Chemistry

2019 Term 1
Theory Examination

General Instructions

- Reading time – 5 minutes
- Working time – 50 minutes
- Write using black pen
- Write your Student Number at the top of the response sheet on page 7.

A data sheet and a periodic table are provided.

Theory

Total Marks – 40

Part A – 11 marks
Attempt Questions 1 – 11

Part B – 29 marks
Attempt Questions 12-18

Part A- Multiple Choice   11 marks
Attempt Questions 1-11
Allow about 10 minutes for this part

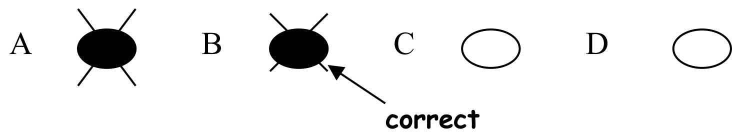
Use the multiple-choice answer sheet.

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

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

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.



▸ **Mark your answers for Questions 1- 11 in the Answer Box on page 9**

1. Which is an acidic salt?

(A) CH_3COONa

(B) $NaHCO_3$

(C) NH_4Cl

(D) $NaCl$

2. Consider an acid-base indicator solution.

$$HIn_{(aq)} \rightleftharpoons H^+_{(aq)} + In^-_{(aq)}$$

Colour A Colour B

What is the effect on this acid-base indicator when sodium hydroxide is added to it?

(A) The equilibrium shifts to the right and more of colour B is observed.

(B) The equilibrium shifts to the left and more of colour B is observed.

(C) The equilibrium shifts to the right and more of colour A is observed.

(D) The equilibrium shifts to the left and more of colour A is observed.

Considering the water-gas shift reaction shown below for questions 3 and 4,

$$CO\,(g) + H_2O\,(g) \rightleftharpoons CO_2\,(g) + H_2\,(g)$$

3. What is the change in the equilibrium constant when there is an increase in pressure?

(A) Increase

(B) Remain the same

(C) Decrease

(D) Equal to zero

4. The K_{eq} of the reaction decreases when the temperature is increased.

What is the enthalpy change of the reaction?

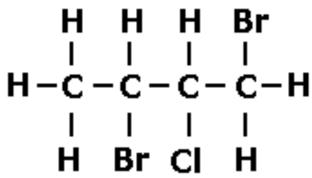
(A) Zero

(B) Positive

(C) Negative

(D) It cannot be determined

5. What is the name of the haloalkane pictured?



(A) 1,3-dibromo -2-chloropropane

(B) 2,4 dibromo – 3- chloropropane

(C) 1,3-dibromo-2-chlorobutane

(D) 2,4 dibromo – 3- chlorobutane

6. What volume of gas is produced when 8.5 g of zinc is reacted with excess hydrochloric acid at 298K?

(A) 2.95 L

(B) 3.0 L

(C) 3.2 L

(D) 3.22 L

7. The following equation represents a chemical system in equilibrium:

$HCOOH(l) + H_2O(l) \rightarrow HCOO^-(aq) + H_3O^+(aq)$

Which of the following is an acid/base conjugate pair?

