CHEMISTRY

THE INSTITUTE OF EDUCATION

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ACIDS AND BASES

STUDENT NAME:

THE INSTITUTE OF EDUCATION

CONTENTS

In this section of our course we will study both acids and bases. Both of these substances occur around us in our every day lives. For example, indigestion is caused by the over production of acid in our stomachs and to relieve this we take a base i.e. 'Milk of Magnesia'. Bee stings are acidic and can be neutralised by using baking soda paste (sodium hydrogencarbonate). Shampoos are slightly basic and we use conditioner that is slightly acidic to neutralise the effects of the shampoo.
Other examples are limestone can be added to lakes to reduce the effects of acid rain on the flora and fauna. Farmers spread lime on land if the soil is too acidic. Toothpaste is slightly basic to neutralise acidic foods that can cause tooth decay.

ARRHENIUS' THEORY OF ACIDS AND BASES

ACIDS
Defn - An acid produces H^+ ions in water.

For example:
$HCl \rightarrow H^+ + Cl^-$
$HNO_3 \rightarrow H^+ + NO_3^-$
$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$

Problems with Arrhenius' theory

- Arrhenius' theory of acids allowed the existence of independent H^+ ions. Now we now that this is not true. The H^+ ion reacts with water to form H_3O^+ (this is known as the hydronium ion or the **oxonium ion**). For simplicity sake we use the term hydrogen ion when discussing acidic solutions, eventhough we know that they do not exist.

- Arrhenius' theory also based his definitions to reactions occurring in polar water, so non-polar organic solvents were excluded.

BASES
Defn - A base produces OH^- ions in water.

For example
$NaOH \rightarrow Na^+ + OH^-$
$Mg(OH)_2 \rightarrow Mg^{2+} + 2OH^-$

Alkali – an alkali is a base that is soluble in water.
NaOH is an alkali while $Mg(OH)_2$ is not.

Problem with Arhennius' theory

- Arhennius' theory of bases excluded common bases such as NH_3.

Examples-
The Arrhenius definitions of acidity and alkalinity are restricted to aqueous solutions and refer to the concentration of the solvent ions. Under this definition, pure H2SO4 or HCl dissolved in toluene are not acidic, and molten KOH and solutions of sodium amide in liquid ammonia are not alkaline.

General equation for acids dissociating in solution (where HA is an acid):

$$HA + H_2O \rightarrow A^- + H_3O^+$$

Q. Write an equation to show the reaction of nitric acid with water.

Monobasic acids

Defn – A monobasic acid produces one H^+ ion in solution e.g. HCl and HNO_3.

Dibasic acids

Defn – A dibasic acid produces two H^+ ions in solution e.g. H_2SO_4.

Tribasic acids

Defn – A tribasic acid produces three H^+ ions in solution e.g. H_3PO_4.

BRONSTED-LOWRY THEORY OF ACIDS AND BASES.

A newer definition was put forward by two chemists **BRONSTED-LOWRY.**

ACID

Defn - an acid is a proton (H^+) donor.

BASE

Defn - a base is a proton (H^+) acceptor.

For example

$$HCl + H_2O \rightarrow Cl^- + H_3O^+$$

acid base

$$NH_3 + H_2O \rightarrow NH_4^+ + OH^-$$

base acid

Note - from the two examples we can see that water can act as both an acid and a base, therefore water is said to be amphoteric.

AMPHOTERIC

Defn - a substance that can act as both an acid and a base.

$$H_2O + H_2O \rightarrow H_3O^+ + OH^-$$

acid base

Note - An acid only acts as an acid in the presence of a base.

CONJUGATE PAIRS
Defn - Two species that differ by one proton.

CONJUGATE ACID
Defn – a base plus a H^+ ion.

CONJUGATE BASE
Defn – an acid minus a H^+ ion.

For example each of these pairs are a conjugate pair as they differ by only one proton.

$$HCl / Cl^- \qquad HNO_3 / NO_3^- \qquad NH_3 / NH_4^+$$

Sample question
Pick out the acid, base and conjugate acid, conjugate base from the following equation.

$$H_2SO_4 + H_2O \rightarrow H_3O^+ + HSO_4^-$$
acid base c.a c.b

H_2SO_4 is the acid as it donates a H^+ to become HSO_4^-.

HSO_4^- is the conjugate base.

H_2O is the base as it accepts a proton to become H_3O^+.

H_3O^+ is the conjugate acid.

QUESTIONS

1. Which of the following acid/base pairs is not a conjugate pair? (LCH 1991)

$$H_3O^+ / H_2O \qquad HSO_4^- / H_2SO_4 \qquad H_3PO_4 / HPO_4^{2-}$$

2. Identify the two species acting as acids in the following system: (LCH 1992)

$$H_2SO_4 + H_2F_2 \square \quad H_3SO_4^+ + HF_2^-$$

3. Write down the conjugate acid of the following:

(a) NH_3 _____

(b) SO_4^{2-} _____

(c) HS^- _____

Note – if the question is looking for the conjugate acid then the substances in the question must be bases so accept a proton onto each to get the answer.

