CHEMISTRY
Stage 6

Module 6: Acid/Base Reactions
Properties of Acids and Bases

Teacher: Samantha Wong
Exam Equivalent Time: 106.5 minutes *(based on allocation of 1.5 minutes per mark)*

Questions

1. CHEMISTRY, M6 2016 HSC 7 MC

Which indicator in the table would be best for distinguishing between lemon juice (pH = 2.3) and potato juice (pH = 5.8)?

	Indicator	*Colour at different pH*	
(A)	Crystal violet	0.2 – yellow	1.8 – blue
(B)	Methyl orange	3.2 – red	4.4 – yellow
(C)	Bromothymol blue	6.0 – yellow	7.6 – blue
(D)	Phenolphthalein	8.2 – colourless	10.0 – pink

2. CHEMISTRY, M6 2015 HSC 5 MC

The oxides CaO, CO_2, Na_2O and N_2O_4 are placed in water to form four separate solutions.

Which row of the table correctly indicates the solutions with pH less than 7 and the solutions with pH greater than 7?

	Solutions			
	pH less than 7		*pH greater than 7*	
(A)	CO_2	N_2O_4	CaO	Na_2O
(B)	CaO	N_2O_4	CO_2	Na_2O
(C)	CaO	Na_2O	CO_2	N_2O_4
(D)	CO_2	Na_2O	CaO	N_2O_4

3. CHEMISTRY, M6 2019 HSC 2 MC

Which of the following is an Arrhenius base?

A. Na

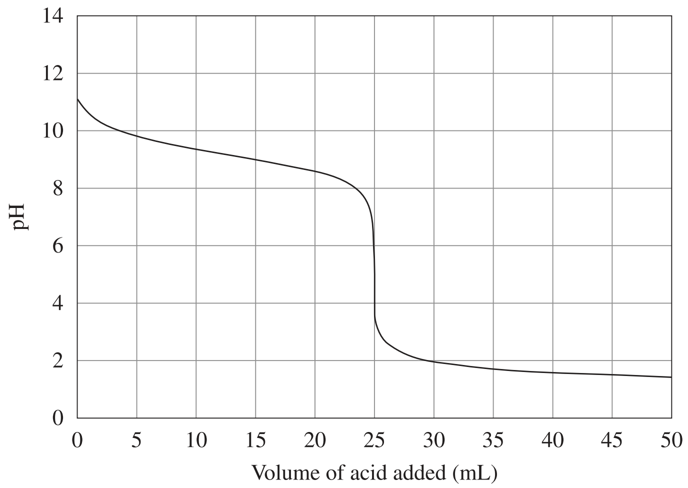
B. $NaOH$

C. Na_2CO_3

D. $NaHCO_3$

4. CHEMISTRY, M6 2019 HSC 5 MC

The diagram represents the titration curve for a reaction between a particular acid and a particular base.



Which indicator would be best for this titration?

	Indicator	*Colour change range* (pH)
A.	Martius yellow	2.0 – 3.2
B.	Magdala red	3.0 – 4.0
C.	Isopicramic acid	4.0 – 5.6
D.	Cresol red	7.2 – 8.8

5. CHEMISTRY, M6 2020 HSC 2 MC

Which indicator in the table would be best for distinguishing between a face cleanser (pH = 5.0) and a soap (pH = 9.0)?

	Indicator	*Colour* (low pH – high pH)	*pH range*
A.	Bromophenol blue	Yellow – blue	3.0–4.6
B.	Methyl orange	Red – yellow	3.1–4.4
C.	Phenol red	Yellow – red	6.4–8.0
D.	Thymolphthalein	Colourless – blue	9.4–10.6

6. CHEMISTRY, M6 2024 HSC 3 MC

Which of the following compounds can be correctly described as an Arrhenius base when dissolved in water?

A. Sodium nitrate

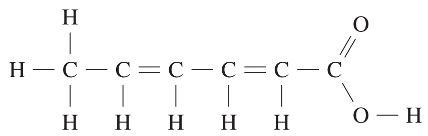
B. Sodium sulfate

C. Sodium chloride

D. Sodium hydroxide

7. CHEMISTRY, M6 EQ-Bank 3 MC

The structure of an organic compound is shown.



Which row of the table correctly shows how this compound reacts with bromine water and with blue litmus?

	Bromine water	*Blue litmus*
A.	No reaction	No reaction
B.	No reaction	Turns red
C.	Decolourises	No reaction
D.	Decolourises	Turns red

8. CHEMISTRY, M6 2018 HSC 9 MC

Which of the following would NOT have been classified as an acid by Antoine Lavoisier in 1780?