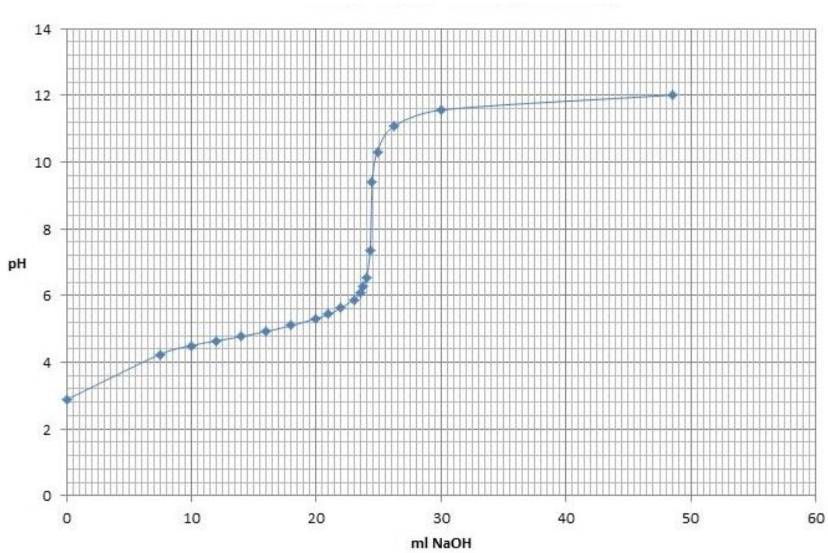
(A) $HCOOH/ HCOO^-$

(B) $HCOOH/ H_3O^+$

(C) $HCOO^-/ H_3O^+$

(D) $H_2O/ HCOO^-$

8. Which statement describes components of this titration?



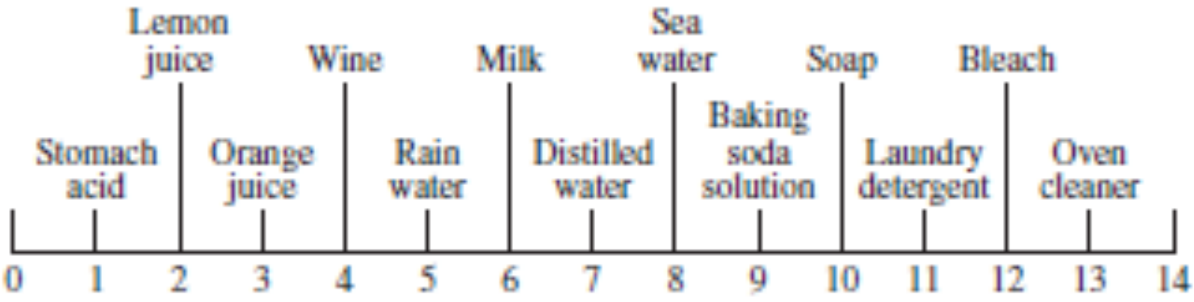
(A) Strong acid + weak base with equivalence at pH=8.4

(B) Strong acid + strong base with equivalence at pH=7

(C) Weak acid + weak base with equivalence at pH=7

(D) Weak acid + strong base with equivalence at pH=8.4

9. The diagram shows the pH of some substances



Based on the information provided, which of the following statements about the relative concentration of hydrogen ions is correct?

(A) It is 100 times higher in baking soda solution than in distilled water.

(B) It is 2 times higher in soap than it is in rain water.

(C) It is 10 times lower in lemon juice than in bleach.

(D) It is 1000 times lower in sea water than in rain water.

10. 10.0 mL of a 0.010 $molL^{-1}$ magnesium hydroxide solution is added to 15.0 mL of 0.020 $molL^{-1}$ nitric acid solution.

What is the pOH of the final solution?

