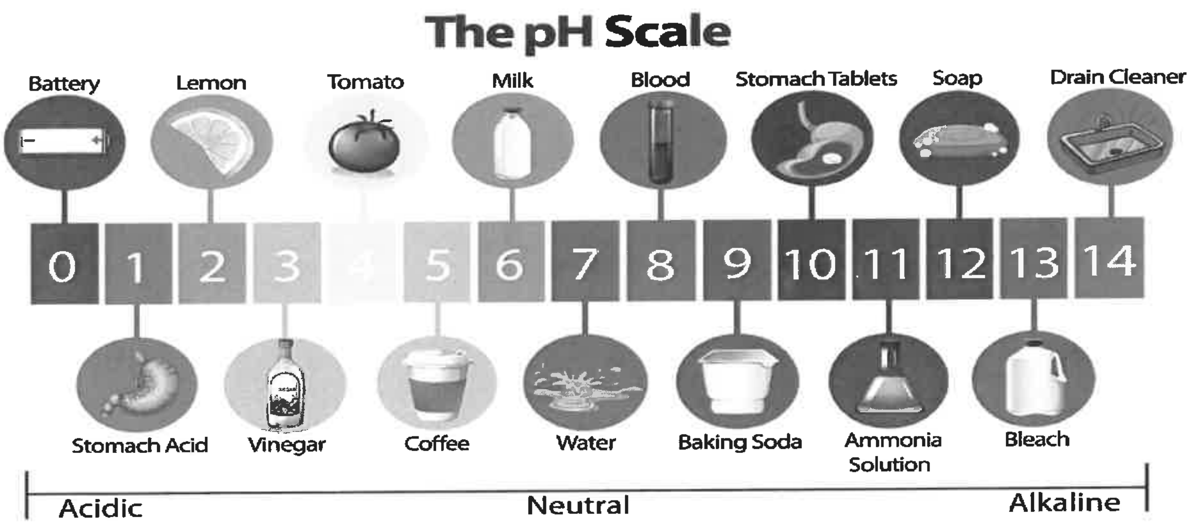
Acid-Base Basics

Solutions can be acidic, neutral, or basic as defined using the pH scale.

The pH scale measures something acidic as a pH from 0-6.9, neutral is a pH of 7.0, and basic (or alkaline) has a pH of 7.1 - 14.



Acidic solutions were traditionally thought of as anything that was sour (e.g. lemons contain citric acid, vinegar is diluted acetic acid.)

Basic solutions were characterized by their bitter taste and slippery feel (e.g. soap).

Traditional/Arrhenius Theory

- The properties of acids were due to the presence of hydrogen ions, H^+. Thus, acids were defined as compounds that produce H^+ ions in aqueous solution.

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

$$H_2SO_{4\,(aq)} \rightarrow 2\,H^+_{(aq)} + SO_4^{2-}{}_{(aq)}$$

- The properties of bases were due to the presence of hydroxide ions, OH-. Thus, bases were defined as compounds that produce OH^- ions in aqueous solution.

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

$$Mg(OH)_{2\,(s)} \rightarrow Mg^{2+}_{(aq)} + 2\,OH^-_{(aq)}$$

This theory explained a lot of acid-base chemistry but was limited because it only described one type of base – those containing the hydroxide ion.

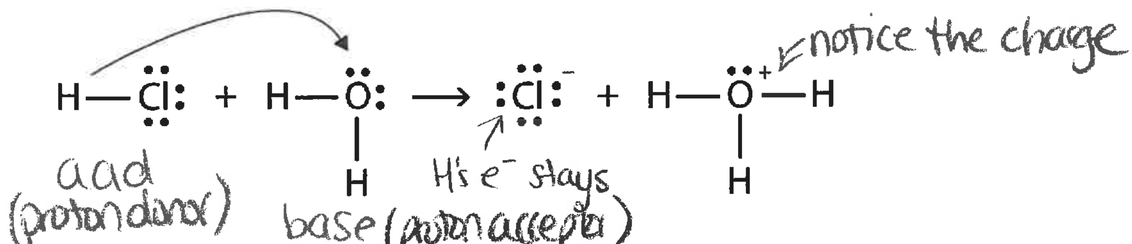
Brønsted-Lowry Theory

This theory applies to Arrhenius acids and bases, plus others – it is said to be the better explanation of acid-base chemistry.

- An acid is a proton donor while a base is proton acceptor.