A. Acetic acid

B. Citric acid

C. Sulfuric acid

D. Hydrochloric acid

9. CHEMISTRY, M6 2023 HSC 11 MC

An indicator solution was obtained by boiling a flower in water.

Flower water indicator chart

Colour	Red			Purple			Blue		Blue-green		Green-yellow	
pH	1	2	3	4	5	6	7	8	9	10	11	12

Two solutions were tested with this indicator.

Which row of the table correctly identifies the colour of each solution?

	H_2SO_4 (1×10^{-5} mol L^{-1})	$NaOH$ (5×10^{-5} mol L^{-1})
A.	Red	Green-yellow
B.	Red	Blue-green
C.	Purple	Blue-green
D.	Purple	Green-yellow

10. CHEMISTRY, M6 EQ-Bank 8 MC

Which of the following is NOT a Bronsted-Lowry reaction?

A. $NH_4^+ + NH_2^- \rightleftharpoons 2\,NH_3$

B. $CO_2 + OH^- \rightleftharpoons HCO_3^-$

C. $HClO_4 + CH_3COOH \rightleftharpoons CH_3COOH_2^+ + ClO_4^-$

D. $CH_3CH_2O^- + CH_3NH_3^+ \rightleftharpoons CH_3CH_2OH + CH_3NH_2$

11. CHEMISTRY, M6 2015 VCE 23 MC

The following table shows the value of the ionisation constant of pure water at various temperatures and at a constant pressure.

Temperature ($^{\circ}$C)	0	25	50	75	100
K_W	1.1×10^{-15}	1.0×10^{-14}	5.5×10^{-14}	2.0×10^{-13}	5.6×10^{-13}

Given this data, which one of the following statements about pure water is correct?

A. The $[OH^-]$ will decrease with increasing temperature.

B. The $[H_3O^+]$ will increase with increasing temperature.

C. Its pH will increase with increasing temperature.

D. Its pH will always be exactly 7 at any temperature.

12. CHEMISTRY, M6 2020 HSC 10 MC

Equimolar solutions of $NaCl(aq)$, $NH_4Cl(aq)$ and $NaCH_3COO(aq)$ were prepared.

In which of the following are these salt solutions listed from least to most acidic?

A. $NaCl(aq)$, $NH_4Cl(aq)$, $NaCH_3COO(aq)$

B. $NaCl(aq)$, $NaCH_3COO(aq)$, $NH_4Cl(aq)$

C. $NH_4Cl(aq)$, $NaCl(aq)$, $NaCH_3COO(aq)$

D. $NaCH_3COO(aq)$, $NaCl(aq)$, $NH_4Cl(aq)$

13. CHEMISTRY, M6 2022 HSC 22

The following equation describes an equilibrium reaction.

$$HF\,(aq) + PO_4{}^{3-}\,(aq) \rightleftharpoons HPO_4{}^{2-}\,(aq) + F^-\,(aq)$$

Identify ONE base and its conjugate acid in the above equation. ***(2 marks)***

Base	*Conjugate acid*

14. CHEMISTRY, M6 2024 HSC 21

A solution of acetic acid reacts with magnesium metal.

Write the names of the products of this reaction in the boxes provided. ***(2 marks)***

acetic acid + magnesium $\longrightarrow$ $\boxed{}$ + $\boxed{}$

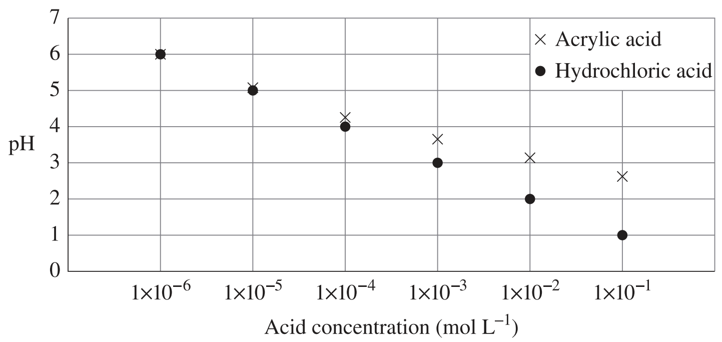
15. CHEMISTRY, M6 2015 HSC 21

a. Outline a suitable method to prepare a natural indicator. ***(2 marks)***

b. How could a natural indicator be tested? ***(2 marks)***

16. CHEMISTRY, M6 2020 HSC 34

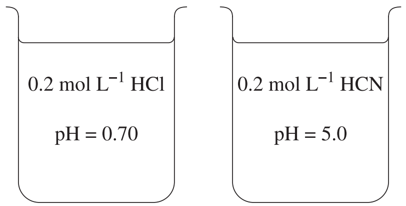
The effect of concentration on the pH of acrylic acid (C_2H_3COOH) and hydrochloric acid (HCl) solutions is shown in the graph. Both of these acids are monoprotic.