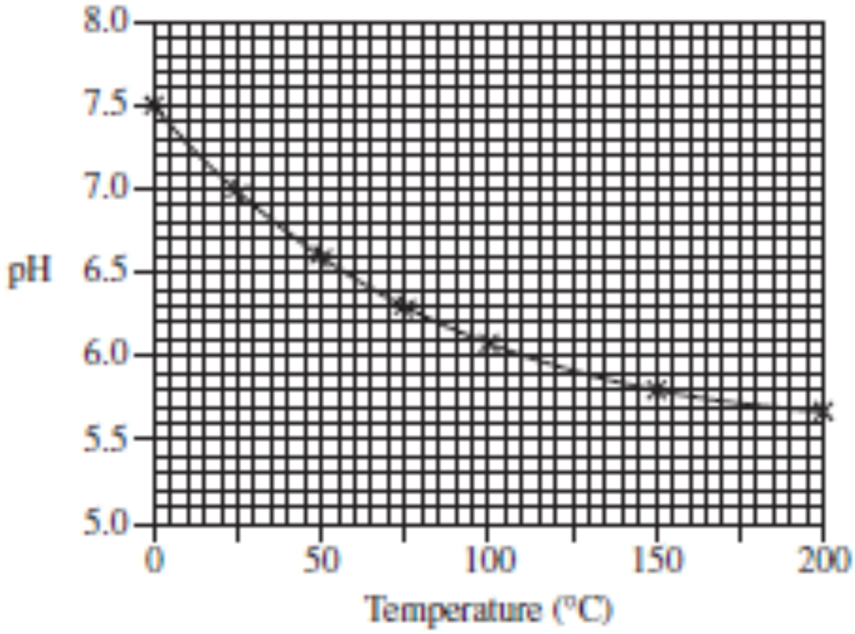
(A) 1.4

(B) 2.01

(C) 11.9

(D) 12.6

11. The graph shows the pH of a solution of a weak acid, HA as a function of temperature.



What happens as the temperature increases?

(A) HA becomes more ionised and the concentration of H^+ increases.

(B) HA becomes more ionised and the concentration of H^+ decreases.

(C) HA becomes less ionised and the concentration of H^+ increases.

(D) HA becomes less ionised and the concentration of H^+ decreases.

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Student Number	
Theory Mark / 36	

Part A: Answer grid for multiple choice questions.

1.	A O	B O	C O	D O
2.	A O	B O	C O	D O
3.	A O	B O	C O	D O
4.	A O	B O	C O	D O
5.	A O	B O	C O	D O
6.	A O	B O	C O	D O
7.	A O	B O	C O	D O
8.	A O	B O	C O	D O
9.	A O	B O	C O	D O
10.	A O	B O	C O	D O
11.	A O	B O	C O	D O
12.	A O	B O	C O	D O
13.	A O	B O	C O	D O

Part B – 25 marks **Marks**

Attempt questions 12 – 18

Allow about 40 minutes for this part

Show all relevant working in questions involving calculations.

Question 12 (3 marks)

Distinguish between static and dynamic equilibrium and give an example of each. **3**

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Question 13 (3 marks)

Explain the exothermic dissolution of an identified salt. **3**

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Question 14 (5 marks)

Photosynthesis is an example of a non-equilibrium system.

(a) Write balanced chemical equation for photosynthesis. **1**

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(b) The following values occur for the photosynthesis reaction at 25°C

$\Delta H^o = +2803 \text{ kJmol}^{-1}$
$\Delta S^o = -212 \text{ Jmol}^{-1}\text{K}^{-1}$

Calculate the Gibbs free energy for photosynthesis at 25°C and explain the spontaneous or non-spontaneous nature of the reaction. **4**

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Question 15 (5 marks)

A 0.80 M solution of acetic acid was found to have a pH of 2.40.

(a) Calculate the K_a for acetic acid. **3**

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(b) Lactic acid has a pK_a of 3.85.

Calculate the pK_a of acetic acid and compare the relative strengths of these acids. **2**

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Question 16 (2 marks)

Use net ionic equations to demonstrate the amphiprotic nature of potassium dihydrogen phosphate. **2**

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Question 17 (7 marks)

Using appropriate examples, explain how the Bronsted-Lowry theory of acids and bases overcame the limitations of Arrhenius' theory. **7**

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Part B extra writing space

If you use this space, clearly indicate which question you are answering.

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End of Theory Test

Term1 Theory Chemistry answers 2019

1. Which is an acidic salt?

   (A) CH_3COONa

   (B) $NaHCO_3$

   (C) NH_4Cl

   (D) $NaCl$

2. Consider an acid-base indicator solution.

$$HIn_{(aq)} \rightleftharpoons H^+_{(aq)} + In^-_{(aq)}$$

Colour A Colour B

   What is the effect on this acid-base indicator when sodium hydroxide is added to it?

   (A) The equilibrium shifts to the right and more of colour B is observed.

   (B) The equilibrium shifts to the left and more of colour B is observed.