4. Write down the conjugate base of the following:

(a) H_2O _____

(b) HS^- _____

(c) NH_4^+ _____

Note – if the question is looking for the conjugate base then the substances in the question must be acids so donate a proton from each to get the answer.

5. Indicate in each of the following equations the acids, bases and conjugate acids and conjugate bases.

(a) $HNO_3 + OH^- \rightarrow NO_3^- + H_2O$

(b) $NH_4^+ + CO_3^{2-} \rightarrow HCO_3^- + NH_3$

DISSOCIATION

When acids are placed in solutions they **split up** into their ions, hydrogen ions and anions. (The anion produced depends on the acid involved.) This is known as **dissociation**. The number of dissociations depends on whether the acids are monobasic, dibasic or tribasic.

DISSOCIATION EQUATIONS

Monobasic acids have <u>one equation</u> for their dissociation.

Example 1-

$HCl + H_2O \rightarrow Cl^- + H_3O^+$

Example 2 –

$CH_3COOH + H_2O \rightarrow CH_3COO^- + H_3O^+$

Ethanoate ion

Dibasic acids have <u>two equations</u> to show their dissociations:

1st dissociation of H_2SO_4

$H_2SO_4 + H_2O \rightarrow HSO_4^- + H_3O^+$

2nd dissociation of H_2SO_4

$HSO_4^- + H_2O \rightarrow SO_4^{2-} + H_3O^+$

Tribasic acids have <u>three equations</u> to show their dissociations:

1st dissociation of H_3PO_4

2nd dissociation of H_3PO_4

3rd dissociation of H_3PO_4

Fill in the appropriate equations!!!

REACTIONS OF ACIDS WITH METALS AND BASES

1. $\text{Acid} + \text{Metal} \rightarrow \text{Salt} + H_2$

2. $\text{Acid} + \text{metal oxide/ hydroxide} \rightarrow \text{Salt} + H_2O$

3. $\text{Acid} + \text{Metal carbonate / hydrogencarbonate} \rightarrow \text{Salt} + H_2O + CO_2$

Note – these must be learned off by heart!

WRITE AND BALANCE THE FOLLOWING EQUATIONS

(a) Sulphuric acid + sodium
(b) Nitric acid + potassium hydroxide
(c) Hydrochloric acid + magnesium hydrogen carbonate
(d) Nitric acid + aluminium oxide
(e) Sulphuric acid + aluminium carbonate

NEUTRALISATION REACTION

Alkalis react with acids to produce a salt and water; this is called a neutralisation reaction. The H^+ from the acid reacts with the OH^- from the alkali to form H_2O which is neutral.

SALTS

Defn - A salt is formed when the H^+ of the acid is replaced by a metal ion or NH_4^+ (ammonium ion).

The non-metal part of a salt is called a radical or complex ion.

'STRONG' AND' WEAK'

We have already learned that when acids are placed in solution they dissociate into their ions. When some acids are placed in solution **ALL of the molecules will dissociate**. However when other acids are placed in solution only **SOME of the molecules will dissociate**, the remaining molecules will remain undissociated. **The degree to which acids dissociate is referred to as the 'strength' of the acid.**

You will not be able to identify the strength of an acid or base by looking at it, you must familiarise yourself with the ones on your course as you meet them.

STRONG ACID

Defn –a strong acid is a good proton donor. All the molecules dissociate in solution.

i.e. all the acid molecules split up into hydrogen ions and anions.

Strong acids are good proton donors.

Examples: HCl, HNO_3, H_2SO_4. These acids fully ionise in solution. This is not evident from the equation and must be memorised.

A strong acid has a weak conjugate base.

WEAK ACID

Defn - is an acid is a poor proton donor and only some of the molecules dissociate in solution

i.e. only some of the molecules split up into hydrogen ions and anions.

Weak acids are poor proton donors.

Examples: CH_3COOH (ethanoic acid). In a dilute solution only about one molecule of ethanoic acid in a hundred splits into ions. This is not evident from the equation.

A weak acid has a strong conjugate base

A ***STRONG BASE*** is a good ***acceptor*** of protons and a ***WEAK BASE*** is a poor ***acceptor*** of protons.

Household examples of acids and bases.

1. Ethanoic acid in vinegar
2. Citric acid in citrus fruits such as oranges and lemons.
3. Carbonic acid in fizzy drinks.
4. Ammonia solution in cleaning agents. Ammonia is very caustic and will burn through the dirt.
5. Magnesium hydroxide in indigestion remedies i.e. Milk of Magnesia
6. Zinc oxide in skin creams.

WORK SHEET

1. (i) Sulfuric acid is a strong, dibasic acid. Explain the underlined terms.
   (ii) The equation for the first dissociation of sulfuric acid in aqueous solution is

   $$H_2SO_4 + H_2O \rightarrow HSO_4^- + H_3O^+$$

   Indicate the conjugate pairs in the equation. Show, by means of an equation, that the conjugate base of sulfuric acid can act as an acid in aqueous solution. (LCH 2000).

