SCH 4U

PROPERTIES OF ACIDS & BASES

PROPERTY	ACIDS	BASES
Taste	Sour	Bitter
Feel	No characteristic feel	Slippery
Phenolphthalein	Colourless	Pink
Litmus paper	Turns blue litmus red	Turns red litmus blue
Reaction with $Mg_{(s)}$	H_2 gas releases	No reaction
Reaction with $NaHCO_3$	CO_2 releases	No reaction
Formation	$NM\text{-}O_x + H_2O \rightarrow$ acids	$M\text{-}O_x + H_2O \rightarrow$ bases
Neutralization	acid + base → salt + water	base + acid → salt + water

PART 1: ACID/BASE THEORIES

① ARRHENIUS THEORY (1887)

ACID -- substance that dissociates in water to form H^+ ions.

EG. $HCl_{(aq)} \longrightarrow H^+_{(aq)} + Cl^-_{(aq)}$

EG. $H_2SO_{4(aq)} \longrightarrow H^+_{(aq)} + HSO_4^-{}_{(aq)}$

BASE -- substance that dissociates in water to form OH^- ions.

EG. $NaOH_{(aq)} \longrightarrow Na^+_{(aq)} + OH^-_{(aq)}$

... Explains neutralization:

EG. $HCl_{(aq)} + NaOH_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$ $\Delta H = -56$ kJ

Total Ionic Equation: $H^+_{(aq)} + Cl^-_{(aq)} + Na^+_{(aq)} + OH^-_{(aq)} \longrightarrow Na^+_{(aq)} + Cl^-_{(aq)} + H_2O_{(l)}$ $\Delta H = -56$ kJ

Net Ionic Equation: $H^+_{(aq)} + OH^-_{(aq)} \longrightarrow H_2O_{(l)}$ $\Delta H = -56$ kJ

<u>Limitations of Arrhenius Theory</u>:

- $H^+_{(aq)}$ (bare proton) does not exist-- instead $H^+_{(aq)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)}$ hydronium ion
- NH_3 is a base, but does not dissolve to form OH^-.
- NH_3 neutralizes acids
- many salt solutions are basic
- some neutralizations required no water -- $NH_{3(g)} + HCl_{(g)} \rightarrow NH_4Cl_{(s)}$

② BRONSTED-LOWRY THEORY (1923)

- acid/base reaction is actually chemical equilibrium with $\rightleftharpoons$
- involves transfer of a proton
- acid -- substance from which proton can be removed ("proton donor")
- base -- substance that can accept a proton ("proton receiver")

... Explains limitations of Arrhenius.

EG. $HCl_{(aq)} + H_2O_{(l)} \rightarrow Cl^-_{(aq)} + H_3O^+_{(aq)}$

H^+ transfer

EG. $NH_{3(g)} + H_2O_{(l)} \rightleftharpoons$

EG. $NH_{3(aq)} + HCl_{(aq)} \rightarrow$

CONJUGATE ACID-BASE PAIRS

- differ by one proton (H^+)
- involves weak acids or bases dissociating -- equilibrium reactions

EG. Identify the conjugate acid/base pairs.

1. $CH_3COOH_{(aq)} + H_2O_{(l)} \rightleftharpoons CH_3COO^-_{(aq)} + H_3O^+_{(aq)}$

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

EG. What is the conjugate acid of the base HCO_3^-?

EG. What is the conjugate base of the acid $H_2PO_4^-$?

EG. Complete and identify the conj. acid-base pairs if only one proton is transferred

i) phosphoric acid and ammonia

ii) carbonate ion and sulfuric acid

AMPHOTERIC SUBSTANCES:

- Substances that be either acids or bases depending on the other substance present.