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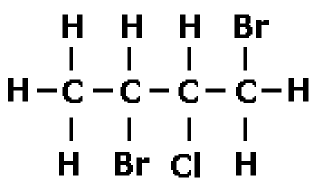
   (D) The equilibrium shifts to the left and more of colour A is observed.

3. What is the name of the haloalkane pictured?



   (A) 1,3-dibromo -2-chloropropane

   (B) 2,4 dibromo – 3- chloropropane

   (C) 1,3-dibromo-2-chlorobutane

   (D) 2,4 dibromo – 3- chlorobutane

Consider the water-gas shift reaction shown below for questions 4 and 5,

$$CO\ (g)\ +\ H_2O\ (g)\ \rightleftharpoons\ CO_2\ (g)\ +\ H_2\ (g)$$

4. What is the change in the equilibrium constant when there is an increase in pressure?

(A) Increase

(B) Remain the same

(C) Decrease

(D) Equal to zero

5. The equilibrium of the reaction decreases when the temperature is increased. What is the enthalpy change of the reaction?

(A) Zero

(B) Positive

(C) Negative

(D) It cannot be determined

6. What volume of gas is produced when 8.5 g of zinc is reacted with excess hydrochloric acid at 298K?

(A) 2.95 L

(B) 3.0L

(C) 3.2 L

(D) 3.22 L

7. The following equation represents a chemical system in equilibrium:

$HCOOH(l) + H_2O(l) \rightleftharpoons HCOO^-(aq) + H_3O^+(aq)$

Which of the following is an acid/base conjugate pair?

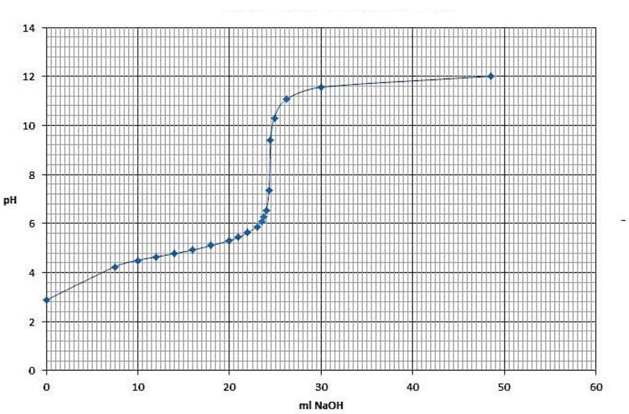
(A) $HCOOH/ HCOO^-$

(B) $HCOOH/ H_3O^+$

(C) $HCOO^-/ H_3O^+$

(D) $H_2O/ HCOO^-$

8. Which statement describes components of this titration?



(A) Strong acid + weak base with equivalence at pH=8.4

(B) Strong acid + strong base with equivalence at pH=7

(C) Weak acid + weak base with equivalence at pH=7

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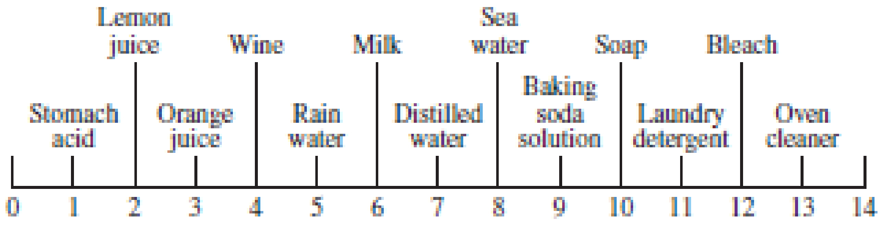

Based on the information provided, which of the following statements about the relative concentration of hydrogen ions is correct?

(A) It is 100 times higher in baking soda solution than in distilled water.

