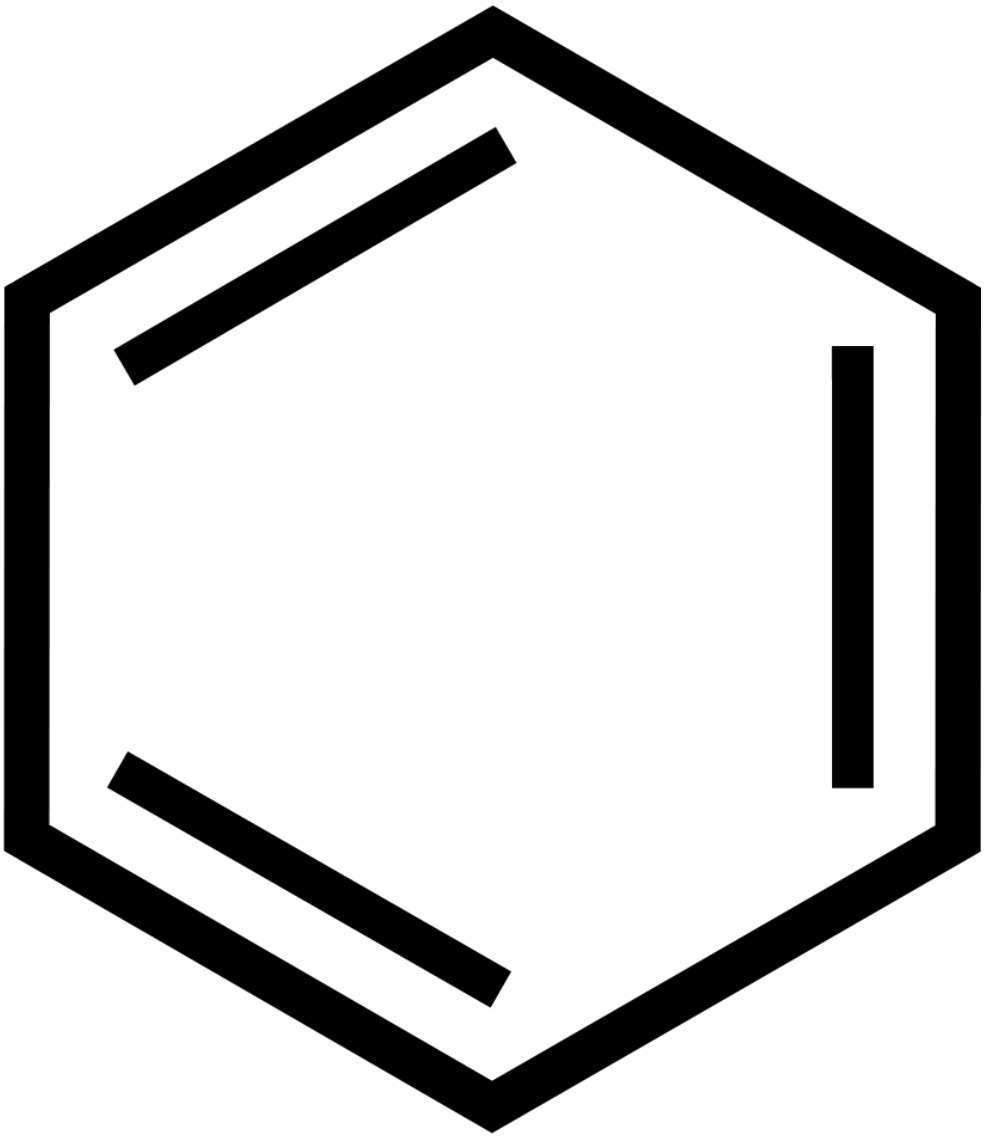

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CONCEPT: ARRHENIUS ACIDS AND BASES

The most general definition for acids and bases was developed by Svante Arrhenius near the end of the 19th century.

- According to him, the _____ cation and the _____ anion are fundamental to the concept of acids and bases.
- His definition however failed to describe acidic and basic behavior in nonaqueous media.

The Arrhenius definition states an acid is a compound that increases _____ when dissolved in a solvent.

The Arrhenius definition states a base is a compound that increases _____ when dissolved in a solvent.

EXAMPLE 1: Which ions are formed from the dissociation of the following compound?

a) H_2SO_4 (aq) $\xrightarrow{\text{Dissolves in } H_2O}$

EXAMPLE 2: Which ions are formed from the dissociation of the following compound?

a) $Ca(OH)_2$ $\xrightarrow{\text{Dissolves in } H_2O}$

CONCEPT: BRONSTED-LOWRY ACIDS AND BASES

In 1923, Johannes Brønsted and Thomas Lowry developed a new set of definitions for acids and bases.