Explain the trends in the graph. Include relevant chemical equations in your answer. ***(4 marks)***

17. CHEMISTRY, M6 2022 HSC 25

The pH of two aqueous solutions was compared.



Explain why the $HCN(aq)$ solution has a higher pH than the $HCl(aq)$ solution. Include a relevant chemical equation for the $HCN(aq)$ solution. ***(3 marks)***

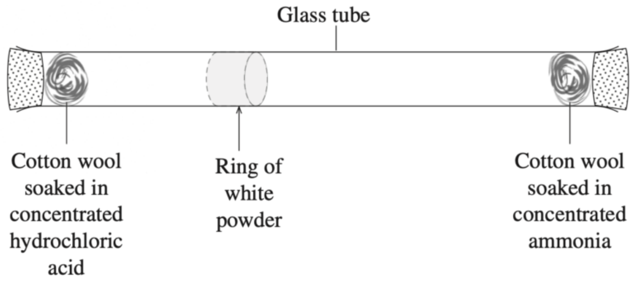
18. CHEMISTRY, M6 2023 HSC 22

Explain how the following substances would be classified under the Arrhenius and Brønsted-Lowry definitions of acids. Support your answer with relevant equations. ***(4 marks)***

- $HCl(aq)$
- $NH_4Cl(aq)$

19. CHEMISTRY, M6 2015 HSC 28

The equipment shown is set up. After some time a ring of white powder is seen to form on the inside of the glass tube.



a. Why would this NOT be an acid-base reaction according to Arrhenius? ***(1 mark)***

b. Explain why this would be considered a Bronsted-Lowry acid-base reaction. Include an equation in your answer. ***(2 marks)***

20. CHEMISTRY, M6 2022 HSC 26

Students conducted an experiment to determine ΔH for the reaction between sodium hydroxide and hydrochloric acid.

The data from one student are shown in the table below.

Mass of 100.0 mL of 0.50 mol L^{-1} HCl	100.7 g
Mass of 100.0 mL of 0.50 mol L^{-1} NaOH	102.0 g
Initial temperature of HCl solution	21.0°C
Initial temperature of NaOH solution	21.2°C
Final temperature of mixture	24.4°C

Assume that all the solutions have the same specific heat capacity as water.

a. Calculate the heat energy released in this experiment. ***(2 marks)***

b. A second student using the same procedure obtained 2.6×10^3 J for the heat energy released in their experiment.

Use this value to determine the enthalpy of neutralisation, ΔH, in $\mathrm{kJ\ mol^{-1}}$, for the reaction shown.

$\mathrm{NaOH\,(aq) + HCl\,(aq) \longrightarrow NaCl\,(aq) + H_2O\,(l)}$ ***(2 marks)***

21. CHEMISTRY, M6 2024 HSC 36

14.7 g of solid sodium hydrogen carbonate (MM = 84.008 g mol^{-1}) was reacted with 120 mL of 1.50 mol L^{-1} hydrochloric acid solution (density 1.02 g mL^{-1}) in a calorimeter. The temperature of the solution before and after reaction was recorded.

Initial temperature of hydrochloric acid solution ($°C$)	*Final temperature of reaction solution* ($°C$)
21.5	11.5

Assume that all CO_2 produced is lost from the reaction solution and that the specific heat capacity of the reaction solution is 3.80 J K^{-1} g^{-1}.

What is the enthalpy of reaction, in kJ mol^{-1}? ***(5 marks)***

22. CHEMISTRY, M6 2020 HSC 25

Citric acid reacts with sodium hydroxide according to the following chemical equation:

$$C_6H_8O_7\,(aq) + 3\,NaOH\,(aq) \longrightarrow Na_3C_6H_5O_7\,(aq) + 3\,H_2O\,(l)$$

Various volumes of 1.0 mol L^{-1} citric acid solution were mixed with 8.0 mL of a sodium hydroxide solution of unknown concentration and sufficient deionised water added to make the total volume of the resulting solution 14.0 mL. The change in temperature of each solution was measured.