(proton is H^+ (H atom that lost an e^-))

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

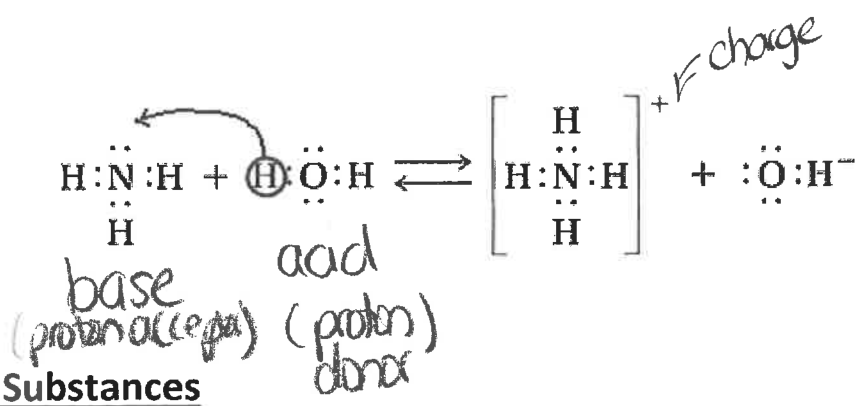


Experimental evidence suggests that sometimes the H^+ ion is not stable on its own, but rather reacts with a water molecule to form the hydronium ion, $H_3O^+_{(aq)}$.

Thus, in this reaction, hydrogen chloride is a Brønsted-Lowry acid because it donates the proton that bonds with the water molecule. Water, in this reaction, is the Brønsted-Lowry base because it accepts the proton.

Example: According to Brønsted-Lowry, identify the acid and base in the following reaction:

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



Amphiprotic Substances

Notice how water acted as a base in one reaction, and an acid in the other. Substances that be classified as a Brønsted-Lowry acid or base, depending on the reaction, are called amphiprotic.

Example: The bisulfate ion, HSO_4^-, is amphiprotic. Identify if it is acting as the Brønsted-Lowry acid or base in each of the following reactions:

H^+

$$HSO_4^-{}_{(aq)} + H_3O^+{}_{(aq)} \leftrightarrow H_2SO_{4(aq)} + H_2O_{(l)}$$

base acid

H^+

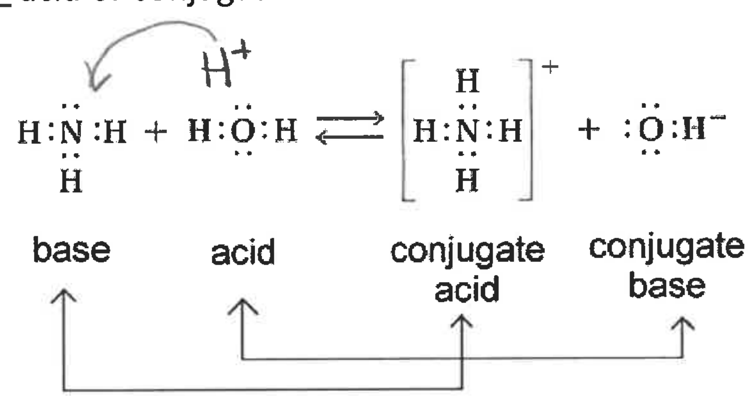
$$HSO_4^-{}_{(aq)} + OH^-{}_{(aq)} \leftrightarrow H_2O_{(l)} + SO_4^{2-}{}_{(aq)}$$

acid base

Conjugate Acid-Base Pairs

Since acid-base reactions are reversible, a proton transfer may occur in the forward reaction and also in the reverse reaction. Thus, there is a Brønsted-Lowry acid and base on each side of the equation.

When the acid and base are on the product side of the equation, they are referred to as the conjugate acid or conjugate base.



The conjugate acid is the substance that forms when a base accepts a proton.

The conjugate base is the substance that forms when an acid loses a proton.

This means that for any acid-base reaction, each acid has a conjugate base and each base has a conjugate acid.

These conjugate pairs only differ by a hydrogen ion. (or proton!)

Example: Identify the conjugate acid-base pairs in the reaction below:

H^+ →

$HNO_{2(aq)} + H_2O_{(l)} \rightleftharpoons NO_2^-{}_{(aq)} + H_3O^+{}_{(aq)}$

acid base conjugate base conjugate acid

HNO_2, NO_2^-

H_2O, H_3O^+

Example: Identify the conjugate bases for the following acids: watch charges!

H^+ ↗

(a) HCO_3^- CO_3^{-2} (b) H_2O OH^- (c) $HC_2H_3O_2$ $C_2H_3O_2^-$

Example: Identify the conjugate acids for the following bases: charges!

H^+ ↘

(a) NH_3 NH_4^+ (b) H_2O H_3O^+ (c) $HCOO^-$ $HCOOH$