Conjugate Acids and Bases

A. The heart of the Bronsted-Lowey concept of acids and bases is that acid-base reactions are proton transfer reactions.

An **acid** is a proton ***donor***.

A **base** is a proton ***acceptor***.

Example: $HCl + H_2O\ (aq) \rightarrow H_3^+O + Cl^-\ (aq)$

$\therefore$ HCl is an acid, it donates a H^+ and H_2O is a base, it accepts the H^+.

Example: $HCHO_2\ (aq) + H_2O\ (aq) \rightleftharpoons H_3^+O\ (aq) + CHO_2^-\ (aq)$

The formic acid molecule is donating a proton to a water molecule and behaves as an acid. Water accepts the proton and behaves as a base (proton acceptor).

B. The reverse reaction:

$$CHO_2^-\ (aq) + H_3^+O\ (aq) \rightarrow HCHO_2\ (aq) + H_2O\ (aq)$$

H_3^+O behaves as in acid, as it donates a proton to the CHO_2^- ion. The CHO_2^- ion behaves as a base accepting the proton. Accordingly, there are two acids and two bases in this reaction. Substances that differ from each other by a proton are referred to as a <u>conjugate acid base pair</u> (CJ Pair).

CJ Pair

$$\therefore \underset{\text{Acid}}{HCHO_2} + \underset{\text{Base}}{H_2O} \rightleftharpoons \underset{\text{Acid}}{H_3O^+} + \underset{\text{Base}}{CHO_2^-}$$

CJ Pair

C. One method of solving these problems involves identifying the acid in the left side of the equation as the other component will be the base on the left side of the equation. On the right side of this equation look for the material that has a difference of a proton from the left side. Therefore H_3^+O is a CJ acid of H_2O and CHO_2^- is conjugate base of $HCHO_2$, since it cannot provide another hydrogen for H_2O.

D. Determining the conjugate acid or conjugate base of existing compound.

<u>Question 1</u>: Find the conjugate base of HNO_3 and conjugate acid of HSO_4^-.

1. The first step is to recognize that members of any conjugate acid-base pair differ by one $H^{+.}$ The member having the greater number of hydrogen ions is the acid.

2. The second step is to recognize that the <u>conjugate *base* (CB) of an acid will have one **less** hydrogen ion</u> and that the <u>conjugate acid (CA) *of a pair* will have one **more** hydrogen ion</u>. Another option for expressing this statement is to note that the H^+ ion is positive and will involve addition while the OH^- ion is negative and will involve a subtraction of a proton. H^+ represents acid and OH^- represents base.

   HNO_3 (Subtract CB H^+ from HNO_3) $\longrightarrow$ $NO_3^- + H^+$
   Acid CB

   HSO_4^- (add H^+ to HSO_4^-) $\longrightarrow$ H_2SO_4
   Base CA

   $HNO_3 + HSO_4^- \longrightarrow NO_3^- + H_2SO_4$
   Reaction of the acid and base

3. Charges on these substances also change so that solutions remain electrically neutral.

   <u>Question 2</u>: Identify the two acids and the two bases in this reaction.

   $HCO_3^- + H_2PO_4^- \longrightarrow H_2CO_3\,(aq) + HPO_4^{-2}$

   1. Acids have more H^+ than bases:

      $H_2PO_4^-$ (acid) H_2CO_3 (acid)

      HPO_4^- (base) HCO_3^- (base)

E. Determine if a substance is amphoteric
   a. When a negative charge is associated with a compound and a hydrogen atom is available within the compound, it will always be amphoteric.
   b. If a compound has no H present within the structure, it will not be amphoteric. There is no proton (i.e. hydrogen) to donate.
   c. Otherwise, a Lewis structure must be drawn to determine if the central atom of a compound can accept a hydrogen atom. Are there unpaired electrons that can accept a hydrogen atom?
      i. If there are no unpaired electrons, then no hydrogen can be added and the material is not amphoteric.
      ii. If there are unpaired electrons, draw a Lewis structure and determine if the structure is stable and satisfies valence electron criteria.
   d. Strong acids cannot accept H^+.

Quiz: Is it amphoteric or not??

1.	$H_2PO_4^-$	Amphoteric
2.	HPO_4^-	Amphoteric, can accept and donate, check Lewis structure
3.	H_2S	Amphoteric (same structure as water)
4.	H_3PO_4	Not amphoteric, strong acid, can only donate
5.	NH_4^+	Not amphoteric, can only donate, check Lewis structure
6.	H_2O	Amphoteric, check Lewis structure
7.	HI	Not amphoteric, can only donate, check Lewis structure
8.	HNO_3	Not amphoteric, strong acid, can only donate

F. The position of an acid-base equilibrium favors weaker acids and bases. Therefore, the strongest acid-base pair is on the opposite side.

In this equation, the position of the equilibrium lies to the left. Which is the strongest acid in the system?

$$\underset{\text{base}}{NH_2OH} + \underset{\text{acid}}{CH_3NH_3^+} \longrightarrow \underset{\text{base}}{CH_3NH_2} + \underset{\text{acid}}{NH_3OH^+}$$

Answer is NH_3OH^+.