The data are given in the table.

Volume of 1.0 mol L^{-1} citric acid (aq) (mL)	*Temperature increase* (°C)
0.0	0.00
1.0	2.50
2.0	5.20
3.0	6.15
4.0	6.10
5.0	6.20
6.0	6.15

By graphing the data in the table and performing relevant calculations, determine the concentration of the sodium hydroxide solution. ***(7 marks)***

23. CHEMISTRY, M6 2020 HSC 36

100.00 mL of 2.00 mol L^{-1} $HCl\,(aq)$ was initially at a temperature of 22.5°C. The mass of this solution was 103 g.

10.0 g of solid $NaOH$ was added to the acid. The specific heat capacity of the resulting solution was 3.99 J g^{-1} K^{-1}.

Assuming no energy loss to the environment, calculate the maximum temperature reached by the solution. ***(5 marks)***

Use the following information in your calculations.

$$NaOH\,(s) \longrightarrow Na^+\,(aq) + OH^-\,(aq) \qquad \Delta H = -\,44.5\text{ kJ mol}^{-1}$$
$$NaOH\,(aq) + HCl\,(aq) \longrightarrow NaCl\,(aq) + H_2O\,(l) \qquad \Delta H = -\,56.1\text{ kJ mol}^{-1}$$

24. CHEMISTRY, M6 2018 HSC 29

The concentration of hydrochloric acid in a solution was determined by an acid base titration using a standard solution of sodium carbonate.

a. Explain why sodium carbonate is a suitable compound for preparation of a standard solution. ***(2 marks)***

b. A 25.00 mL sample of 0.1050 mol L^{-1} sodium carbonate solution was added to a conical flask and three drops of methyl orange indicator added. The mixture was titrated with the hydrochloric acid and the following readings were recorded.

Initial burette reading (mL)	*Final burette reading* (mL)	*Titre* (mL)
0.00	22.00	22.00
22.00	43.65	21.65
0.00	21.70	21.70
21.70	43.30	21.60

Using the data from the table, calculate the concentration of the hydrochloric acid. ***(3 marks)***

c. Explain the effect on the calculated concentration of hydrochloric acid if phenolphthalein is used as the indicator instead of methyl orange. ***(2 marks)***

25. CHEMISTRY, M6 2019 HSC 28

Assess the usefulness of the Brønsted-Lowry model in classifying acids and bases. Support your answer with at least TWO chemical equations. ***(5 marks)***

26. CHEMISTRY, M6 2021 HSC 32

The molar enthalpies of neutralisation of three reactions are given.

Reaction 1:

$$\mathrm{HCl}(aq) + \mathrm{KOH}(aq) \longrightarrow \mathrm{KCl}(aq) + \mathrm{H_2O}(l) \qquad \Delta H = -57.6\ \mathrm{kJ\,mol^{-1}}$$

Reaction 2:

$$\mathrm{HNO_3}(aq) + \mathrm{KOH}(aq) \longrightarrow \mathrm{KNO_3}(aq) + \mathrm{H_2O}(l) \qquad \Delta H = -57.6\ \mathrm{kJ\,mol^{-1}}$$

Reaction 3:

$$\mathrm{HCN}(aq) + \mathrm{KOH}(aq) \longrightarrow \mathrm{KCN}(aq) + \mathrm{H_2O}(l) \qquad \Delta H = -12.0\ \mathrm{kJ\,mol^{-1}}$$

Explain why the first two reactions have the same enthalpy value but the third reaction has a different value. ***(4 marks)***

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Worked Solutions

1. CHEMISTRY, M6 2016 HSC 7 MC

If Methyl orange is used:

→ Lemon juice would be red, potato juice yellow

$\Rightarrow B$

2. CHEMISTRY, M6 2015 HSC 5 MC

→ Acidic solutions (pH < 7) – non-metal oxide solutions

→ Basic solutions (pH > 7) – metal oxide solutions

$\Rightarrow A$

3. CHEMISTRY, M6 2019 HSC 2 MC

Arrhenius bases produce $\mathrm{OH^-}$ ions when dissolved in water.

$\Rightarrow B$

4. CHEMISTRY, M6 2019 HSC 5 MC

→ The pH range at which isopicramic acid exhibits a colour change includes the point at which the acid and base react in equal amounts (equivalence point), which is at approximately pH 5.

→ The colour change can be used to identify when the equivalence point has been reached in a titration.

