1. Write the conjugate acid of the following:

$HC_2O_4^-$ $H_2C_2O_4$

CH_3NH_2 B $CH_3NH_3^+$

2. Write the conjugate base of the following:

HNO_2 NO_2^-

HS^- S^{2-}

3. Write the Brønsted-Lowry acid-base equilibria which occur when the following are mixed in solution:

$$HPO_4^{2-} + SO_4^{2-} \rightleftharpoons PO_4^{3-} + HSO_4^{1-}$$

A B B

$$S^{2-} + HCOOH \rightleftharpoons HCOO^- + HS^-$$

B A B

Strengths of Acids and Bases

The relative strength of an acid or a base depends on how well it ionizes in water to produce ions.

- STRONG acids and bases ionize completely (100% ionized)

ex. $HCl(g) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$

$NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$

- WEAK acids and bases do not ionize completely (< 100% ionized)
- Weak acids are better represented by an equilibrium system where the conjugate acid and base pairs both exist

ex. $HF(aq) + H_2O(l) \leftrightarrows H_3O^+(aq) + F^-(aq)$

$NH_3(aq) + H_2O(l) \leftrightarrows NH_4^+(aq) + OH^-(aq)$

the terms strong or weak refer to the degree of ionization of the acid or base NOT the molar concentration

0.0010 M HCl is a STRONG acid
6.0 M HF is a WEAK acid

Refer to the Data Booklet "Relative Strengths of Acids and Bases" table.

a) STRONG ACIDS

- the strong acids are the **top six acids** on the **left side** of the table

HBr, HCl, HI, HNO_3, $HClO_4$, H_2SO_4

- all six reactions have **one-way reaction** arrows pointing to the right. This means that aqueous molecules of the acid do not exist and the **conjugate bases cannot accept a proton from water.**

$$HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$$

b) STRONG BASES

- the strong bases are the **bottom two bases** listed on the **right side** of the table

O^{2-} and NH_2^-

- once again, these two reactions have one-way reaction arrows pointing to the left. This means that aqueous molecules of the base do not exist and the **conjugate acids cannot donate a proton from water.**

$$NH_3(aq) + OH^-(aq) \leftarrow NH_2^-(aq) + H_2O(l)$$

$$NH_2^-(aq) + H_2O(l) \rightarrow NH_3(aq) + OH^-(aq)$$

- in addition to these two strong bases, **soluble metal hydroxides are also strong bases**

ex. $NaOH$, KOH, $Mg(OH)_2$, $Ca(OH)_2$, $Fe(OH)_3$, $Zn(OH)_2$

c) WEAK ACIDS

- the weak acids are the species on the **left side of the table** from HIO_3 down to H_2O
- aqueous molecules of the conjugate acid and base coexist in solution

$$HIO_3 \leftrightarrows H^+ + IO_3^-$$
$$\downarrow$$
$$H_2O \leftrightarrows H^+ + OH^-$$

- the last two species on the left, O^{2-} and NH_2^-, can not act as acid in aqueous solutions

d) WEAK BASES

- the weak bases are the species on the **right side of the table** from H_2O down to PO_4^{3-}
- aqueous molecules of the conjugate base and acid coexist in solution

$$H_3O^+ \leftrightarrows H^+ + H_2O$$
$$\downarrow$$
$$HPO_4^{2-} \leftrightarrows H^+ + PO_4^{3-}$$

- the top six species on the right, HSO_4^-, NO_3^-, Cl^-, Br^-, I^-, ClO_4^-, can not act as bases in aqueous solutions

<u>LEVELLING EFFECT</u> = all **strong acids** have **identical strengths** in water because they are **100% ionized in aqueous solutions**

Additional things to note . . .

1. Although all of the reactions are written as ionization equations, they are all occurring in aqueous solutions.

   > When a substance acts as an acid, water accepts the proton to become H_3O^+, so **all acid solutions will produce H_3O^+.**

   > When a substance acts as a base, water donates the proton to become OH^-, so **all base solutions will produce OH^-.**

2. Since **strong acids and bases** ionize completely, they will have a **higher electrical conductivity** than weak acids and bases. This property can be used to distinguish between strong and weak acids and bases.

3. The six strong acids, HBr, HCl, HI, HNO_3, $HClO_4$ and H_2SO_4, can not exist as molecules in aqueous solutions because they ionize completely to produce H_3O^+ and an anion. Hence, **H_3O^+ is the strongest acid** that can exist in aqueous solutions.

   In the same way, O^{2-} and NH_2^-, can not exist as molecules in aqueous solutions because they ionize completely to produce OH^-. Hence, **OH^- is the strongest base** that can exist in aqueous solutions.