According to the Bronsted-Lowry definition, acids are considered _____ and bases are considered _____ .

- Unlike Arrhenius acids and bases, they are not limited to aqueous solutions.
- Every Arrhenius acid is a Brønsted-Lowry acid (and likewise for the bases).
- Brønsted-Lowry acids and bases always occur in pairs called _____ .

EXAMPLE 1: Write the formula of the **conjugate base** for each of the following compounds:

HSO_3^-

EXAMPLE 2: Write the formula of the **conjugate acid** for each of the following compounds:

HPO_3^{2-}

EXAMPLE 3: Identify the acid, base, conjugate acid and conjugate base in the following reactions:

a) $HF\,(aq) + H_2O\,(aq) \rightleftharpoons F^-\,(aq) + H_3O^+\,(aq)$

CONCEPT: LEWIS ACIDS AND BASES

In the 1920s, Gilbert Lewis proposed a new set of definitions for acids and bases.

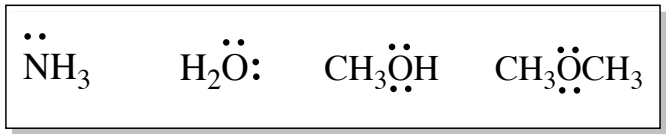
A Lewis acid is a(n) _____.

- _____ charged hydrogen or metals.

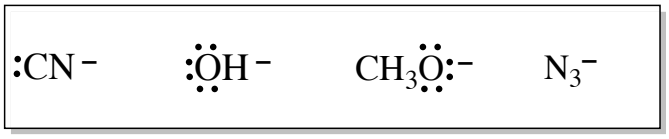
- If your central element has _____ 8 valence electrons.

A Lewis base is a(n) _____.

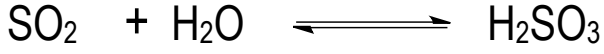
- Compounds with _____ .



- Compounds with a _____ .



EXAMPLE: Identify the Lewis acid and base in the following reaction.



CONCEPT: AUTO-IONIZATION

Water can react with itself in a reaction called ***self–ionization*** where _____ and _____ are produced.

$$H_2O\,(l) + H_2O\,(l) \rightleftharpoons$$

This reaction is usually written more simply as:

$$H_2O\,(l) \rightleftharpoons$$

The equilibrium constant for water is called the _____ (K_W) for water and is given by the following:

$$K_W = [H^+][OH^-]$$

At 25^{o}C, K_W = _____, but remember K_W, like all other equilibrium constants K, is temperature dependent.

EXAMPLE 1: At 0^{o}C, the Kw for a neutral solution is recorded as 1.2 x 10^{-15}. Based on what you've reviewed, what can be said in terms of K_w and the solution?

a) The reaction is exothermic.

b) The reaction is endothermic.

c) The reaction is thermoneutral.

d) Not enough information is given.

EXAMPLE 2: Determine the concentration of hydronium ions for pure water at 50^{o}C. K_w is 5.3 x 10^{-14}.

CONCEPT: Ka AND Kb OF COMPOUNDS

Associated with any weak acid or weak base is a K_a or K_b value respectively.

- K_a represents the _____ dissociation constant and it measures the strength of weak acids.
- K_b represents the _____ dissociation constant and it measures the strength of weak bases.

In general, the _____ the K_a the _____ the pK_a then the stronger the acid and _____ the concentration of H^+.

- Weak acids possess K_a values _____ 1, while weak bases possess K_b values _____ 1.

The equilibrium expressions of K_a and K_b are the same as other equilibrium constants you've seen.

Weak Acids: $HA\,(aq) + H_2O\,(l) \rightleftharpoons A^-\,(aq) + H_3O^+\,(aq)$ $\quad K_a = \dfrac{\text{Products}}{\text{Reactants}} = \dfrac{[A^-][H_3O^+]}{[HA]}$

Weak Bases: $A^-\,(aq) + H_2O\,(l) \rightleftharpoons HA\,(aq) + OH^-\,(aq)$ $\quad K_b = \dfrac{\text{Products}}{\text{Reactants}} = \dfrac{[HA][OH^-]}{[A^-]}$

K_a and K_b are connected by the following equation:

$$K_W = K_a \cdot K_b$$

Recall that at 25 ^oC, Kw the ion-product constant of water equals _____.