$\Rightarrow C$

5. CHEMISTRY, M6 2020 HSC 2 MC

→ The phenol red would be yellow for face cleanser (pH of 5.0) and red for soap (pH of 9.0).

→ The other indicators would give off the same colour for both.

$\Rightarrow C$

6. CHEMISTRY, M6 2024 HSC 3 MC

→ An Arrhenius base is a compound that increases the concentration of $\mathrm{OH^-}$ ions when it is dissolved in water.

→ Sodium hydroxide is the only compound that dissolves in water to produce hydroxide ions.

$$\mathrm{NaOH\,(s)} \longrightarrow \mathrm{Na^+\,(aq)} + \mathrm{OH^-\,(aq)}$$

$\Rightarrow D$

7. CHEMISTRY, M6 EQ-Bank 3 MC

→ Organic compound is sorbic acid.

→ Bromine water changes from a bright yellow to a colourless solution when it reacts with sorbic acid.

→ The acidic nature of the organic compound will turn blue litmus red.

$\Rightarrow D$

8. CHEMISTRY, M6 2018 HSC 9 MC

→ A Levoisier acid must contain oxygen.

→ HCl does not contain oxygen.

$\Rightarrow D$

9. CHEMISTRY, M6 2023 HSC 11 MC

→ pH can be calculated from the $\mathrm{H_2SO_4}$ and NaOH concentrations, allowing the colour of the solutions to be determined

$\Rightarrow C$

10. CHEMISTRY, M6 EQ-Bank 8 MC

→ A Bronsted-Lowry reaction occurs when one species (acid) transfers a proton to another species (base).

→ Although it is an acid-base reaction, no proton transfer occurs in $\mathrm{CO_2 + OH^- \rightleftharpoons HCO_3{}^-}$

$\Rightarrow B$

11. CHEMISTRY, M6 2015 VCE 23 MC

♦ Mean mark 55%.

$\mathrm{2\,H_2O\,(l) \rightleftharpoons H_3O^+\,(aq) + OH^-\,(aq)}$

→ Table shows that K_W increases as temperature increases.

→ Ionisation equation shifts right as temperature increases, causing an increase in $[\mathrm{H_3O^+}]$ and $[\mathrm{OH^-}]$ (eliminate A).

→ pH decreases as $[\mathrm{H_3O^+}]$ and temperature increase (eliminate C).

→ pH of water = 7 at 25°C only (eliminate D).

$\Rightarrow B$

12. CHEMISTRY, M6 2020 HSC 10 MC

♦ Mean mark 42%.

→ NaCl is a neutral salt, $\mathrm{NH_4Cl}$ is an acidic salt and $\mathrm{NaCH_3COO}$ is a basic salt.

→ Therefore, least to most acidic:
$\mathrm{NaCH_3COO\,(aq),\ NaCl\,(aq),\ NH_4Cl\,(aq)}$

$\Rightarrow D$

13. CHEMISTRY, M6 2022 HSC 22

Possible answers:

Base	Conjugate Acid
$\mathrm{PO_4{}^{3-}\,(aq)}$	$\mathrm{HPO_4{}^{2-}\,(aq)}$
$\mathrm{F^-\,(aq)}$	$\mathrm{HF\,(aq)}$

14. CHEMISTRY, M6 2024 HSC 21

→ Acid + active metal $\longrightarrow$ hydrogen + salt

→ Products: hydrogen gas $\mathrm{H_2\,(g)}$ and magnesium acetate/ethanoate $\mathrm{Mg(CH_3COO)_2\,(aq)}$

15. CHEMISTRY, M6 2015 HSC 21

a. Methodology:

→ Collect plant material that is a natural indicator of pH. Examples include rose petals and red cabbage.

→ Cut the coloured parts into small pieces.

→ Place material into a beaker with water and boil until the solution becomes coloured.

→ Allow the mixture to cool at room temperature.

→ Decant the liquid into a container, leaving the solid behind.

b. → Prepare test tubes of various acids and bases (pH of each is known).

→ Add some of the indicator to each test tube.

→ Record the natural indicator colour of each example and whether it differentiates between acids and bases and their concentrations.

16. CHEMISTRY, M6 2020 HSC 34

$\mathrm{HCl\,(aq)} \longrightarrow \mathrm{H^+\,(aq)} + \mathrm{Cl^-\,(aq)}$

$\mathrm{C_2H_3COOH\,(aq)} \rightleftharpoons \mathrm{H^+\,(aq)} + \mathrm{C_2H_3COO^-\,(aq)}$

→ HCl is a strong acid that fully dissociates in water, resulting in a high concentration of $\mathrm{H^+}$ ions and a low pH.