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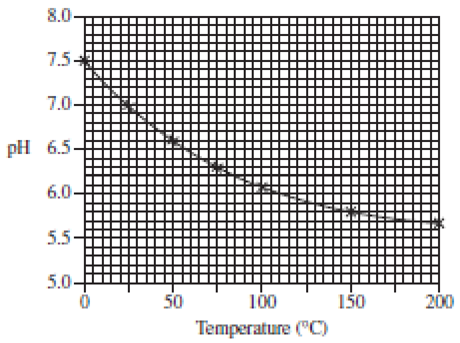
11. The graph shows the pH of a solution of a weak acid, HA as a function of temperature.



What happens as the temperature increases?

(A) HA becomes more ionised and the concentration of H^+ increases.

(B) HA becomes more ionised and the concentration of H^+ decreases.

(C) HA becomes less ionised and the concentration of H^+ increases.

(D) HA becomes less ionised and the concentration of H^+ decreases.

1.	A O	B O	C √	D O
2.	A √	B O	C O	D O
3.	A O	B O	C √	D O
4.	A O	B √	C O	D O
5.	A O	B O	C √	D O
6.	A O	B O	C √	D O
7.	A √	B O	C O	D O
8.	A O	B O	C O	D√
9.	A O	B O	C O	D √
10.	A O	B O	C O	D √
11.	A √	B O	C O	D O

Question 12 (3 marks)

Distinguish between static and dynamic equilibrium, giving an example of each **3**

Static equilibrium is a state where the rate of change is zero.
Dynamic equilibrium is a state where the reverse reaction rate is equal to the forward reaction rate, and both are non-zero.
E.g. $CO\ (g) + H_2O\ (g) \rightleftharpoons CO_2\ (g) + H_2\ (g)$

Marking Criteria	*Mark(s)*
• Distinguishes between static and dynamic equilibrium. • Provides a correct example of a dynamic equilibrium.	3
• Defines static equilibrium. OR Defines dynamic equilibrium. • Provides a correct example of a dynamic equilibrium.	2
• Defines static equilibrium. OR	1

Defines dynamic equilibrium.	

Question 13 (3 marks)

Explain the exothermic dissolution of a named salt. **3**

In the process of salt dissolution in water, positive and negative ions in the lattice are separated by water molecules. The ion-dipole forces between the ions and surrounding water molecules overcomes the electrostatic forces between the ions as well as the hydrogen bonds between the water molecules.

This process describes the breaking of ionic bonds and intermolecular forces which require energy. The separated ions are surrounded by water molecules and form ion-dipole bonds (the cation is surrounded by the partially negative oxygen atom and the anion is surrounded by the partially positive hydrogen atoms of the water molecules) where energy is released. Overall, energy is released, the change in enthalpy is negative and hence the process is exothermic.

Exothermic examples: $MgCl_2$, $NaCO_3$, CH_3COONa, $CaSO_4$, $LiNO_3$, $CaCl_2$

Endothermic examples: $NaCl$, NH_4Cl, KCl, $FeSCN$, KNO_3, $AgNO_3$

Not soluble: Ag_2CO_3, $CaCO_3$

Not salt: $NaOH$

Marking Criteria	*Mark(s)*
• Correctly identifies a salt which will undergo an exothermic dissolution. • Outlines the changes in energy as bonds are broken and formed. • Identifies the forces involved in the process of salt dissolution. • Identifies that enthalpy is negative for an exothermic reaction.	3
• Outlines the changes in energy as bonds are broken and formed. OR Identifies the forces involved in the process of salt dissolution. • Identifies that enthalpy is negative for an exothermic reaction.	2
• Identifies the forces involved in the process of salt dissolution. OR Identifies that enthalpy is negative for an exothermic reaction.	1

Question 14 (5 marks)

Photosynthesis is an example of a non-equilibrium system.

(a) Write the balanced chemical equation for photosynthesis. **1**

$6CO_2\,(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6\,(aq) + 6O_2\,(g)$

(b) The following values exist for the photosynthesis reaction at 25°C

$\Delta H^o = +2803\ kJmol^{-1}$
$\Delta S^o = -212\ Jmol^{-1}K^{-1}$

Calculate the Gibbs free energy for photosynthesis at 25°C and explain the spontaneous or non-spontaneous nature of the reaction. **4**

$\Delta G^o = \Delta H^o - T\Delta S^o$
$= +2803 - (298 \times 0.212)$
$= +2866 kJmol^{-1}$

As is positive, this is a non-spontaneous reaction that requires a continual supply of energy for the reaction to occur.