EXAMPLE: Consider two aqueous solutions of equal concentration. Which statement is true?

chlorous acid ($HClO_2$, $K_a = 1.1 \times 10^{-2}$) and phenol (HC_6H_5O, $K_a = 1.3 \times 10^{-10}$)

a) $HClO_2$ produces more $[H_3O^+]$ than HC_6H_5O

b) $HClO_2$ is basic compared with HC_6H_5O

c) $HClO_2$ produces less $[H_3O^+]$ than HC_6H_5O

d) $HClO_2$ is a strong acid

e) ClO_2^- produces more $[OH^-]$ than $C_6H_5O^-$

PRACTICE: Ka AND Kb OF COMPOUNDS CALCULATIONS 1

EXAMPLE 1: Which of the following compounds has the strongest conjugate acid?

a) $C_2H_5NH_2$ ($K_b = 5.6 \times 10^{-4}$)

b) H_2NNH_2 ($K_b = 1.3 \times 10^{-6}$)

c) NH_3 ($K_b = 1.75 \times 10^{-5}$)

d) $HONH_2$ ($K_b = 1.1 \times 10^{-8}$)

EXAMPLE 2: At 0 °C, the ion product constant of water is 1.2×10^{-15}. The pH of pure water at this temperature is:

a) 6.88

b) 7.00

c) 7.46

d) 7.56

PRACTICE: A^- is a weak base. Which equilibrium corresponds to the equilibrium constant K_a for HA?

a) $A^-(aq) + OH^-(aq) \rightleftharpoons HOA^{2-}(aq)$

b) $HA(aq) + H_2O(l) \rightleftharpoons H_2A^+(aq) + OH^-(aq)$

c) $HA(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + A^-(aq)$

d) $A^-(aq) + H_2O(l) \rightleftharpoons HA(aq) + OH^-(aq)$

e) $A^-(aq) + H_3O^+(l) \rightleftharpoons HA(aq) + H_2O(l)$

PRACTICE: WEAK ACID-BASE EQUILIBRIA CALCULATIONS 1

EXAMPLE 1: What is the original molarity of a solution of weak acid with a K_a of 4.7×10^{-3} and pH of 4.12 at 25 ºC?

EXAMPLE 2: You are seeking to identify an unknown monoprotic acid by determining its K_a value. A 6.05×10^{-2} M solution of this unknown monoprotic acid has a pH of 2.122. Determine the K_a of this unknown acid?

a) 4.47×10^{-4}

b) 9.42×10^{-4}

c) 2.85×10^{-2}

d) 1.08×10^{-3}

e) 3.58×10^{-1}

PRACTICE: WEAK ACID-BASE EQUILIBRIA CALCULATIONS 2

EXAMPLE: A weak acid has a pKa of 5.35. What is the hydronium ion concentration in a 0.10 M solution of this weak acid?

a) 5.4×10^{-4} M

b) 6.3×10^{-6} M

c) 3.5×10^{-5} M

d) 2.3×10^{-6} M

e) 4.5×10^{-6} M

f) 6.7×10^{-4} M

PRACTICE: The pH of an aqueous 0.10 M nitrite ion is 8.17. What is the base dissociation constant of the base?

a) $4.6 \times 10^{\mathbf{-16}}$

b) $2.2 \times 10^{\mathbf{-11}}$

c) $1.6 \times 10^{\mathbf{-6}}$

d) $1.6 \times 10^{\mathbf{-5}}$

e) $1.2 \times 10^{\mathbf{-3}}$

CONCEPT: IONIC SALTS

When an acid neutralizes a base an ionic compound called a _____ is formed. These solutions can be neutral, acidic or basic, depending on the acid-base properties of the cations and anions formed.

Cations ⊕

- Transition Metals
  ___ or higher charge will be acidic, less than ___ will be neutral
  $TiBr_2$ ⟶
- Main Group Metals
  ___ or higher charge will be acidic, less than ___ will be neutral
  GaI_3 ⟶
- Positive Amines
  Positively charged amines are acidic
  NH_4NO_2 ⟶

Anions ⊖

- Add an H^+ to the anion and if you create a weak acid then your negative ion is basic.
  KF ⟶ $\xrightarrow{H^+}$
- Add an H^+ to the anion and if you create a strong acid then your negative ion is neutral.
  LiBr ⟶ $\xrightarrow{H^+}$

Amphoteric

- Acidic
  HSO_4^- HSO_3^- $H_2PO_4^-$
- Basic
  HCO_3^- HS^- HPO_4^{2-}

CONCEPT: BUFFERS

A buffer is a solution composed of a weak acid with its conjugate base.

HClO + **NaClO (aq)**

Weak oxyacid — **Conjugate base (Has 1 less Hydrogen)**

- A buffer works to keep both _____ and _____ constant.

If a ***strong base*** then the buffer resists a pH change by having the ***weak acid*** neutralize it.

HClO (aq) + **NaOH (aq)** ⟶ **NaClO (aq)** + **H_2O (l)**

Weak oxyacid — **Strong Base**

If a ***strong acid*** then the buffer resists a pH change by having the ***conjugate base*** neutralize it.