→ Acrylic acid, on the other hand, is a weak acid that only partially dissociates in water, resulting in a lower concentration of $\mathrm{H^+}$ ions and a higher pH.

→ When the concentration of HCl decreases by a factor of 10, its pH increases by 1 due to the decrease in $\mathrm{H^+}$.

→ However, when the concentration of acrylic acid decreases by a factor of 10, its pH increases by less than 1.

→ This is due to the change in pH causing the equilibrium to shift right, producing more $\mathrm{H^+}$ ions in response to the dilution, resulting in a smaller change in the concentration of $\mathrm{H^+}$, and thus smaller change in pH.

→ At very dilute concentrations, the degree of dissociation of acrylic acid approaches 100% and its pH converges closely to that of HCl.

17. CHEMISTRY, M6 2022 HSC 25

Mean mark 57%.

→ HCl is a strong acid, ie it completely ionises in water to form $\mathrm{H^+}$ ions.

→ On the other hand, HCN is a weak acid, ie it partially ionises in water to form $\mathrm{H^+}$ ions.

$\mathrm{HCl\,(aq)} \longrightarrow \mathrm{H^+\,(aq)} + \mathrm{Cl^-\,(aq)}$

$\mathrm{HCN\,(aq)} \rightleftharpoons \mathrm{H^+\,(aq)} + \mathrm{CN^-\,(aq)}$

→ As $[\mathrm{H^+}]$ decreases, pH increases $(\mathrm{pH} = -\log\,[\mathrm{H^+}])$

→ Therefore, at the same 0.2M, the HCN solution would have a lower $[\mathrm{H^+}]$ and thus would have a higher pH than HCl.

18. CHEMISTRY, M6 2023 HSC 22

→ Acids are defined by Arrhenius as hydrogen-containing compounds that dissociate in water to give $\mathrm{H^+}$ ions.

→ $\mathrm{HCl\,(aq)}$ produces $\mathrm{H^+}$ ions in water and therefore qualifies within Arrhenius' definition of an acid.

$\mathrm{HCl\,(aq)} \rightarrow \mathrm{H^+\,(aq)} + \mathrm{Cl^-\,(aq)}$

→ The salt $\mathrm{NH_4Cl}$ would not be recognised as an acid with Arrhenius' definition, since the predominant ions present in aqueous solution are ammonium and chloride.

→ The Brønsted–Lowry theory states that acids are proton donors. $\mathrm{HCl\,(aq)}$ is a proton donor and therefore also qualifies as a Brønsted–Lowry acid.

→ In contradiction to Arrhenius, ammonium chloride $(\mathrm{NH_4Cl})$ is also classified as a Brønsted–Lowry acid. This is due to the ammonium ion donating a proton to water to form a hydronium ion.

$\mathrm{NH_4{}^+\,(aq)} + \mathrm{H_2O\,(l)} \rightleftharpoons \mathrm{NH_3\,(aq)} + \mathrm{H_3O^+\,(aq)}$

19. CHEMISTRY, M6 2015 HSC 28

a. According to Arrhenius:

♦♦ Mean mark (a) 37%.

→ An acid is a solution that produces hydrogen ions when in a solution.

→ A base is a solution that produces hydroxide ions when in a solution.

→ This reaction does not occur in an aqueous solution and would not be an acid-base reaction according to Arrhenius.

b. $\mathrm{HCl\,(g)} + \mathrm{NH_3\,(g)} \longrightarrow \mathrm{NH_4{}^+} + \mathrm{Cl^-}$

Mean mark (b) 53%.

→ A Bronsted-Lowry acid donates a proton while a base accepts a proton.

→ This reaction involves proton transfer (HCl donates, $\mathrm{NH_3}$ receives) and would therefore be considered a Bronsted-Lowry acid-base reaction.

20. CHEMISTRY, M6 2022 HSC 26

a. $T_{\text{avg initial}} = \dfrac{21.0 + 21.2}{2} = 21.1^\circ\mathrm{C}$

$$\begin{aligned} q &= mc\Delta T \\ &= (100.7 + 102.0)(4.18)(24.4 - 21.1) \\ &= 2796.04\ldots \\ &= 2800 \text{ J (to 2 s.f.)} \end{aligned}$$

Therefore, 2800 J of heat energy is released in this experiment (assuming no energy loss).

b. $q = 2600$ J

♦ Mean mark (b) 43%.

