Chemistry 132 NT

The best things in life aren't things

Anon

1

2

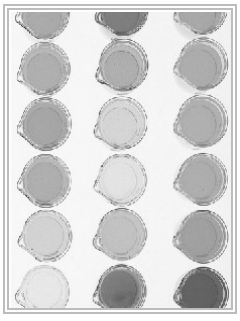
Chem 132 NT

Acids and Bases

Module 2

Acid and Base Strengths

- **Relative Strengths of Acids and Bases**
- **Molecular Structure and Acid Strength**



Acid-base indicator dye.

3

Review

- **Arrhenius Concept** Acids:
  - H+ donors
  - Bases: OH- donors
- **Bronsted-Lowry concept**
  - Acids: H+ donors
  - Bases: H+ acceptors
- **Lewis concept**
  - Acids: electron pair acceptors
  - Bases: electron pair donors

4

Relative Strength of Acids and Bases

- The Brønsted-Lowry concept introduced the idea of **conjugate acid-base pairs** and proton-transfer reactions.
  - We consider such acid base reactions to be a competition between species for hydrogen ions.
  - From this point of view, **we can order acids by their relative strength as hydrogen ion donors** .

5

Relative Strength of Acids and Bases

- The Brønsted-Lowry concept introduced the idea of **conjugate acid-base pairs** and proton-transfer reactions.
  - The stronger acids are those that lose their hydrogen ions more easily than other acids.
  - For example,

HCl **vs** $HC_2H_3O_2$

weak bond
strong acid

stronger bond
weaker acid

6

Relative Strength of Acids and Bases

- The Brønsted-Lowry concept introduced the idea of **conjugate acid-base pairs** and proton-transfer reactions.
  - Similarly, the stronger bases are those that accept hydrogen ions more readily than other bases.
  - For example,

Cl^- **vs** $C_2H_3O_2^-$

Not likely to accept proton | **Verylikely to accept proton**

7

Relative Strength of Acids and Bases

- The Brønsted-Lowry concept introduced the idea of **conjugate acid-base pairs** and proton-transfer reactions.
  - Similarly, the stronger bases are those that accept hydrogen ions more readily than other bases.
  - For example,

Cl^- **vs** $C_2H_3O_2^-$

Poor Bronsted-Lowry base | **Very good Bronsted-Lowry base**

8

Relative Strength of Acids and Bases

- The Brønsted-Lowry concept introduced the idea of **conjugate acid-base pairs** and proton-transfer reactions.
  - If an acid loses its H^+, the resulting anion is now in a position to reaccept a proton making it a Brønsted-Lowry base
  - It is logical to assume that if an acid is considered strong, its conjugate base (that is, its anion) would be weak, since it is unlikely to accept a hydrogen ion.

9

Relative Strength of Acids and Bases

- Consider the equilibrium below.

$$HC_2H_3O_2(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + C_2H_3O_2^-(aq)$$

acid base acid base

conjugate acid-base pairs

- In this system we have two opposing Brønsted-Lowry acid-base reactions.
- In this example, H_3O^+ is the stronger of the two acids, consequently the equilibrium is skewed toward reactants.

10

Relative Strength of Acids and Bases

- Consider the equilibrium below.

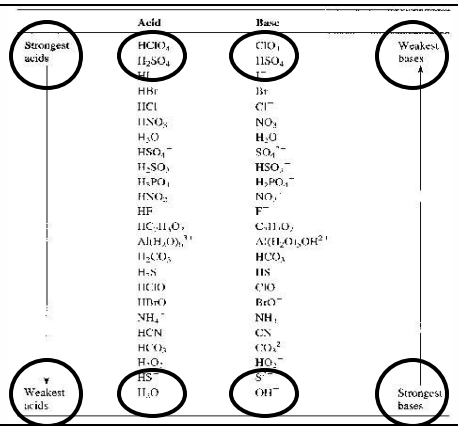
$$HC_2H_3O_2(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + C_2H_3O_2^-(aq)$$

acid base acid base

conjugate acid-base pairs

- The next slide outlines the relative strength of some common acids and their conjugate bases.
- This concept of conjugate pairs is fundamental to understanding why certain salts can act as acids or bases.

11



12

A Problem To Consider

- For the following reaction, decide which species (reactants or products) are favored at the completion of the reaction.

$$SO_4^{2-}(aq) + HCN(aq) \leftrightarrows HSO_4^-(aq) + CN^-(aq)$$

- Use the table on previous slide to compare the relative strengths of acids and bases.
- Comparing the two acids, HCN and HSO_4^-, we see that HCN is weaker.

13

A Problem To Consider

- For the following reaction, decide which species (reactants or products) are favored at the completion of the reaction.

$$SO_4^{2-}(aq) + HCN(aq) \leftrightarrows HSO_4^-(aq) + CN^-(aq)$$

weaker acid **stronger acid**

- Comparing the two acids, HCN and HSO_4^-, we see that HCN is weaker.

14

A Problem To Consider

- For the following reaction, decide which species (reactants or products) are favored at the completion of the reaction.

$$SO_4^{2-}(aq) + HCN(aq) \leftrightarrows HSO_4^-(aq) + CN^-(aq)$$

weaker base **weaker acid** **stronger acid** **stronger base**

- Or, comparing the bases SO_4^{2-} and CN^-, we see that SO_4^{2-} is weaker.