EG. H_2O is a common example of an amphoteric substance, as shown in the following:

$HCl_{(aq)}$ +	H_2O	$\longrightarrow$	$H_3O^+_{(aq)}$ +	$Cl^-_{(aq)}$
acid	base		acid	base

$NH_{3(aq)}$ +	H_2O	$\longrightarrow$	$NH_4^+{}_{(aq)}$ +	$OH^-_{(aq)}$
base	acid		acid	base

PART 2: STRENGTHS OF ACIDS & BASES

STRONG ACIDS

- **BINARY** -- $HX_{(aq)}$ where X = Cl, Br, I
  (all other binary acids are weak)

electronegativity ↑
acid strength ↑
⟶

-- as one moves to the right along a period of the periodic table, the increasing strength of the EN of the non-metal draws electrons away from H, making it δ^+

-- the δ^- of H_2O then attracts and pulls away H^+

-- as one moves down a group of the periodic table, the attraction between H and non-metal decreases due to larger radius, therefore it is easier to pull H^+ away.

↓ **acid strength ↑**
as bond strength ↓

- **OXOACIDS** -- $(\#\ Oxygens) - (\#\ dissociable\ H) \ \geq\ 2$

EG.	H_2SO_4	4 - 2 = 2	-- strong acid
EG.	H_2SO_3	3 - 2 = 1	-- weak acid
EG.	CH_3COOH	2 - 1 = 1	-- weak acid

-- only H's attached to O's dissociate

-- oxygen more EN than hydrogen

-- as # of O's increase, electron density around hydrogen decreases (greater polarity of H – O bond), therefore H^+ is more easily pulled away by water.

EG. HClO $HClO_2$ $HClO_3$ $HClO_4$

weakest acid ⟶ strongest acid

POLYPROTIC ACIDS

- more than 1 H^+ can be removed.
- $HNO_{3(aq)}$ is monoprotic (only 1 H^+ removed)
- $H_2CO_{3(aq)}$ is diprotic (2 H^+ can be removed)

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

$HCO_3^-{}_{(aq)} + H_2O_{(l)} \rightleftharpoons CO_3^{-2}{}_{(aq)} + H_3O^+{}_{(aq)}$

weaker

-- harder to remove H^+ from already negative ion

STRONG BASES

- all 1A **HYDROXIDES** -- such as NaOH and KOH
- all 2A **HYDROXIDES**, except Be -- such as $Ca(OH)_2$ and $Ba(OH)_2$

-- reason for Be -- small atom, so with O, it is hard to break strong bond.

- all 1A **OXIDES** -- such as Na_2O and K_2O
- all 2A **OXIDES**, except Be -- such as CaO and BaO

EG. $CaO_{(aq)} \longrightarrow Ca^{+2}{}_{(aq)} + O^{-2}{}_{(aq)}$

$O^{-2}{}_{(aq)} + H_2O_{(l)} \longrightarrow 2OH^-{}_{(aq)}$

In general,

- Equilibrium systems involving Bronsted acids & bases favour the weaker species.
- Stronger acids and bases tend to react with each other to produce weaker conjugates.
- The stronger the acid, the weaker its conjugate base.
- The weaker the acid, the stronger its conjugate base.

EG. Describe the following equilibrium system:

$$CH_3COOH_{(aq)} + H_2O \rightleftharpoons CH_3COO^-{}_{(aq)} + H_3O^+{}_{(aq)}$$

PART 3: CALCULATIONS WITH STRONG ACIDS & BASES

1. What is the $[H_3O^+]$ of 0.035 mol/L $HNO_{3(aq)}$?

2. What is the $[OH^-]$ of 0.45 mol/L $Ba(OH)_2$?

DILUTING SOLUTIONS: $c_1v_1 = c_2v_2$

3. What is the $[OH^-]$ of 15.0 mL of 2.50 mol/L NaOH diluted to 75.0 mL?

MIXING ACIDS & BASES UNEVENLY

1. Balance chemical equation.

2. moles of each acid and base (H^+ and OH^-)

3. determine the LR.

4. $moles\ ER - moles\ LR = amount\ of\ ER\ leftover.$

5. $[ER] = \frac{n\ ER\ leftover}{v_1+v_2}$

EG. 40.0 mL of 3.25 mol/L $HCl_{(aq)}$ is mixed with 30.0 mL of 2.50 mol/L $Ca(OH)_{2(aq)}$. Is the solution acidic or basic? What is the [ ] of the ion that causes this?