$\mathrm{n} = 0.1 \times 0.5 = 0.05$ mol

$$\begin{aligned} \Delta H &= -\frac{q}{\mathrm{n}} \\ &= -\frac{2600}{0.05} \\ &= -52\,000 \text{ J mol}^{-1} \\ &= -52 \text{ kJ mol}^{-1} \end{aligned}$$

21. CHEMISTRY, M6 2024 HSC 36

♦ Mean mark 55%.

$$\mathrm{NaHCO_3\,(s) + HCl\,(aq) \longrightarrow NaCl\,(aq) + H_2O\,(l) + CO_2\,(g)}$$

$n(\mathrm{NaHCO_3}) = \dfrac{14.7}{84.008} = 0.0175\ \mathrm{mol}$

$n(\mathrm{HCl}) = 1.5 \times 0.120 = 0.180\ \mathrm{mol}$

HCl and $\mathrm{NaHCO_3}$ react in a $1:1$ ratio $\Rightarrow$ $\mathrm{NaHCO_3}$ is the limiting reagent.

$n(\mathrm{CO_2}) = 0.175\ \mathrm{mol}$

Find mass of $\mathrm{CO_2}$ lost to the surroundings

$n \times MM = 0.175 \times (12.01 + 2(16.00)) = 7.70\ \mathrm{g}$

Mass of the final solution $= 14.7 + (120 \times 1.02) - 7.7 = 129.4\ \mathrm{g}$

$$\begin{aligned}\Delta H &= \frac{-q}{n}\\ &= \frac{-mc\Delta t}{n}\\ &= \frac{-129.4 \times 3.8 \times (11.5 - 21.5)}{0.175}\\ &= +\,2810\ \mathrm{J\ mol^{-1}}\\ &= +\,28.1\ \mathrm{kJ\ mol^{-1}}\end{aligned}$$

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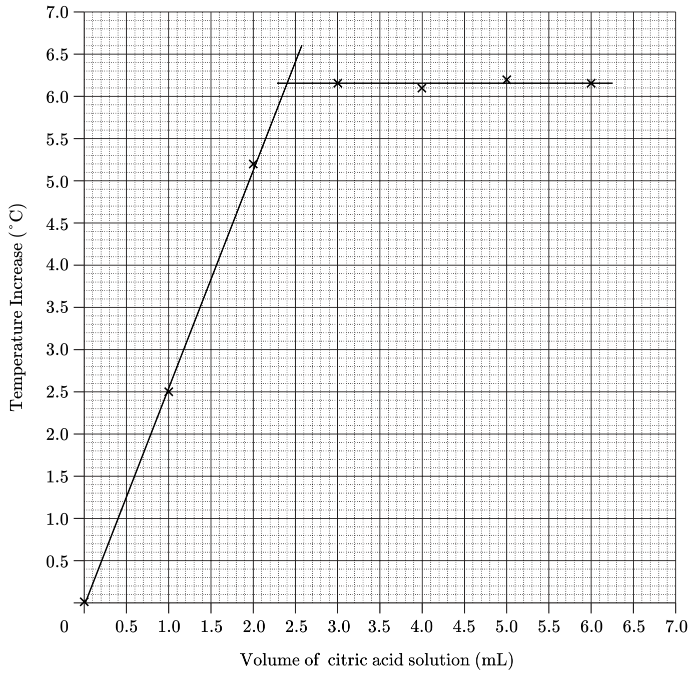
22. CHEMISTRY, M6 2020 HSC 25

♦ Mean mark 53%.



$\mathrm{n(citric\ acid)} = c \times V = (1.0) \times \left(2.4 \times 10^{-3}\right) = 2.4 \times 10^{-3}\ \mathrm{mol}$

$\mathrm{n(sodium\ hydroxide)} = 3 \times \left(2.4 \times 10^{-3}\right) = 7.2 \times 10^{-3}\ \mathrm{mol}$

$[\mathrm{sodium\ hydroxide}] = \dfrac{7.2 \times 10^{-3}}{8.0 \times 10^{-3}} = 0.90\ \mathrm{mol\ L^{-1}}$

23. CHEMISTRY, M6 2020 HSC 36

♦ Mean mark 49%.

