

Acid-Base Equilibrium

- Acid-base reactions are also reversible reaction, so they have the ability to form an equilibrium
- Recall Arrhenius's modified definition of acids and bases
 - Acids are species that produce H^+/H_3O^+ ions in a reaction and have a pH lower than 7
 - Bases are species that produce OH^- ions in a reaction and have a pH higher than 7
- This definition of acids and bases is **still true and applicable**, but it is a limited.
- Bronsted and Lowry extended Arrhenius definition of an acid and base to overcome its limitations

* • **Bronsted-Lowry** definition of acids and bases:

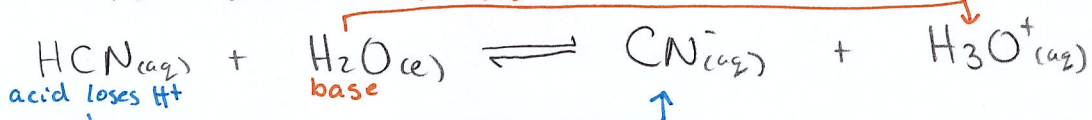
a list of common acids & bases are found on pg. 8-9 of data booklet

- An acid is a substance that produces a hydrogen ion (H^+)/hydronium ion (H_3O^+) and is therefore called a proton donor. H^+ is a proton!
- A base is a substance that can accept a hydrogen ion and is therefore also called a proton acceptor.
- In order for an acid to be able to donate a proton, there needs to be a base present to accept that proton (and vice versa). Therefore, an acid always needs a base to react with (and vice versa).
- Since most acids and bases are dissolved in water and water has the ability to accept and donate a proton, the acidic and basic properties of chemicals can be explained by a reaction with water.

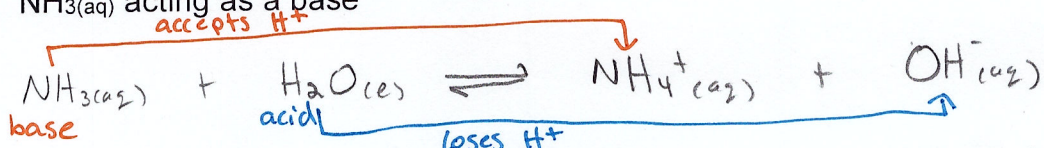
EXAMPLES:

1. Write out the acid-base reactions for

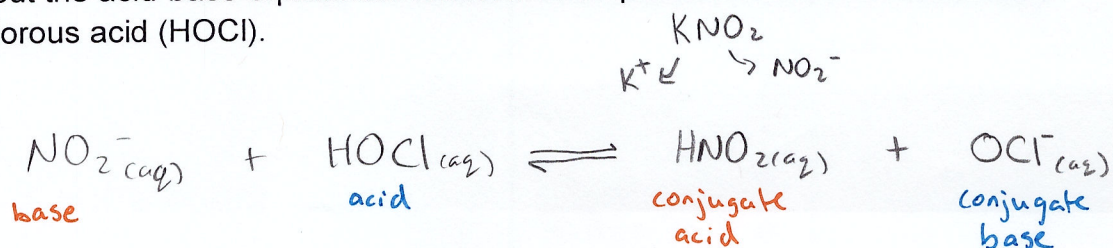
a. $HCN_{(aq)}$ acting as an acid



b. $NH_3_{(aq)}$ acting as a base



2. Write out the acid-base equilibrium reaction when potassium nitrite is mixed with hypochlorous acid (HOCl).



- When chemicals **only differ from each other by the presence or absence of a single hydrogen ion/proton**, we call the chemicals a **conjugate acid-base pair**
 - Every acid has a conjugate base and every base has a conjugate acid
 - * The actual acid/base will always be on the reactant side and the conjugate will always be on the product side

EXAMPLE: Hydrogen bromide is a gas at room temperature, but is soluble in water to form hydrobromic acid. Identify the conjugate base for hydrobromic acid. Identify the other conjugate acid-base pair that is involved in the reaction.

