<u>ACIDS AND BASES</u>
1: INTRODUCTION AND ACID BASE STRENGTH

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ACIDS BASES: PROPERTIES

Acids and bases are very common chemicals found in the lab and our daily lives. Below are some of the common properties of acids and bases.

Properties	Acids	Bases
Taste	Sour	Bitter
Sense		Slippery
Reaction	Corrosive	Caustic
pH	0-7	7-14
Chemically	Has H^+	Has OH^-
Litmus paper	Blue to red	Red to blue
<u>Examples</u>		
Inorganic Usually strong	HCl, H_2SO_4, HNO_3, H_3PO_4	$NaOH$, KOH, $Ca(OH)_2$, NH_4OH
Organic Usually weak	CH_3COOH	CH_3NH_2 and other carbon and nitrogen based compounds

ACIDS AND BASES: DEFINITIONS

Below are the three common definitions of acids and bases. We can classify a chemical as acid or base using any of these definitions.

Amphoteric substances behave like acids and bases depending on the conditions.

Definition	Acid	Base
Arrhenius	proton (H^+) donor E.g.: HCl	hydroxide (OH^-) donor E.g. : NaOH
Brønsted–Lowry	proton (H^+) donor E.g.: HCl	proton (H^+) acceptor E.g.: NH_3
Lewis	electron pair acceptor E.g.: BF_3	electron pair donor E.g.: NH_3

One thing to remember is that when acid dissociates in water, it forms H_3O^+ and does not exist as H^+.

$HCl \longrightarrow H^+ + Cl^-$ generally written dissociation.

$HCl + H_2O \longrightarrow Cl^- + H_3O^+$ in reality, these ions exist in water.

***NOTE**: All acids and ions are (aq), water is (l). I may not be writing these all the time.*

ACID BASE: REACTIONS

Typically: ACID + BASE gives SALT + WATER (for Arrhenius acid/base)

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

But Bronsted Lowry are different.

$$HCl + NH_3 \longrightarrow NH_4Cl$$ (*note: no water!*)

REACTION OCCURS IN THE DIRECTION OF WEAKER ACID-BASE

Monoprotic acids: give one proton on ionization: HCl, HNO_3.

Diprotic acid: give two protons on ionization – but one can write two ionization steps: H_2SO_4 .

$$H_2SO_4 + H_2O \longrightarrow HSO_4^- + H_3O^+ \rightleftharpoons SO_4^{2-} + H_3O^+$$

(*Note: the first ionization is easy but second is in equilibrium*).

Triprotic acid: three acidic protons: H_3PO_4, with each ionization of a proton, the 2nd one gets harder and the 3rd even more hard. (*WHY?*)

CONJUGATE ACIDS AND BASES

Substances in the acid–base reaction that differ by the gain or loss of a proton, H^+, are called a conjugate acid–base pair.

- ***Conjugate base*** – what remains of the acid after the donation of a proton
- ***Conjugate acid*** – newly formed protonated species (base)

Loses a proton

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

acid base conjugate acid conjugate base

Gains a proton

Gains a proton

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

base acid conjugate acid conjugate base

Loses a proton

Acid	Conjugate base
CH_3COOH	CH_3COO^-
H_2O	OH^-
NH_3	NH_2^-
H_2SO_4	HSO_4^-

Base	Conjugate acid
OH^-	H_2O
H_2O	H_3O^+
NH_3	NH_4^+
H_2NCONH_3	$H_2NCONH_4^+$

CONJUGATE ACID-BASE -STRENGTH

- Strong acids give weak conjugate base (SA $\longrightarrow$ Weak CB)
- Weak acids give strong conjugate bases (WA $\longrightarrow$ Strong CB)
- Strong bases give weak conjugate acid (SB $\longrightarrow$ Weak CA)
- Weak bases give strong conjugate acid (WB $\longrightarrow$ Strong CA)

For monoprotic mineral acids, the ionization/dissociation is good i.e., all protons are in solution (ionized); but for diprotic acids, the first ionization is good, but 2nd ionization becomes harder because the conjugate base that forms is weaker acid than the original acid.

$$H_2SO_4 + H_2O \longrightarrow HSO_4^- + H_3O^+ \rightleftharpoons SO_4^{2-} + H_3O^+$$

