ACIDS and BASES

LESSON 7

ACID - BASE PROPERTIES OF IONIC SALTS (HYDROLYSIS) :

✯ We are often left with salts at the end of an acid - base neutralisation. One would expect the solution to be neutral, but this is not always the case.

✯ Some ions react with H^+ or OH^- from the ***autoionisation*** of H_2O creating an imbalance in their amounts and hence making the solution acidic or basic.

Neutralisation

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

acid + base → aqueous salt + water

* $NaCH_3COO_{(aq)} \rightleftharpoons Na^+_{(aq)} + CH_3COO^-_{(aq)}$ one line hydrolysis

* CH_3COO^- ion will react with H^+ ion and cause an imbalance in the water ionisation. It is said therefore to have an "***affinity***" for H^+ ion.

Competing equilibrium diagram.

$\therefore$

$$\begin{array}{ccccc} & & CH_3COO^- & & \\ & & + & & \\ H_2O & \rightleftharpoons & H^+ & + & OH^- \\ & & \Downarrow & & \\ & & CH_3COOH & & \end{array}$$

* The amount of H^+ ion in solution is reduced and thus there is now more OH^- ions than H^+ and so the solution is ***basic***.

✯ To determine whether or not an aqueous ion has an ***affinity*** for H^+ or OH^- we need to consider where they come from in terms of the strong or weak acids and bases that we know.

ANIONS OF MONOPROTIC STRONG ACIDS :

$HCl \rightarrow H^+ + Cl^-$

Here there is ***no affinity*** as the reaction proceeds all the way to the right. (The $H^+ + Cl^-$ do not get back together again!)

$\therefore$ Cl^- will not interfere with the H_2O ionisation.

NB: Anions of monoprotic strong acids are **neither acids nor bases**!

CATIONS OF STRONG BASE

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

Here there is ***no affinity*** for the reaction

$\therefore$ Na^+ will not interfere wit the H_2O ionisation.

NB: Anions of monoprotic st ong bases are neither acids nor bases!

Question: Will an aqueous solu tion of NaCl be acidic, basic or neutral? Explain your answer.

ANIONS OF MONOPROTIC WEAK ACIDS :

$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$

High affinity as acetic acid is a weak electrolyte. The left hand side of the equation is heavily favoured hence the H^+ and the CH_3COO^- must get back together!

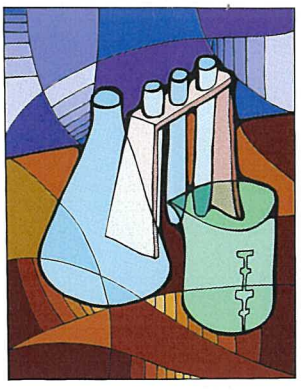
$\therefore$ CH_3COO^- will interfere with the H_2O ionisation.

$$H_2O \rightleftharpoons \begin{matrix} CH_3COO^- \\ + \\ H^+ \\ \Downarrow \\ CH_3COOH \end{matrix} + OH^- \quad or \quad CH_3COO^- + H_2O \rightleftharpoons CH_3COOH + OH^-$$

Hydrolysis

★ H^+ decreases and OH^- is in excess, so the CH_3COO^- ion is **BASIC** in solution.

NB: Anions of ***monoprotic weak acids*** are basic! The weaker the acid the more basic, as it has greater affinity.



CATIONS OF WEAK BASES :

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

High affinity as the reaction favors the left as NH_3 is a **weak electrolyte**.

$\therefore$ NH_4^+ will interfere with the H_2O ionisation.

$H_2O \rightleftharpoons H^+ + OH^-$ (NH_4^+ + OH^- → $NH_3 + H_2O$) *or* $NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$ ($H_2O + H^+$)

Hydrolysis

★ OH^- decreases and H^+ is in excess, so the NH_4^+ ion is acidic in solution.

NB: Anions of weak bases are ACIDIC ! The weaker the base the more acidic.

ANIONS → 1ST IONISATION OF DIPROTIC ACIDS :

$H_2SO_4 \rightarrow H^+ + HSO_4^-$

Here there is ***no affinity*** as the reaction unidirectional.

$\therefore$ HSO_4^- will not interfere with the H_2O ionisation:

$\therefore$ HSO_4^- = **NEUTRAL** (seemingly)

NB: $HSO_4^- \rightarrow H^+ + SO_4^{2-}$ $\therefore$ Slightly **ACIDIC** !

ANIONS → 2ND IONISATION OF DIPROTIC ACIDS :

$HSO_4^- \overset{10\%}{\rightleftharpoons} H^+ + SO_4^{2-}$

High affinity as the reaction favors the left.

$\therefore$ SO_4^{2-} will interfere with the H_2O ionisation, and is slightly **BASIC** !

$Na_2CO_3 \rightleftharpoons CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$

basic

Exercise:

By examining the nature of the ions decide whether the following ionic salts would be acidic, basic or neutral in aqueous solution. Explain your answers with the aid of a diagram and a ***HYDROLYSIS*** reaction.