Dissolution of $NaOH(s)$:

$$NaOH(s) \longrightarrow Na^+(aq) + OH^-(aq)$$

$$n(NaOH) = \frac{m}{MM} = \frac{10.0}{22.99 + 16.00 + 1.008} = 0.250 \text{ mol}$$

$$q_1 = -\Delta H \times n = 44.5 \times 0.250 = -11.125 \text{ kJ}$$

Reaction between $NaOH(aq)$ and $HCl(aq)$:

$$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$$

$$n(HCl) = c \times V = 2.00 \times 0.100 = 0.200 \text{ mol}$$

$\Rightarrow$ HCl = limiting reagent

$$n(H_2O) \text{ formed} = 0.200 \text{ mol}$$

$$q_2 = -\Delta H \times n = 56.1 \times 0.200 = 11.22 \text{ kJ}$$

$$q_{total} = q_1 + q_2 = 11.125 + 11.22 = 22.345 \text{ kJ} = 22\ 345 \text{ J}$$

$$q_{total} = mc\Delta T$$

$$22\ 345 = (103 + 10.0) \times 3.99 \times (T_{final} - T_{initial})$$

$$= (103 + 10.0) \times 3.99 \times (T_{final} - 22.5)$$

$$T_{final} = \frac{22\ 345}{(103 + 10.0) \times 3.99} + 22.5$$

$$= 72.1^\circ\text{C} \quad \text{(to 1 d.p.)}$$

24. CHEMISTRY, M6 2018 HSC 29

a. → Na_2CO_3 is a stable compound.

♦ Mean mark (a) 43%.

→ Na_2CO_3 is a pure solid that will not readily absorb water from the atmosphere.

→ An accurate weight of Na_2CO_3 can therefore be obtained in the experiment's measurements.

b. $Na_2CO_3(aq) + 2HCl(aq) \longrightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$

$$\text{Average titre} = \frac{21.65 + 21.70 + 21.60}{3} = 21.65 \text{ mL}$$

$$n(Na_2CO_3) = c \times V = 0.1050 \times 0.0250 = 0.002625 \text{ mol}$$

$$n(HCl) = 2 \times n(Na_2CO_3) = 0.005250 \text{ mol}$$

$$[HCl] = \frac{n}{V} = \frac{0.005250}{0.02165} = 0.2425 \text{ mol L}^{-1}$$

c. → This is a strong acid / weak base titration.

♦♦♦ Mean mark (c) 29%.

→ Its equivalence point will occur at a pH less than seven and phenolphthalein changes colour in the pH range 10 – 8.3.

→ Phenolphthalein indicator would therefore signal the end point before equivalence (i.e. with a lower volume of acid).

→ The calculated concentration of HCl would be higher than the correct concentration.

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♦♦♦ Mean mark 35%.
MARKER'S COMMENT: Two relevant equations required to achieve full marks.

→ The Bronsted-Lowry model is a way of classifying acids and bases based on their ability to donate or accept protons.

→ This model is more comprehensive than the Arrhenius model, as it can explain the acid-base behaviour of more species, including those that do not contain OH^- ions, and non-aqueous acid-base reactions.

→ Consider the reaction $NH_3(g) + HCl(g) \longrightarrow NH_4Cl(s)$ where a proton is transferred from hydrogen chloride to ammonia (according to the Bronsted-Lowry model). Ammonia is not an Arrhenius base as it doesn't dissociate to produce OH^- ions and the reaction cannot be described using the Arrhenius model.

→ However, the Bronsted-Lowry model does have some limitation, such as its inability to explain the acidity of certain acidic oxides and their reactions with basic oxides.

→ e.g. $CaO(s) + SO_3(g) \longrightarrow CaSO_4(s)$ is an acid-base reaction but since there is no proton transfer, it cannot be described using the Bonsted-Lowry model.

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→ Reaction 1 and reaction 2 are both neutralisation reactions between strong acids and strong bases. These reactions completely ionise in solution when added to water.

♦ Mean mark 44%.

→ Both reactions have the same net ionic equation:

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

→ Therefore, the enthalpy values obtained are the same for both reactions.

→ In reaction 3, HCN is a weak acid that only partially ionises in an equilibrium reaction with water.

$$\mathrm{HCN}(aq) + \mathrm{H_2O}(l)\ \leftrightharpoons\ \mathrm{CN^-}\ (aq) + \mathrm{H_3O^+}(aq).$$

→ As the reaction continues, HCN will further ionise as the equilibrium shifts to the right.

→ The bond-breaking is an endothermic process and thus will consume energy to break the bonds. As a result, the overall reaction is less exothermic than reaction 1 and reaction 2.