SA	weak CB	weakest CB
1st dissociation	weak acid	weaker CB
	2nd dissociation	

EXAMPLE: CONJUGATE ACID AND BASE

1) Write the conjugate acid for the following bases.

a) SO_4^{2-} b) HPO_4^{2-} c) I^-

Answer:

a) HSO_4^- b) $H_2PO_4^-$ c) HI

2) Write the conjugate base in the following acids.

a) H_2O b) NH_3 c) H_3PO_4

Answer:

a) OH^- b) NH_2^- c) $H_2PO_4^-$

3) Identify the acid/conjugate base and base/conjugate acid pair in the following reaction.

a) $\underset{\text{Acid}}{HSO_4^-} + \underset{\text{Base}}{F^-} \rightleftharpoons \underset{\text{CA}}{HF} + \underset{\text{CB}}{SO_4^{2-}}$

b) $\underset{\text{Acid}}{C_5H_5NH^+} + \underset{\text{Base}}{H_2O} \rightleftharpoons \underset{\text{CB}}{C_5H_5N} + \underset{\text{CA}}{H_3O^+}$

STRENGTH OF ACIDS AND BASES

It is important to know the strength of acids and bases so we can predict the direction of reactions.

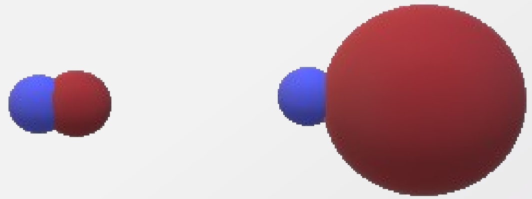
- Strong acids ionize completely; weak acids will be in equilibrium.
  1) In simple terms a strong acid will have more H^+ ions, so 2 M HCl will be stronger than 1 M HCl.
  2) Mineral acids/bases will be stronger than organic acids/bases. (see slide 2). Keep in mind that $Ca(OH)_2$ has twice more hydroxide ions than NaOH, hence will be stronger.
- Some other conditions that determine strength of acids and bases are:
  - Atomic size
  - Polar bonds (electronegativity)
  - Number of oxygen (polarity)

STRENGTH – ATOMIC SIZE

This has to do with bond strength. The better the overlap of bonds the stronger the bond – the less the H^+ will be able to ionize.

For haloacids: HF << HCl < HBr < HI

- HI bond is not strong because ionic size of iodide is too large compared to H^+, so the bond overlap is not great leading to a weaker bond which results in more protons in solution. (*See figure below, blue is the H atom*).



H-F H-I

- The same principle is used for H_2O and H_2S. H_2S is stronger because sulfur is larger in atomic size than oxygen, so bond strength is not good for H-S but good for H-O.

STRENGTH – POLAR BONDS AND OXYGEN

Polarity: The more polar the bond, the easy it is to break it.

- Comparing HCl with H_2S: HCl more acidic because H-Cl bond is more polar than H-S bond.
- Comparing HClO and HBrO: The former is stronger than the latter because Cl makes the H-O bond more polar.

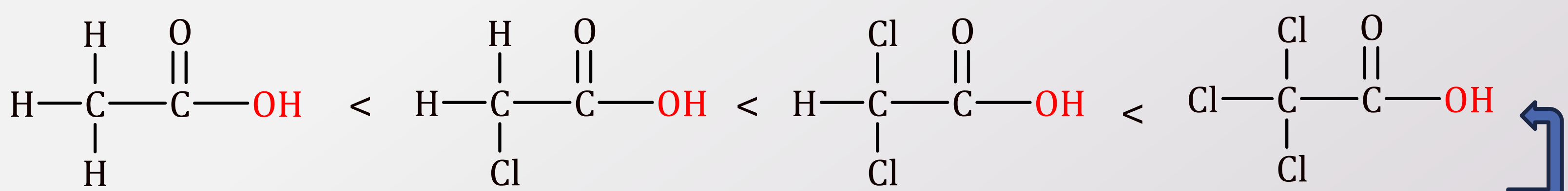
Number of Oxygen: As the number of oxygen atoms increase in an acid, the polarity increases between H and O.

- E.g. CH_3OH and CH_3COOH: the second CH_3COOH (acetic acid) is more acidic because of two oxygen atoms.
- E.g. H_2SO_4 and H_2SO_3: sulfuric acid is stronger than sulfurous because of higher number of oxygen atoms.