2. Define (i) acid, (ii) conjugate pair, in the Bronsted-Lowry theory of acids and bases. Identify the species acting as acids and also the conjugate pairs in the following acid-base reaction. (LCH 1996)

   $$H_2O + CH_3NH_2 \rightarrow CH_3NH_3^+ + OH^-$$

3. What is (a) the conjugate acid of the sulfate ion, (b) the conjugate base of nitric acid? (LCH 1997).

4. What is the conjugate acid of (a) HS^-, and (b) SO_3^{2-}? (LCH 1996)

5. Explain the terms (a) monobasic acid, (b) conjugate acid-base pair in the Bronsted-Lowry theory. Write an equation for the reaction that takes place between a strong monobasic acid (HA) and water. Write also an equation for the reaction that takes place when a weak monobasic acid (HX) accepts a proton from the strong monobasic acid (HA). Identify the conjugate pairs in the reaction between the two acids. (LCH 1995).

LEAVING CERT 2003

Define (i) *an acid*, (ii) *a base* according to the Bronsted-Lowry theory.(8)
Identify the *acid*, and *conjugate acid* in the following system.

$$H_2S + O^{2-} \rightarrow OH^- + SH^- \text{ (6)}$$

LEAVING CERT 2004

Write (i) the conjugate acid and (ii) the conjugate base of HPO_4^{2-}. **(6)**

LEAVING CERT 2005 Q8.

(a) Define (i) acid, (ii) base, according to the Bronsted-Lowry theory. (8)
(b) Identify one species acting as an acid, and also identify its conjugate base in the following system.

$$H_2F^+ + Cl^- \rightleftharpoons HCl + HF$$

LEAVING CERT 2007

Define (i) acid, (ii) conjugate pair, according to the Bronsted-Lowry theory. (8)

Identify the two conjugate pairs in the following dissociation of nitrous acid (HNO_2):

$$HNO_2 + H_2O \rightleftharpoons NO_2^- + H_3O^+ \qquad (6)$$

Distinguish between a strong acid and a weak acid. (6)

LEAVING CERT 2008

Not on the paper!

LEAVING CERT 2009
Define a conjugate pair according to the Brønsted-Lowry theory.

LEAVING CERT 2010
Define (i) acid, (ii) conjugate acid, according to the Bronsted-Lowry theory. (8)

In acting as an acid-base indicator methyl orange behaves like a weak acid. Letting HX represent methyl orange, it dissociates as follows:

$$HX \rightleftharpoons H^+ + X^-$$

In aqueous solution, the undissociated form (HX) is red and the dissociated form (X^-) is yellow. Distinguish between a strong and a weak acid. (6)

What is the conjugate base of HX. (3)

LEAVING CERT 2011
Sulfuric acid is a strong dibasic acid. The formula **HA** represents a weak monobasic acid.

(*a*) How do strong acids differ from weak acids in their behaviour in water according to

(*i*) the Arrhenius theory, (*ii*) the Brønsted-Lowry theory? (12)

(*b*) What is the conjugate base of (*i*) sulfuric acid, (*ii*) the weak acid **HA**?

Which of these conjugate bases is the stronger? Explain. (12)

(*c*) Explain, by giving a balanced equation for its dissociation in water, that the conjugate base of

sulfuric acid is itself an acid. (6)

LEAVING CERT 2012
Define *an acid* in terms of the Brønsted-Lowry theory.

What is a *conjugate pair*? (7)

LEAVING CERT 2013
Define a base according to (*i*) the Arrhenius theory, (*ii*) the Brønsted-Lowry theory. (7)

Give (*i*) the conjugate acid, (*ii*) the conjugate base, of $\mathbf{HPO_4^{2-}}$.

LEAVING CERT 2014

Distinguish between a *strong acid* and a *weak acid* according to the Brønsted-Lowry theory. (6)

LEAVING CERT 2015

Define *acid* according to the theory of (*i*) Arrhenius, (*ii*) Brønsted-Lowry. (6)

2016 LEAVING CERT

Distinguish between a strong acid and a weak acid. (6)

LEAVING CERT 2018

What is the Arrhenius definition of a base?

Why is **NH_3** considered to be a base according to Brønsted-Lowry theory? (6)

LEAVING CERT 2019

Use equations to show that, when dissolved in water,

(*i*) **HCl** acts as a Brønsted-Lowry acid,

(*ii*) **NH_3** acts as a Brønsted-Lowry base.

Explain why

(*iii*) **HCl** has a weak conjugate base,

(*iv*) **NH_3** has a strong conjugate acid. (12)

LEAVING CERT 2022

What is the conjugate base of CH3COOH?

LEAVING CERT 2023

Sulfuric acid is a strong dibasic acid; chloric(I) acid (HOCl) is a weak monobasic acid.

(i) Define an acid according to the Brønsted-Lowry theory.

(ii) What is a strong acid?

(iii) Identify the conjugate base of HOCl.

(iv) Identify the conjugate acid of HSO_4^-. (12)

LEAVING CERT 2024

(i) Explain why ammonia (NH_3) is considered to be a base according to the Brønsted-Lowry theory but is not considered to be a base according to the Arrhenius theory.