Arrhenius Theory

Svante Arrhenius (Swedish)
1880s

Acid - a substance that produces H^+(*aq*)in solution

Base - a substance that produces OH^-(*aq*) in solution

Brønsted-Lowry Theory

Johannes Brønsted (Danish)
Thomas Lowry (English)
1923

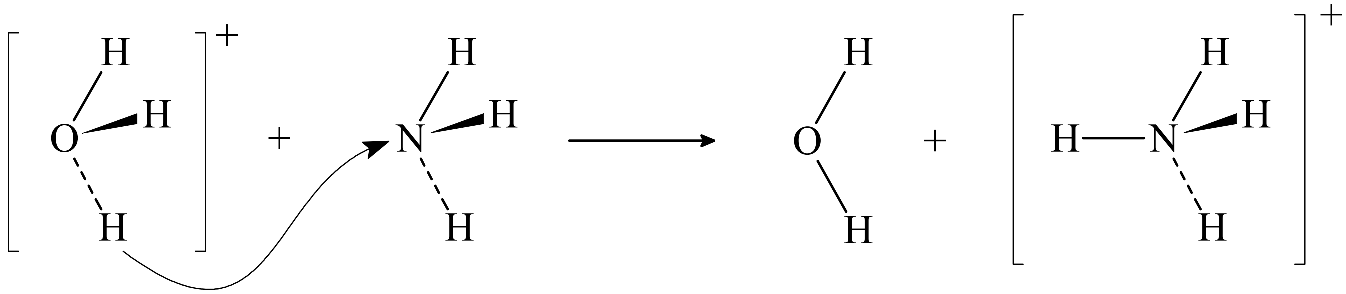
Acid - a substance that donates protons (H^+)

Base - a substance that accepts protons (H^+)

Proton Transfer Reaction

$$H_3O^+(aq) + NH_3(aq) \rightarrow H_2O(l) + NH_4^+(aq)$$

hydronium ion   ammonia   water   ammonium ion



proton donor = acid   proton acceptor = base

☞ In general terms, all acid-base reactions fit the general pattern

$$HA \quad + \quad B \quad \rightleftharpoons \quad A^- \quad + \quad HB^+$$

acid   base

Conjugate Acid-Base Pairs

☞ When an acid, HA, loses a proton it becomes its **conjugate base**, A^-, a species capable of accepting a proton in the reverse reaction.

HA	$\rightleftharpoons$	A^-	+	H^+
acid		conjugate base		

☞ When a base, B, gains a proton, it becomes its **conjugate acid**, BH^+, a species capable of donating a proton in the reverse reaction.

B	+	H^+	$\rightleftharpoons$	HB^+
base				conjugate acid

Acid-Base Reactions

☞ We can analyze Brønsted-Lowry type proton transfer reactions in terms of conjugate acid-base pairs. The generic reaction between HA and B can be viewed as

$$\begin{array}{lllllll} & & HA & \rightleftharpoons & A^- & + & H^+ \\ H^+ & + & B & \rightleftharpoons & HB^+ & & \\ \hline HA & + & B & \rightleftharpoons & A^- & + & HB^+ \\ \text{acid}_1 & & \text{base}_2 & & \text{base}_1 & & \text{acid}_2 \end{array}$$

- Species with the same subscripts are conjugate acid-base pairs.

Acid Hydrolysis and the Role of Solvent Water

☞ When any Brønsted-Lowry acid HA is placed in water it undergoes *hydrolysis* to produce hydronium ion, H_3O^+, and the conjugate base, A^-, according to the equilibrium:

HA	+	H_2O	⇌	A^-	+	H_3O^+
$acid_1$		$base_2$		$base_1$		$acid_2$

- The acid HA transfers a proton to H_2O, acting as a base, thereby forming the conjugates A^- and H_3O^+, respectively.

- The position of this equilibrium indicates the strength of the acid.

HCl	+	H_2O	⇌	Cl^-	+	H_3O^+
$acid_1$		$base_2$		$base_1$		$acid_2$

Equilibrium lies right. ⇒ HCl is a strong acid.

HOAc	+	H_2O	⇌	OAc^-	+	H_3O^+
$acid_1$		$base_2$		$base_1$		$acid_2$

Equilibrium lies left. ⇒ HOAc is a weak acid.

Base Hydrolysis and the Role of Solvent Water

☞ Hydrolysis of a base also involves water as an active participant, functioning as an acid.

B	+	H_2O	⇌	HB^+	+	OH^-
base_1		acid_2		acid_1		base_2

- H_2O acts as the acid, transferring a proton to B, thereby forming the conjugates OH^- and HB^+, respectively.

- The position of this equilibrium indicates the strength of the base.

O^{2-}	+	H_2O	⇌	OH^-	+	OH^-
base_1		acid_2		acid_1		base_2

Equilibrium lies right. ⇒ O^{2-} is a strong base.

NH_3	+	H_2O	⇌	NH_4^+	+	OH^-
base_1		acid_2		acid_1		base_2

Equilibrium lies left. ⇒ NH_3 is a weak base.

Water - An Amphiprotic Solvent

- Water can act as either a base or an acid, because it is the conjugate base of H_3O^+ and the conjugate acid of OH^-.

H_3O^+	⇌	H_2O	+	H^+→
acid		conjugate base		to a base

OH^-	+	←H^+	⇌	H_2O
base		from an acid		conjugate acid

☞ Substances such as H_2O that can act as acids or bases through proton donation or acceptance are called **amphiprotic**.

Polyprotic Acids

☞ With polyprotic acids, each acid anion is the conjugate base of the acid from which it is formed, and it is also the acid by which the next conjugate base in the sequence is formed.

H_3PO_4	+	H_2O	⇌	$H_2PO_4^-$	+	H_3O^+
$acid_1$		$base_2$		$base_1$		$acid_2$
$H_2PO_4^-$	+	H_2O	⇌	HPO_4^{2-}	+	H_3O^+
$acid_1$		$base_2$		$base_1$		$acid_2$
HPO_4^{2-}	+	H_2O	⇌	PO_4^{3-}	+	H_3O^+
$acid_1$		$base_2$		$base_1$		$acid_2$

✓ Acid anions are indicated in purple.

✓ For virtually all polyprotic acids, the species formed from successive proton losses are progressively weaker acids.

✓ Acid anions are inherently amphiprotic species.