1. $NaHSO_4$

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

Slightly acidic $HSO_4^- \rightarrow H^+ + SO_4^{2-}$

Na^+ no affinity for H_2O ionisation

2. KCl

neutral $KCl \rightarrow K^+ + Cl^-$

come from strong base / acid e.g. KOH & HCl.

3. $NaCH_3COO$

Slightly basic $CH_3COO^- + H^+ \rightarrow CH_3COOH$

Na^+.

4. NH_4Cl

Slightly acidic $NH_4^+ \rightleftharpoons NH_3 + H^+$

5. Na_2SO_4

$SO_4^{2-} + H_2O \rightleftharpoons HSO_4^- + OH^-$

strong base

basic $Na_2SO_4 \rightleftharpoons SO_4^{2-}$ from strong acid

6. $NH_3^+CH_2COO^-$ *(hard)*

$NH_2CH_2COO^- \rightleftharpoons NH_3^+CH_2COO^- \rightleftharpoons NH_3^+CH_2COOH$

$+H_2O$ (buffer) OH^- H^+

Zwitterion.

7. $FeCl_3$

acidic $Fe^{III} + H_2O \rightleftharpoons Fe(OH)_3 + 3H^+$

Precipitate

8. K_2CO_3 $CO_3^{2-} + H_2O \rightleftharpoons HCO_3^- + OH^-$ basic

1. Explain why the salt of a strong acid and a strong base yields a neutral solution.

Both strong acids and strong bases produce ions in a complete, irreversable manner in water.

2. Explain why the salt of a strong acid and a weak base yields an acidic solution.

	Colour of universal indicator	pH	Acidic/ basic/ neutral	Equation to explain if solution is acidic or basic
Sodium chloride(aq)	Green	7	Neutral	
Potassium chloride(aq)	Green	7	Neutral	
Ammonium chloride(aq)	Yellow	6	Acidic	$NH_{4(aq)}^{+} + H_2O_{(l)} \rightleftarrows NH_{3(aq)} + H_3O_{(aq)}^{+}$
Calcium chloride(aq)	Green	7	Neutral	
Iron (III) chloride(aq)	Red	1	Acidic	$Fe_{(aq)}^{3+} + H_2O_{(l)} \rightleftarrows Fe(OH_2)_{(s)} + 3H_{(aq)}^{+}$
Sodium carbonate(aq)	Purple	11	Basic	$CO_{3(aq)}^{2-} + 2H_2O_{(l)} \rightleftarrows H_2CO_{3(aq)} + 2OH_{(aq)}^{-}$
Sodium ethanoate(aq)	Pale green	8	Basic	$CH_3COO_{(aq)}^{-} + H_2O_{(l)} \rightleftarrows CH_3COOH_{(aq)} + OH_{(aq)}^{-}$
Sodium hydrogencarbonate(aq)	Dark green	9	Basic	$HCO_{3(aq)}^{-} + H_2O_{(l)} \rightleftarrows H_2CO_{3(aq)} + OH_{(aq)}^{-}$
Sodium sulfate (aq)	Green	7	Neutral	
Sodium hydrogen sulfate (aq)	Red	1	Acidic	$HSO_{4(aq)}^{+} + H_2O_{(l)} \rightleftarrows SO_{4(aq)}^{2-} + H_3O_{(aq)}^{+}$
Sodium sulfite(aq)	Dark green	9	Basic	$SO_{3(aq)}^{2-} + H_2O_{(l)} \rightleftarrows HSO_{3(aq)}^{-} + OH_{(aq)}^{-}$
Sodium sulfide(aq)	Purple	11	Basic	$S_{(aq)}^{2-} + 2H_2O_{(l)} \rightleftarrows H_2S_{(aq)} + 2OH_{(aq)}^{-}$
Iron(II) sulfate(aq)	Red	1	Acidic	$Fe_{(aq)}^{3+} + 3H_2O_{(l)} \rightleftarrows Fe(OH_3)_{(s)} + 3H_{(aq)}^{+}$
Sodium oxalate(aq)	Pale green	8	Basic	$C_2O_{4(aq)}^{2-} + 2H_2O_{(l)} \rightleftarrows H_2C_2O_{4(aq)} + 2OH_{(aq)}^{-}$
Ammonium sulfate(aq)	Yellow	6	Acidic	$NH_{4(aq)}^{+} + H_2O_{(l)} \rightleftarrows NH_{3(aq)} + H_3O_{(aq)}^{+}$
Aluminium sulfate(aq)	Red	1	Acidic	$Al_{(aq)}^{3+} + 3H_2O_{(l)} \rightleftarrows Al(OH)_{3(s)} + 3H_{(aq)}^{+}$
Aluminium chloride(aq)	Red	1	Acidic	$Al_{(aq)}^{3+} + 3H_2O_{(l)} \rightleftarrows Al(OH)_{3(s)} + 3H_{(aq)}^{+}$