Marking Criteria	*Mark(s)*
• Correctly calculates ΔG^o • Comments on the spontaneity of the reaction	4
• Correctly calculates ΔG^o • Identifies the reaction as non-spontaneous OR • Does some relevant calculation AND • Comments on the spontaneity of the reaction	3
• Identifies the reaction as non-spontaneous • Does some relevant calculation OR • Correctly calculates ΔG^o	2
• Makes a relevant statement or calculation	1

Question 15 (5 marks)

A 0.80 $molL^{-1}$ solution of acetic acid was found to have a pH of 2.40.

(a) Calculate the K_a for acetic acid. **3**

Sample answer(s):

$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$
$K_a = [CH_3COO^-][H_3O^+] / [CH_3COOH]$

	CH_3COOH	CH_3COO^-	H_3O^+
initial	0.80	0	0
change	- x	+x	+x
equilibrium	0.80 - x	x	x

$[CH_3COO^-] = [H^+] = 10^{-2.4} = 0.004$ mol = x
$K_a = 0.004 \times 0.004 / (0.80 – 0.004) = 2.0 \times 10^{-5}$

OR – small change assumption

$K_a = [CH_3COO^-][H_3O^+] / [CH_3COOH]$
$[CH_3COO^-] = [H^+] = 10^{-2.4} = 0.004$ mol = x
$K_a = 0.004 \times 0.004 / (0.80) = 2.0 \times 10^{-5}$

Marking Criteria	*Mark(s)*
• Provides correct sequence of steps in the calculation of the K_a for acetic acid (concentration of H^+, K_a expression, and K_a value).	3
• Provides some relevant calculation steps (at least TWO of the above).	2
• Provides some relevant information	1

(b) Lactic acid has a pK_a of 3.85.
Calculate the pK_a of acetic acid and compare the relative strengths of these acids. **2**

Sample answer:

$pK_a = -log_{10}(K_a) = -log_{10}(1.9 \times 10^{-5}) = 4.72$.

Since acetic acid has a larger pK_a value of 4.72, it makes this a weaker acid when compared to lactic acid which has a pK_a of 3.85. These values identify that lactic acid has a greater amount of H^+ ions in solution (larger K_a) when compared with acetic acid, indicating a higher degree of ionisation in solution.

Marking Criteria	*Mark(s)*
• Provides correct calculation of acetic acid pK_a. • Compares the relative strengths of acids with reference to the relationship between pK_a, K_a, and the degree of ionisation.	2
• Provides some relevant information.	1

Question 16 (2 marks)

Use net ionic equations to demonstrate the amphiprotic nature of potassium dihydrogen phosphate. **2**

$$H_2PO_4^- + H_3O^+ \rightleftharpoons H_3PO_4 + H_2O$$

$$H_2PO_4^- + OH^- \rightleftharpoons HPO_4^{2} + H_2O$$

Marking Criteria	*Mark(s)*
• Provides TWO correct equations that demonstrate the amphiprotic nature of potassium dihydrogen phosphate.	2
• Provides ONE correct equation OR • Provides TWO equations containing the correct structures of potassium dihydrogen phosphate (NOT ionic, NOT acidic / basic conditions, NOT balanced).	1

Question 17 (7 marks)

Using appropriate examples, explain how the Bronsted-Lowry theory of acids and bases overcame the limitations of Arrhenius' theory. **7**

Sample answer:

