acidic solution.

$$SO_2(g) + H_2O(l) \rightleftharpoons H_2SO_3(aq).$$

However, his theory was ~~disprov~~ disapproved ~~as~~ as it could not explain why HCl and HBr (don't contain oxygen) ① were acids, ~~and~~ ~~why~~

1815s · Davy: Davy observed that when acids reacted with metal it formed hydrogen gas, and proposed that acids were substances that

5 contained replaceable ② hydrogen.

$$2HCl_{(aq)} + Zn_{(s)} \rightarrow ZnCl_{2(aq)} + H_2(g)$$

9

However, this theory was also ~~wrong~~ disproved as it did not explain why some substances that contained hydrogen, were not acidic, such as NH_3

1885s: Arrhenius: He proposed that ~~the~~ acids ~~in~~ were substances that ionised in water ~~forming~~ (3) producing H^+ ions, and bases were substances that ionised in water producing OH^-. This theory allowed us to distinguished between weak and strong acids and led to the development of the pH scale, but it had its limitations such as:-

- It did not take into account other solvents eg →
- It only took into account acidic and basic substances that contained H^+ and OH^- ions in its structure. & ... what other substances are there?
- It didn't account for amphiprotic substances that were basic and acidic in nature eg →

1925s:- Johannes Bronsted and Thomas Lowry, both independently proposed that "acids were proton donors, and bases were proton acceptors", which is the definition of acids that we know today.

Question 16.

(a) Calculate the pH of a solution made by transferring 15 mL of 0.7 mol L^{-1} of sulfuric acid into a 250 mL volumetric flask and then filling it up to the graduation line. 3M

$n_{H_2SO_4} = CV$

$= 0.015 \times 0.7$

$= 0.0105$ moles.

$H_2SO_4\,(aq) \rightarrow 2H^+\,(aq) + SO_4^{2-}\,(aq)$

$n_{H_2SO_4} : n_{H^+}$

$1 : 2$ $\quad n_{H^+} = 2n_{H_2SO_4}$

$n_{H^+} = 0.0105 \times 2$

$= 0.021$ moles

~~$pH = -\log_{10}[H^+]$~~

~~$= -\log_{10} 0.021$~~

~~$= 1.67$~~

~~$pH = 1.7$~~

$[H^+] = \dfrac{0.021}{0.25}$ $\left(\dfrac{n}{V}\right)$

$= 0.084$

$pH = -\log_{10}[H^+]$

$= -\log_{10} 0.084$

$= 1.07$

$= 1.1$

3

Question 16.

(a) Calculate the pH of a solution made by transferring 15 mL of 0.7 mol L^{-1} of sulfuric acid into a 250 mL volumetric flask and then filling it up to the graduation line. 3M

H_2SO_4 = 15 mL 0.7 M/L

$C = \frac{n}{V}$

$0.7 = \frac{n}{0.015}$

n = 0.105 mol.

In 250 mL = $C = \frac{n}{V}$

$C = \frac{0.0105}{0.25}$

= 0.042 mol/L.

Sulfuric acid = diprotic

∴ [H+] = 0.042 × 2

= 0.084 mol/L.

pH = $-\log_{10}$ [H+]

= 1.0757.

= 1.1 (to 2 sig fig).

3

(b) Calculate the pH of a solution made with dissolving 3.76 g of sodium hydroxide in water to make a 200 mL solution. 3M

$n_{NaOH} = \frac{m}{M}$

$= \frac{3.76}{22.99+16.00+1.008}$

= 0.094 moles

NaOH : $C = \frac{n}{V}$

$= \frac{0.094...}{0.2}$

= 0.47 mol/L.

$NaOH \longrightarrow Na^+ + OH^-$

$[OH^-]$ = [NaOH]

= 0.47 mol/L^{-1}

pH = 14 + $\log_{10}$ $[OH^-]$

= 14 + $\log_{10}$ 0.47

= 13.7

3

(b) Calculate the pH of a solution made with dissolving 3.76 g of sodium hydroxide in water to make a 200 mL solution. 3M

$n_{NaOH} = \frac{m}{M} = \frac{3.76}{22.99+16+1.008} \Rightarrow 0.09...$ mol

$C_{NaOH} = \frac{n}{V} = \frac{0.09...}{0.2} = 0.47...$ molL^{-1}

3

NaOH strong base full dissociation, thus $NaOH_{(aq)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$