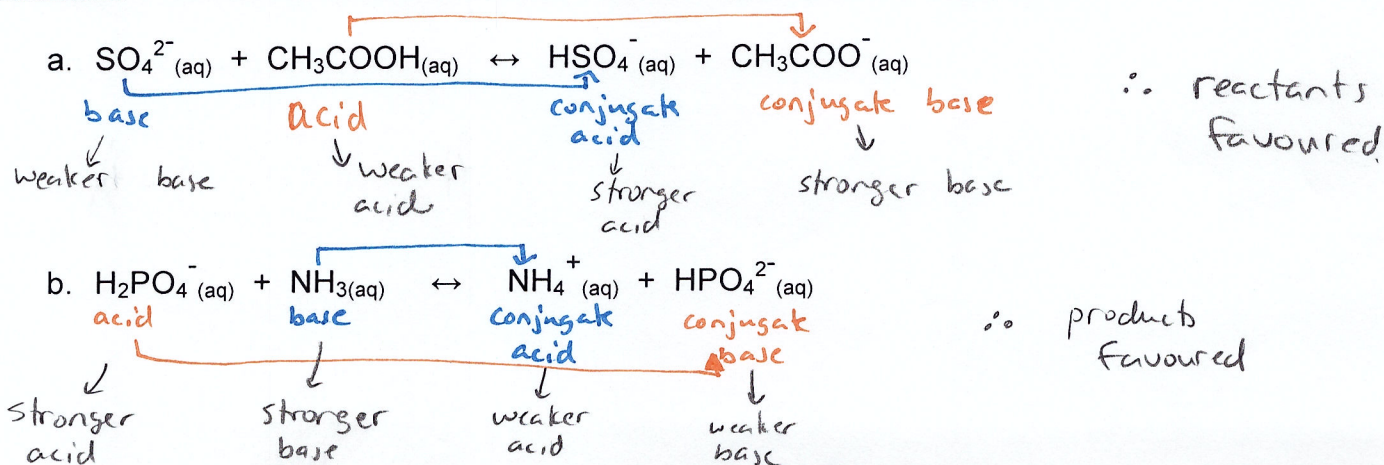


∴ $\text{Br}^{-}_{(aq)}$ is conjugate base of $\text{HBr}_{(g)}$
 $\text{H}_2\text{O}_{(l)}/\text{H}_3\text{O}^{+}_{(aq)}$ is other conjugate acid-base pair

- Acids and bases have different strengths
 - Some acids donate protons more easily (stronger acids) and some bases accept protons more easily (stronger bases)
 - Stronger acids are found at the top left hand side of the table on pg. 8-9 of data booklet and decrease in strength as you go down
 - Stronger bases are found at the bottom right hand side of the table on pg. 8-9 of data booklet and decrease as you go up
- If multiple acids and bases are present in a container, the reaction will be defined by the strongest acid reacting with the strongest base
- * In an acid-base reaction, the reaction will favour the side of the reaction that contains the weaker acid or base

larger K_a values
 smaller K_a values

EXAMPLE: Predict the direction in which the following reaction will proceed.



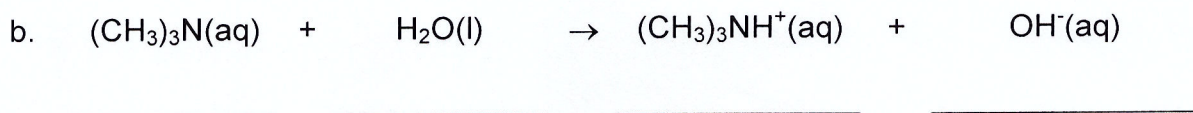
Now try pg. 687 #1, 2, 4 & pg. 690 #8 & Practice Problems

Practice Problems

1. Write the acid-base equilibrium equation for each of the following reactions. State whether the reactant or products are favoured.

- Carbonic acid is combined with ammonia (NH_3).
- Nitrous acid ($\text{HNO}_{2(\text{aq})}$).
- Sodium cyanide is dissolved in water.
- Copper (II) sulphate is dissolved in hydrofluoric acid.

2. For each of the following reactions, identify each substance as a Brønsted-Lowry acid, Brønsted-Lowry base, a conjugate acid, or conjugate base.



Solutions

1.

- a. $\text{H}_2\text{CO}_{3(\text{aq})} + \text{NH}_{3(\text{aq})} \leftrightarrow \text{HCO}_3^-_{(\text{aq})} + \text{HNH}_4^+_{(\text{aq})}$ products favoured
- b. $\text{HNO}_{2(\text{aq})} + \text{H}_2\text{O}_{(\text{l})} \leftrightarrow \text{NO}_2^-_{(\text{aq})} + \text{H}_3\text{O}^+_{(\text{aq})}$ reactants favoured
- c. $\text{CN}^-_{(\text{aq})} + \text{H}_2\text{O}_{(\text{l})} \leftrightarrow \text{HCN}_{(\text{aq})} + \text{OH}^-_{(\text{aq})}$ reactants favoured
- d. $\text{SO}_4^{2-}_{(\text{aq})} + \text{HF}_{(\text{aq})} \leftrightarrow \text{HSO}_4^-_{(\text{aq})} + \text{F}^-_{(\text{aq})}$ reactants favoured

2.

- a. $\text{NH}_4^+_{(\text{aq})} + \text{CN}^-_{(\text{aq})} \rightarrow \text{HCN}_{(\text{aq})} + \text{NH}_3_{(\text{aq})}$
- | | | | | | | |
|-------------|--|-------------|--|-----------------------|--|-----------------------|
| <u>acid</u> | | <u>base</u> | | <u>conjugate acid</u> | | <u>conjugate base</u> |
|-------------|--|-------------|--|-----------------------|--|-----------------------|
- b. $(\text{CH}_3)_3\text{N}_{(\text{aq})} + \text{H}_2\text{O}_{(\text{l})} \rightarrow (\text{CH}_3)_3\text{NH}^+_{(\text{aq})} + \text{OH}^-_{(\text{aq})}$
- | | | | | | | |
|-------------|--|-------------|--|-----------------------|--|-----------------------|
| <u>base</u> | | <u>acid</u> | | <u>conjugate acid</u> | | <u>conjugate base</u> |
|-------------|--|-------------|--|-----------------------|--|-----------------------|