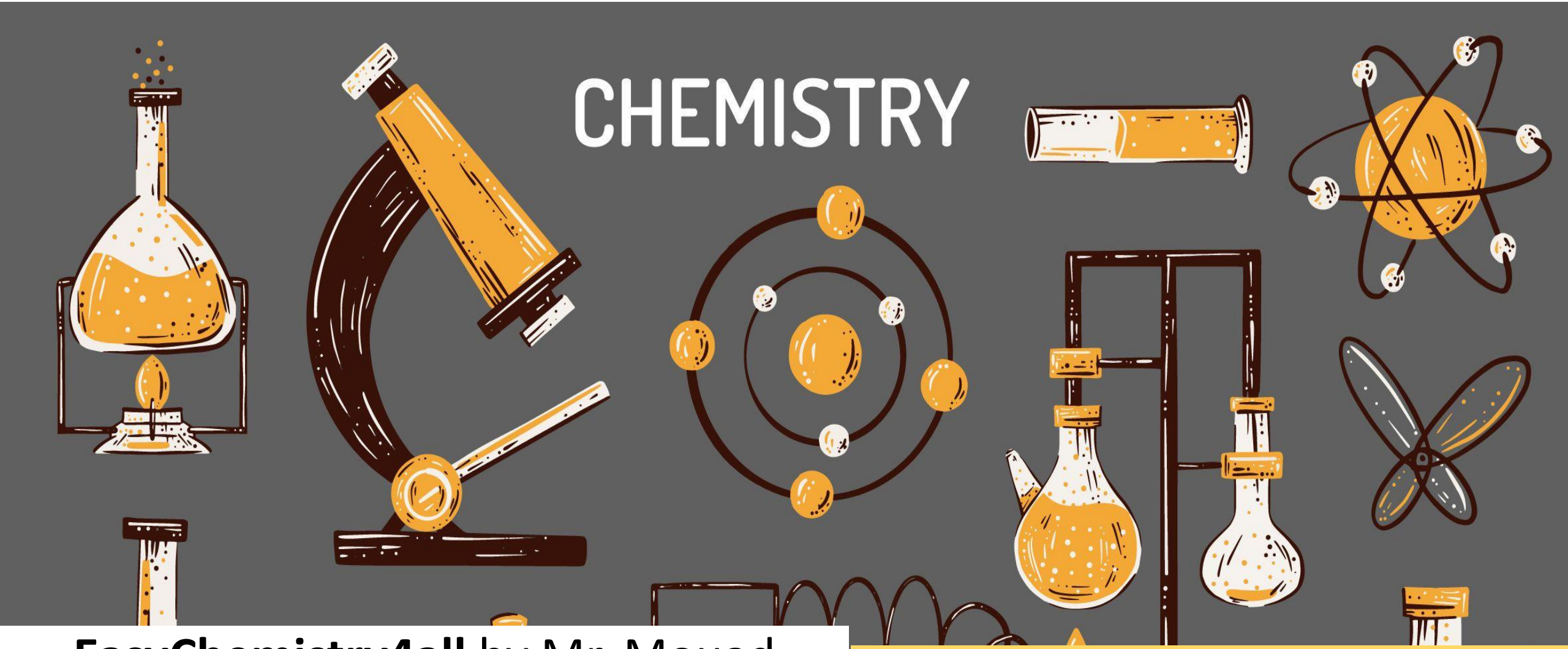


EasyChemistry4all by Mr. Mouad

مناهج دولة الإمارات

عام، متقدم ونخبة 9،10،11،12

00971557903129

PLEASE **Share & Subscribe** to the channel. Let us reach **3000 subscriber**!!

Inspire Chemistry
Module 17
"Acids & Bases"

Mcgraw hill

Lesson 2: "Strengths of acids and Bases"

Learning Outcomes:

- **Relate** the strength of an acid or base to its degree of ionization.
- **Compare** the strength of a weak acid with the strength of its conjugate base.
- **Explain** the relationship between the strengths of acids and bases and the values of their ionization constants.