From equation $n_{NaOH} = n_{OH^-}$ thus $[OH^-] = [NaOH] = 0.47...$ molL^{-1}

pOH = $-\log_{10} [OH^-] = -\log_{10} [0.47...] = 0.3278...$

pH = 14 − pOH = 14 − 0.3278... = 13.672 ≈ 13.7

||

Question 17.
The equation to represent a reaction is as follows

methanol ethanoic acid

$$CH_3-OH + CH_3-\underset{\underset{O}{\|}}{C}-OH \overset{H^+}{\leftrightarrow} CH_3-O-\overset{\overset{O}{\|}}{C}-CH_3 + H_2O$$

(a) Name the products of this reaction. 1M

methyl ethanoate + water 1

(b) Identify the functions of the H$^+$ written above the arrow. 2M

The H$^+$ acts as a catalyst in the reaction to speed it up ~~ans~~ by lowering activation energy. It acts as a dehydrating agent by removing the water molecules from the reaction to ~~produce~~ assist in producing a pure ester. 2

(b) Identify the functions of the H$^+$ written above the arrow. 2M

H$^+$ – is the concentrated sulfuric acid.
- It acts as a catalyst to speed up the rate of reaction
- It acts as a dehydrating agent reacting with water and then removing, in order to increase the yield of the ester – methyl ethanoate. 2

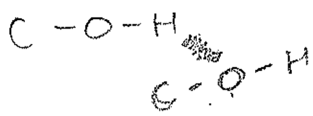
(c) Of the two reactants, identify and justify the reactant with the higher boiling point. 2M

The ethanoic acid has the higher boiling point than the methanol. It contains the (COOH) carboxyl group $-C{=O \atop -O-H}$ and thus contains three polar bonds and is able to create two hydrogen bonds with surrounding molecules. 2 As oppose to methanol with the hydroxyl group $-C-O-H$ will have two polar bonds and only able to make one hydrogen bonding. The extra bonding (hydrogen and polar) in ethanoic acid means that more energy is needed to overcome the stronger bonds thus higher boiling point.

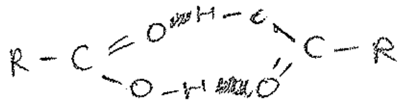
(c) Of the two reactants, identify and justify the reactant with the higher boiling point. 2M

Ethanoic acid has a higher bpt than methanol and is due to several reasons. Ethanoic has a higher molecular weight and therefore strength of dispersion forces are stronger than that of methanol. Furthermore, though both are polar molecules, ethanoic acid experiences an extra hydrogen bond than methanol. This increase in hydrogen bonds mean that more energy is required to break the intermolecular forces between them and hence why ethanoic acid has the higher bpt. 2