15

A Problem To Consider

- For the following reaction, decide which species (reactants or products) are favored at the completion of the reaction.

$$SO_4^{2-}(aq) + HCN(aq) \leftrightarrows HSO_4^-(aq) + CN^-(aq)$$

weaker base weaker acid stronger acid stronger base

- Hence, the reaction would normally go from right to left.
- **The reactants are favored.**

16

Molecular Structure and Acid Strength

- Two factors are important in determining the relative acid strengths.
  - One is the polarity of the bond to which the hydrogen atom is attached.
  - The H atom should have a partial positive charge:

$$\overset{d+}{H} - \overset{d-}{X}$$

  - The more polarized the bond, the more easily the proton is removed and the greater the acid strength.

17

Molecular Structure and Acid Strength

- Two factors are important in determining the relative acid strengths.
  - The second (and more influential) factor is the strength of the bond, that is, how tightly the proton is held.
  - This depends on the size of atom X.

$$H - X$$

  - The larger atom X, the weaker is the bond and the greater the acid strength.

18

Molecular Structure and Acid Strength

- We will focus on two classes of acids:
  - **Binary acids**.
    - Acids of the form H_n-X where "X" is a single atom. (e.g. HCl or H_2S)
  - **Oxoacids**
    - Acids of the form H_mYO_n (e.g. HNO_3 or H_2SO_4)

19

Molecular Structure and Acid Strength

- Consider a series of binary acids from a given column of elements.
  - As you go down the column of elements the **radius increases markedly** and the **H-X bond strength decreases**.
  - You can predict the following order of acidic strength.

$$\underset{\text{weak}}{HF} < \underset{\text{strong}}{HCl < HBr < HI}$$

20

Molecular Structure and Acid Strength

- As you go across a row of elements the **polarity** of ther H-X bond becomes the **dominant factor**.
  - As electronegativity increases going to the right, the polarity of the H-X bond increases and the acid strength increases.
  - You can predict the following order of acidic strength.

$$\underset{\text{Group V}}{H_3N} < \underset{\text{Group VI}}{H_2O} < \underset{\text{Group VII}}{\overset{\text{strong}}{HF}}$$

21

Molecular Structure and Acid Strength

- Consider the oxoacids. An oxoacid has the structure:

H - O - Y -

  - The acidic H atom is always attached to an O atom, which in turn is attached to another atom Y.
  - **Bond polarity is the dominant factor** in the relative strength of oxoacids.
  - This, in turn, depends on the **electronegativity** of the atom Y.

22

Molecular Structure and Acid Strength

- Consider the oxoacids. An oxoacid has the structure:

d^+ d^-

H - O - Y -

  - If the electronegativity of Y is large, then the O-H bond is relatively polar and the acid strength is greater.
  - You can predict the following order of acidic strength.

HOI < HOBr < HOCl

weakest **strongest**

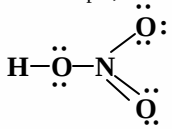
23

Molecular Structure and Acid Strength

- Consider the oxoacids. An oxoacid has the structure:

H - O - Y -

  - Other groups, such as O atoms or O-H groups may be attached to Y.
  - For example, nitric acid, HNO_3.



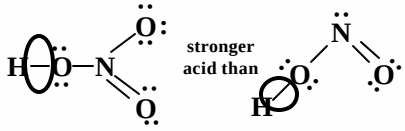
24

Molecular Structure and Acid Strength

- Consider the oxoacids. An oxoacid has the structure:

H - O - Y -

  - With each additional O atom, Y becomes effectively more electronegative increasing the polarity of the bond.



stronger acid than

25

Molecular Structure and Acid Strength

- Consider the oxoacids. An oxoacid has the structure:

H - O - Y -

  - As a result of more oxygen atoms, the H atom becomes more acidic.
  - The acid strengths of the oxoacids of chlorine increase in the following order.

$$HClO < HClO_2 < HClO_3 < HClO_4$$

weakest **strongest**

26

Molecular Structure and Acid Strength

- Consider polyprotic acids and their corresponding anions.

  - Each successive H atom becomes more difficult to remove.
  - Therefore the acid strength of a polyprotic acid and its anions decreases with increasing negative charge.

$$HPO_4^{2-} < H_2PO_4^{-} < H_3PO_4$$

weakest **strongest**

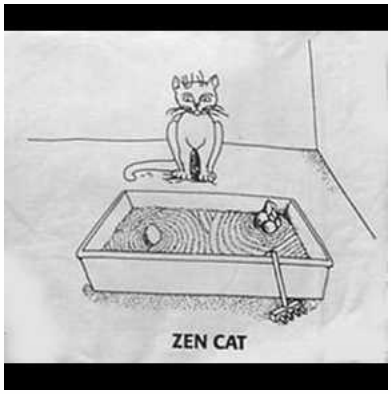
27

Operational Skills

- Deciding whether reactants or products are favored in an acid-base reaction

Time for a few review questions.

28



29