STRENGTH – ORGANIC ACIDS

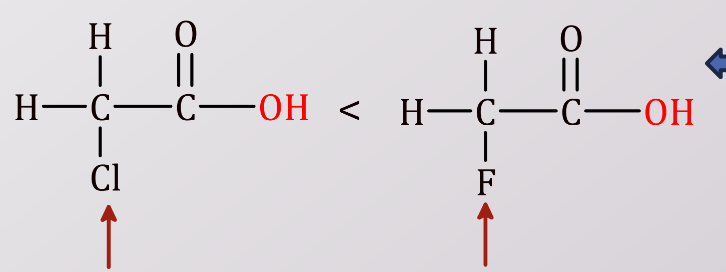
First point is that organic acids will be weaker than mineral acids. Mineral acids have more polar bonds than organic acids.

- The factor that affects strength in organic acids is substituting more electronegative atoms for hydrogens. In acetic acid, the acidic proton is the red one connected to oxygen, since that is the most polar bond. However, substituting Cl for H on the neighboring C can influences the dissociation of the acidic proton. As more electronegative groups, Cl, are added, the weaker the O-H bond becomes due to electronegativity, thus becoming a stronger acid.



Strongest acid

- When F is attached to the carbon instead of Cl, the acid becomes stronger due to polarity created by the more electronegative F.



LEWIS ACID AND BASE

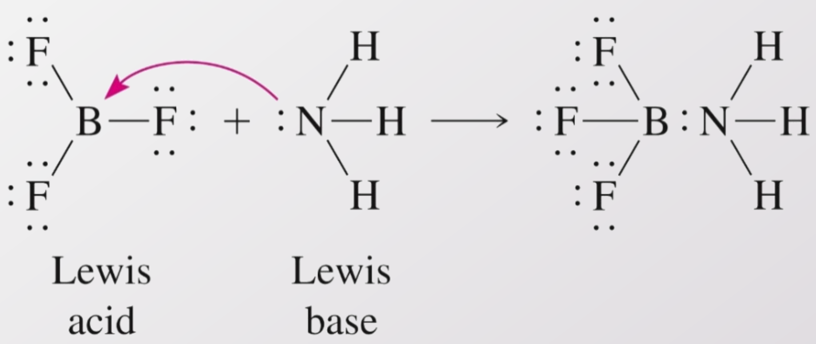
- A Lewis acid can form a covalent bond by accepting an electron pair.

  Lewis acids are identified by their lack of electrons as in a cation (Ca^{2+}, Zn^{2+}) or having incomplete valence shell (BH_3).

- A Lewis base can form a covalent bond by donating an electron pair.

  Lewis bases are identified by having extra electrons as in an anion (Cl^-) or having lone pair of electrons (CH_3OCH_3, oxygen has the lone pairs of electrons).

- A Lewis acid-base reaction is written below. Only one product is formed. No water is formed which is expected in Bronsted Lowry acid-base reactions.



FORMATION OF ACIDS AND BASES

- Acids are made from dissolving nonmetal oxides in water.
  - Example: SO_3 gives H_2SO_4, CO_2 gives H_2CO_3 etc.

$$N_2O_{5(g)} \quad + \quad H_2O_{(l)} \rightleftharpoons 2HNO_{3\,(aq)}$$

- Bases are made from dissolving metal oxides in water.
  - Example: K_2O gives KOH, MgO gives $Mg(OH)_2$ etc.

$$Na_2O_{(s)} \quad + \quad H_2O_{(l)} \longrightarrow 2NaOH_{\,(aq)}$$

- Amphoteric solutions/substances are made from metalloid oxides.
  - Example: Al_2O_3 gives $Al(OH)_3$, SnO_2 gives $Sn(OH)_2$ etc.
  - Below are reactions of aluminum hydroxide with acid and base.

$$Al(OH)_{3(s)} \quad + \quad 3H^+_{\,(aq)} \longrightarrow Al^{3+}_{\,(aq)} \quad + \quad 3H_2O_{(l)}$$

$$Al(OH)_{3(s)} \quad + \quad OH^-_{\,(aq)} \longrightarrow Al(OH)_4^-{}_{\,(aq)}$$

KEY CONCEPTS

- Properties of acids and bases
- Conjugate acids and bases
- Strength of acids and bases
- Identify different types of acids and bases
- Writing simple acid base equations
- Identifying acidic and basic oxides