The Arrhenius model describes acids as molecules that dissolve (ionise) in water to produce hydrogen ions and bases as those which dissolve (dissociate) in water to produce hydroxide ions. Typical Arrhenius acid and base behaviours are presented in the chemical equations below:

$$HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$$

$$NaOH_{(aq)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$$

This provided a very narrow range of possibilities for the classification of substances as either acidic or basic. A major limitation of this theory was its inability to explain the alkaline nature of substances that did not contain hydroxide ions, such as metal carbonates, metal oxides, and ammonia. The Bronsted-Lowry model overcame this issue through refining the definition of acids and bases to highlight their chemical behaviour as opposed to chemical composition. This theory stated that acids would be defined as substances that donate protons (hydrogen ions) and bases as substances that accept protons.

$$NH_{3(aq)} + H_2O_{(l)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-_{(aq)}$$

In this instance, ammonia could be classified as a (Bronsted) base since it receives a proton from the water molecule (Bronsted acid) to generate the ammonium ion and hydroxide ions.

Another limitation of the Arrhenius model was its inability to explain the behaviour of acids and bases in non-aqueous solutions. Reactions such as the one shown in the example below would not be considered an acid-base neutralisation reaction under the Arrhenius theory due to the absence of water.

$$NH_{3(g)} + HCl_{(g)} \rightleftharpoons NH_4Cl_{(s)}$$

However, this example agrees with the Bronsted-Lowry model as gaseous ammonia is again acting as a Bronsted base (proton acceptor) with gaseous hydrochloric acid as a Bronsted acid (proton donor). This was important as it had proven that many acidic and basic substances did not need an aqueous solution to undergo neutralisation reactions.

A further limitation of the Arrhenius model was the assumption that all salts produced by an acid-base neutralisation reaction should neutral. This theory could not explain why certain neutralisation reactions, such as when equal amounts of acetic acid was reacted with sodium hydroxide resulted in an alkaline solution.

$$CH_3COOH_{(aq)} + NaOH_{(aq)} \rightleftharpoons CH_3COONa_{(aq)} + H_2O_{(l)}$$

The Bronsted-Lowry model was able to explain the alkaline nature of the resultant salt solution through the discovery of conjugate acid-base pairs. This theory identified that the conjugate base of acetic acid was relatively strong, and thus was a potent proton acceptor as shown below:

$$CH3COO^-_{(aq)} + H_2O_{(l)} \rightleftharpoons CH_3COOH_{(aq)} + OH^-_{(aq)}$$

In this reaction, we see that the acetate ion could be classified as a Bronsted base since it receives a proton from the water molecule (Bronsted acid) to regenerate acetic acid and hydroxide ions. This instance highlights how the Bronsted-Lowry theory is able to classify the acetate ion as a base and in turn explain the alkaline nature of the resultant solution.

Question 15 (5 marks)

Marking Criteria	*Mark(s)*
• Demonstrates a thorough understanding of the Arrhenius and Bronsted-Lowry theories of acids and bases. **(A + B)** • Thoroughly explains the limitations of the Arrhenius model and how the Bronsted-Lowry model overcame these limitations with appropriate examples. **(TL + TO)** • Provides relevant chemical equations to support explanations. **(E)**	7
• Demonstrates a detailed understanding of the Arrhenius and Bronsted-Lowry definitions of acids and bases. **(A + B)** • Thoroughly explains the limitations of the Arrhenius model OR how the Bronsted-Lowry model overcame these limitations with appropriate examples. **(TL + O OR T + TO)** • Provides a relevant chemical equation to support an explanation. **(E)**	6
• Demonstrates a detailed understanding of the Arrhenius and / or the Bronsted-Lowry definitions of acids and bases. **(A + B OR A OR B)** • Explains a limitation of the Arrhenius model and / or how the Bronsted-Lowry model overcame these limitation. **(L + O)** • Provides a relevant chemical equation to support an explanation. **(E)**	5 – 4
• Correctly defines Arrhenius and / or the Bronsted-Lowry acids and bases. **(A + B OR A OR B)** • Identifies a limitation of the Arrhenius model and / or how the Bronsted-Lowry model overcame a limitation. **(T + O OR T OR O)**	3 – 2
• Provides some relevant information	1