Alkanol



Alkanoic acid



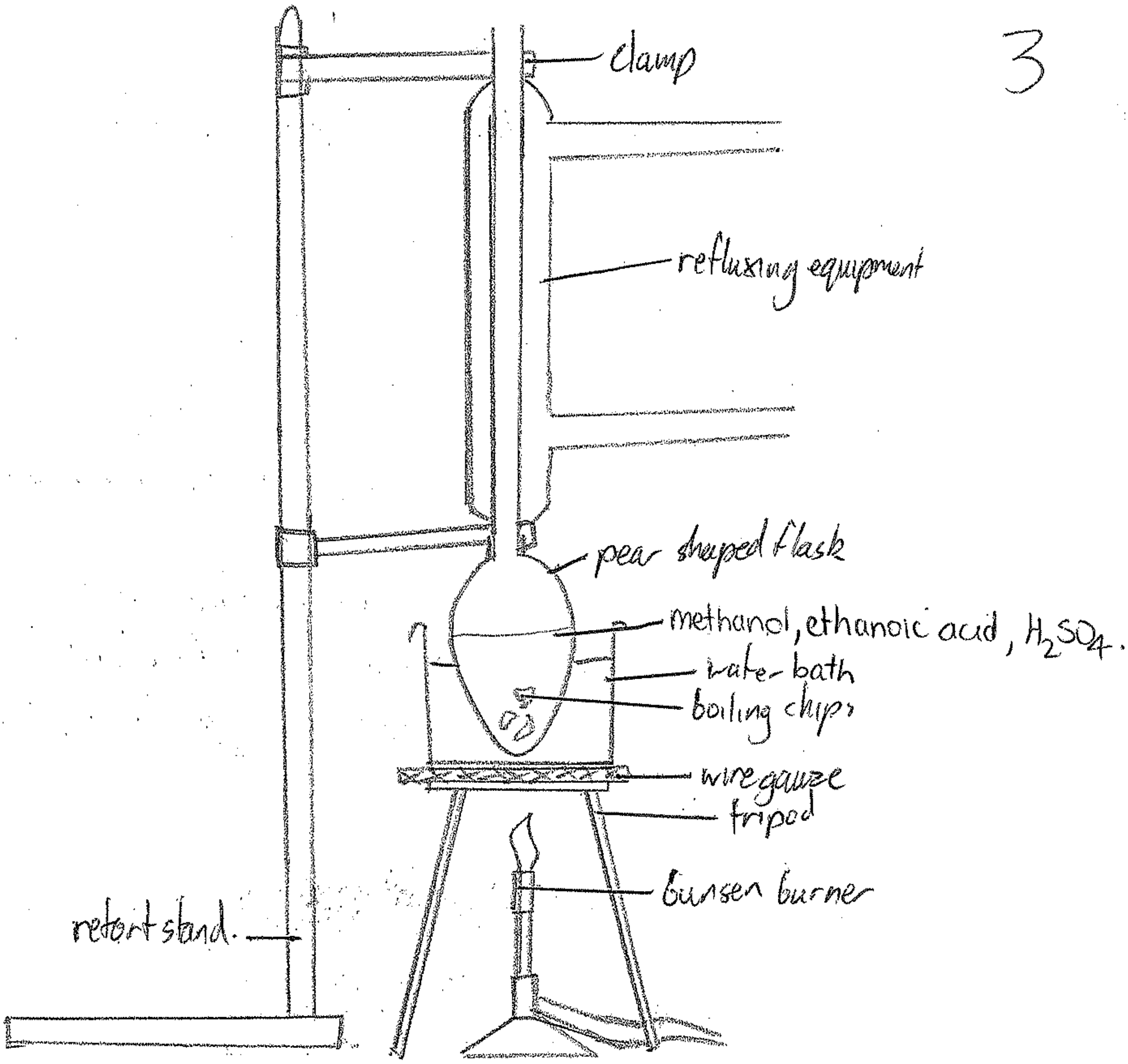
(d) This reaction takes place with the addition of heat. Outline the precautions taken to prevent loss of volatile reactants. 2M

The reaction takes place with the use of refluxing equipment, which condenses any escaping gases, returning them to the reaction. A water bath is used to avoid contact of naked flame and reactants as they would then ~~cat~~ react violently, and be lost. 2

* A condenser is attached to the tube being heat to cool down the temperature to allow for the required prolonged heating. 2
* When heating with a naked flame, a close watch is kept on the rising of the liquid in the tube so that it does not quickly boil and eject from the tube.
* Boiling chips are used to increase the surface area over which heat can be ~~distributed~~ spread.

- condenser attached to the flask with cold water running in at the bottom to condense volatile gas back, so it refluxes and doesn't escape 2
- use of boiling chips for to even heat distribution to prevent bumping! - when reacts spurt out open end.

(e) Draw a labelled scientific diagram of the equipment as it is set up to carry out esterification. 3M



Question 18.

A 500.0 mL sample of concentrated sulfuric acid (18 mol L^{-1}) was dropped in a laboratory accident. Solid sodium hydrogen carbonate was used to neutralise the spilled acid.

(a) Justify the choice of solid sodium hydrogen carbonate to clean up the spill. Include a relevant equation. 3M

in what way?

sodium hydrogen carbonate ($NaHCO_3$) is a weak base, so it won't create an equally dangerous situation than if a strong base was used. It is also a stable solid, thus it is easy and safe to transport ~~and~~, (store), supply and apply. It also fizzes/bubbles when reacting, so we can see ~~whether~~ and detect when the neutralisation is complete. It also neutralises forming harmless products. carbon dioxide and water and Sodium sulfate.

$2NaHCO_{3(s)} + H_2SO_{4(aq)} \longrightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)} + 2CO_{2(g)}$

3

(a) Justify the choice of solid sodium hydrogen carbonate to clean up the spill. Include a relevant equation. 3M

- This substance is suitable as:
- it is a solid it will stop and help to contain the spill rather than spread it
- it is weak so if it is accidently added in excess, it will be relatively harmless
- it is amphiprotic so only one substance is needed to be stored
- it will produce carbon dioxide gas so it can easily be seen when neutralisation is complete (it stops fizzing)

3

$H_2SO_{4(aq)} + 2NaHCO_{3(aq)} \rightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)} + 2CO_{2(g)}$

- $NaHCO_3$ is a weak ~~ba~~ amphiprotic substance which can neutralise an acid or base if unknown and since it is weak it produces little amount of heat since neutralisation is a exothermic reaction.
- Also it is a solid a will thus be more easier to use since the spill can be controlled and not spread (Powder is sprinkled on it).