NaClO (aq) + **HCl (aq)** ⟶ **HClO (aq)** + **NaCl (l)**

Conjugate Base — **Strong Acid**

The weak acid and conjugate base can be different from one another by up to a magnitude of 10.

- This is called the _____ . If they are different by more than 10 then it will not be a buffer.

1.0 M HClO (Weak oxyacid) + **0.10 M NaClO (aq)** (Conjugate base) } Weak Acid is 10 times the amount of the conjugate base

0.05 M HClO (Weak oxyacid) + **0.50 M NaClO (aq)** (Conjugate base) } Conjugate base is 10 times the amount of the weak acid

The more concentrated the weak acid and conjugate base then the better the buffer can counteract strong acid or strong base added.

1.0 M HClO (Weak oxyacid) + **1.0 M NaClO (aq)** (Conjugate base)

0.01 M HClO (Weak oxyacid) + **0.01 M NaClO (aq)** (Conjugate base)

CONCEPT: BUFFER SYNTHESIS

To calculate the pH of a buffer then we use the Henderson Hasselbalch Equation:

$$pH = pKa + \log\frac{\text{conjugate base}}{\text{weak acid}}$$

There are **3** ways to form a buffer:

1) Mixing a _____ acid and a _____ base.

- In this case, a buffer is most ideal when both components are highly concentrated and equal to one another.

0.10 M HClO (Weak oxyacid) + **0.10 M NaClO (aq)** (Conjugate base) } **Ideal Buffer** — Weak Acid & Conjugate Base Equal in Concentrations

2) Mixing a _____ acid and a _____ base.

- In this case since we have a strong species mixing with a weak species then we must make sure the weak species is higher in amount.

1.0 M HCl (Strong Binary Acid) + **1.25 M NH_3 (aq)** (Weak Base) } **Buffer Created** — Weak base is greater in amount

1.50 M HCl (Strong Binary Acid) + **1.25 M NH_3 (aq)** (Weak Base) } **No Buffer Created** — Strong Acid is greater in amount

3) Mixing a _____ acid and a _____ base.

- In this case since we have a strong species mixing with a weak species then we must make sure the weak species is higher in amount.

1.50 moles HNO_2 (Weak Oxyacid) + **1.25 moles NaOH (aq)** (Strong Base) } **Buffer Created** — Weak acid is greater in amount

1.00 moles HNO_2 (Weak Oxyacid) + **1.10 moles NaOH (aq)** (Strong Base) } **No Buffer Created** — Strong Base is greater in amount

PRACTICE: BUFFER SYNTHESIS CALCULATIONS 1

EXAMPLE 1: Which of the following combinations can result in the formation of a buffer?

a) 75 mL of 0.10 M $HClO_3$ with 50 mL of 0.10 M CH_3NH_2.

b) 25 mL of 0.10 M H_2SO_3 with 40.0 mL of 0.10 M NaOH.

c) 50 mL of 0.10 M NH_4Cl with 50 mL of 0.05 M $Sr(OH)_2$.

d) 50 mL of 0.20 M HF with 40 mL of 0.20 M NaOH.

EXAMPLE 2: Calculate the pH of a solution formed by mixing 130.0 mL of a 0.300 M $C_2H_5NH_2$ solution with 70.0 mL of a 0.500 M $C_2H_5NH_3^+$ solution. (K_b of $C_2H_5NH_2$ is 5.0×10^{-4}).

PRACTICE: Which of the following molar ratios is the correct equilibrium ratio of BASE : ACID for a solution made of aniline (Kb = 3.8×10^{-10}) and anilinium nitrate where the pH is 4.80?

a) 1:2

b) 3:5

c) 7:2

d) 2:1

e) 5:3

PRACTICE: BUFFER SYNTHESIS CALCULATIONS 2

EXAMPLE 1: You are asked to go into the lab and prepare a buffer solution with a pH of 6.40 ± 0.2. Which weak acid would be the best choice?

a) carbonic acid $K_a = 4.2 \times 10^{-7}$

b) phenol $K_a = 1.3 \times 10^{-10}$

c) ascorbic acid $K_a = 8.0 \times 10^{-5}$

d) hydrosulfuric acid $K_a = 9.5 \times 10^{-8}$

e) potassium hydrogen phthalate $K_a = 3.1 \times 10^{-6}$

EXAMPLE 2: Calculate the pH of a solution made by mixing 8.627 g of sodium butanoate in enough 0.452 M butanoic acid, $HC_4H_7O_2$, to make 250.0 mL of solution. The K_a of butanoic acid is 1.5×10^{-5}.

a) 4.75

b) 4.82

c) 5.00

d) 2.58

e) 4.65