3

$H_2SO_4(aq) + \cancel{NaHSO_4}\ 2NaHCO_{3(s)} \rightarrow Na_2SO_4(aq) + 2H_2O_{(l)} + 2CO_{2(g)}$

- Adding $NaHCO_3$ will neutralise the acid producing water which will reduce the dangers when cleaning the spill as oppose to cleaning the 18mol L^{-1} sulfuric acid

(b) Calculate the minimum mass of sodium hydrogen carbonate needed to neutralise the acid completely. 3M

$2NaHCO_{3(s)} + H_2SO_{4(aq)} \rightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)} + CO_{2(g)}$

2 : 1 : 1 : 2

H_2SO_4: 500mL of 18M

$\therefore c = \frac{n}{v}$

$cv = n$

$n_{H_2SO_4} = 9$ mols

$\therefore$ According to stoichiometric ratio of 2:1

$n_{NaHCO_3} = 2 \times 9$ mols

$= 18$ mols

$\therefore$ 18 mols of $NaHCO_3$ needed to neutralise completely

$n = \frac{m}{M}$

15

$\therefore m_{NaHCO_3} = 18 \times (22.99 + 1.008 + 12.01 + 3(16))$

$= 1512.144g$ of $NaHCO_3$ needed

$= 1512.14g$ of $NaHCO_3$ needed ✓ 3

(b) Calculate the minimum mass of sodium hydrogen carbonate needed to neutralise the acid completely. 3M

$H_2SO_4(aq) + 2NaHCO_3(s) \rightarrow Na_2SO_4(aq) + 2H_2O(l) + 2CO_2(g)$

$\begin{cases} V = 0.5L \\ C = 18M \end{cases}$ $\begin{cases} m = ? \end{cases}$

$n_{H_2SO_4} = C.V = 18 \times 0.5 = 9mol$

$n_{H_2SO_4} : n_{NaHCO_3}$

1 : 2

$n_{NaHCO_3} = 2 \times n_{H_2SO_4} = 2 \times 9 = 18mol$

$m_{NaHCO_3} = n.M = 18 \times (22.99 + 1.008 + 12.01 + 3(16))$

$= 18 \times 84.008$

$= 1512.144g$

$\approx 1.5kg$ (2 sig fig).

3

Question 19.

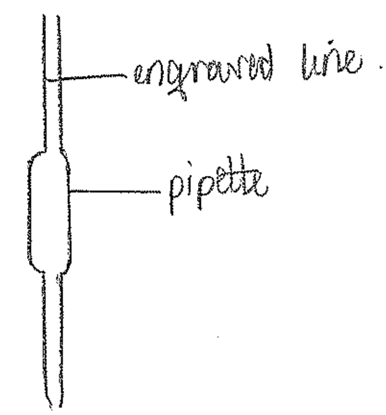
A solution of vinegar (ethanoic acid) was titrated against 0.22 mol L^{-1} sodium hydroxide to determine its concentration.

The 50.00 mL sample of vinegar was diluted to 500.00mL and 20.00mL aliquots of the diluted solution were titrated using an indicator.

The following table records the volumes of sodium hydroxide required to reach the endpoint.

Run number	Volume of sodium hydroxide added (mL)
1	23.50
2	23.10
3	23.00
4	24.00
5	22.90

(a) Make a scientific diagram of the piece of equipment used to measure out the 20.0 mL aliquot of diluted acid. 1M



1

(b) The sodium hydroxide used in the titration needed to be standardised. Explain why this step would be necessary. 2M

This step is necessary as NaOH is not a good primary standard. This is because it reacts with moisture in the air and can also react with CO_2 in air to form sodium hydrogen carbonate, hence not a good primary standard. To find its accurate concentration (standardised) it needs to be titrated against a standard acid such as oxalic acid or potassium hydrogen phtalate 2

excellent answer.

(b) The sodium hydroxide used in the titration needed to be standardised. Explain why this step would be necessary. 2M

NaOH by itself is not suitable for a primary standard. It reacts with molecules in the atmosphere such as H_2O & CO_2. This changes it known concentration & weight & therefore it would not be suitable for a primary standard. Qualities of a primary standard are stability, pure, soluble in water & inert when weighing. ∴ If NaOH is to be used as a standard, it must be standardised beforehand. 2

good answer

(c) Identify one source of error for this experiment. Judgement of where the equivalence pt occurs or when the indicator changes colour. 1M

1

(c) Identify one source of error for this experiment. The burette ~~[illegible]~~ can only release one drop of the solution at ~~the~~ a time. 1/2 a drop may be needed and sometimes a whole drop can cause the reaction to go past the equivalence point. Though 1/2 a drop is not possible - this is an error (we cannot control 1M

1

(d) The following indicators could be selected for this titration. 3M

Indicator	pH range	Colour range
Chlorophenol red	5.2 – 6.8	Yellow - red
Phenolphthalein	8.3 – 10.0	Colourless - crimson
Bromothymol blue	6.0 – 7.6	Yellow - blue
Methyl orange	3.1 – 4.4	Red - yellow

weak acid strong base (basic)

excellent answer !!!

Identify the indicator that you would choose and justify your decision.

• Phenolphthalein (8.3–10 pH) ✓

- The substance that is used in the titration is a weak acid (ethanoic acid) and a strong base (NaOH) and thus it will produce a basic salt.
- This means its equivalence point would be greater than pH > 7 ✓ and the end point (change of colour) is needed to be shown by an indicator than changes in this range. ✓
- phenolphthalein is colourless pH < 8.3 and when equivalante point (basic) it would go from slightly pink (8.3) to a crimson colour (pH > 10).

3.

Identify the indicator that you would choose and justify your decision.

The titration of a weak acid (ethanoic acid) and a strong base (sodium hydroxide) produces a basic salt (sodium ethanoate), which lies in the basic range (pH>7). Therefore, ~~phenol bromothymol blue~~ phenolphthalein would be used because it lies in the basic range (pH>7) ~~...~~ It's use would ensure that the end-point would coincide with the equivalence point. ~~Bco...~~ Chlorophenol red and methyl orange lie in the acidic range (pH<7) whilst bromothymol blue may not ~~a~~ change colour too early ~~as ...~~ due to its limited coverage of the basic range.

3

(f) Calculate the concentration in grams per litre (g/L) of ethanoic acid in the original sample of vinegar. volume of NaOH = $\frac{22.90+23+23.10}{3}$ = 23 mL 4M

$CH_3COOH_{(aq)} + NaOH_{(aq)} \rightarrow NaCH_3COO_{(aq)} + H_2O_{(l)}$

$\{V = 0.02L$. $\{C = 0.22M$, $V = 0.023L$.

$n_{NaOH} = cV = 0.22 \times 0.023 = 0.00506 mol$

$n_{NaOH} : n_{CH_3COOH}$ = 1 : 1 $n_{CH_3COOH} = n_{NaOH} = 0.00506 mol$.

$C_{CH_3COOH} = \frac{n}{V} = \frac{0.00506}{0.02} = 0.253 mol/L$ (diluted)

4

$\therefore$ before dilution $C_{CH_3COOH} = 2.53 mol/L$.

$m_{CH_3COOH} = nM = 2.53 \times (2\times12.01 + 4\times1.008 + 2\times16)$

$= 2.53 \times 60.052$

$= 151.93 g/L$ ✓

(150g/L (2sig fig))

(f) Calculate the concentration in grams per litre (g/L) of ethanoic acid in the original sample of vinegar. 4M

Using run numbers 2, 3 & 5 as they only differ by 0.1 - 0.2 mL

$V_{NaOH} = 23mL$

$n_{NaOH} = C.V$

$= 0.22 \times {}^{23}/_{1000}$

$= 0.00506 mol$

$NaOH + CH_3COOH \rightarrow CH_3COONa + H_2O$

moles theoretical NaOH : CH_3COOH

1 : 1

$n_{CH_3COOH} = 0.00506 mol$.

$C_{CH_3COOH} = n/v$

$= 0.00506/0.02$

$= 0.253 mol/L$

as diluted by factor of ten

$C_{CH_3COOH} = 2.53$

$m_{CH_3COOH} = C \times M$

$= 2.53 mol/L \times 60.052 g/mol$

$\therefore m_{CH_3COOH} = 151.93 g/L$

✓✓

good

4.