K_a and K_b

Part 1

Acids and Bases

Lesson 2: Strengths of acids and bases

Learning objectives:

acid loses H^+

base gains H^+

Define **strong** and **weak** acids using "Bronsted-Lowery model".

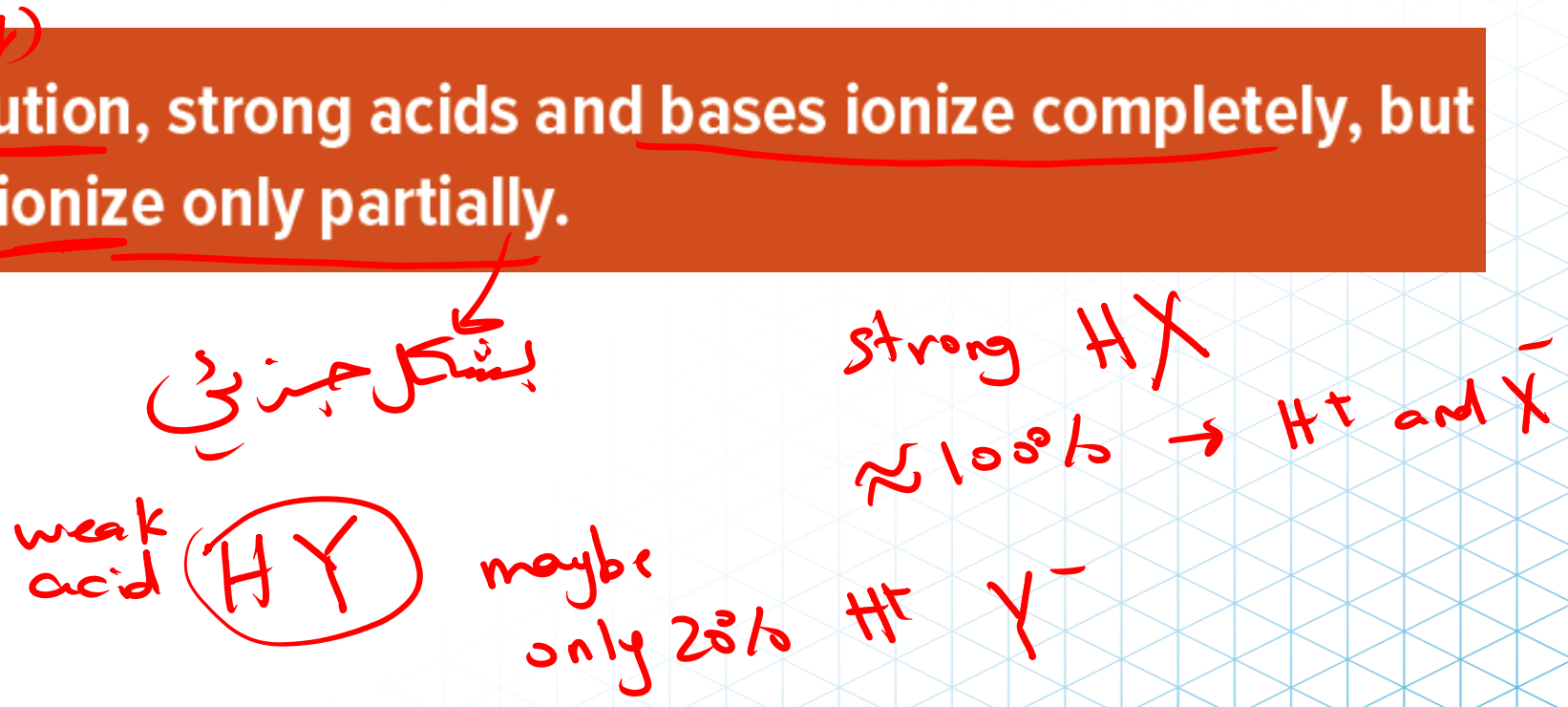
Use ionization equations of acids to write the **acidity constant** equation $\mathbf{K_a}$.

L1

Focus Question

What makes an acid or base strong or weak?

MAINIDEA In solution, strong acids and bases ionize completely, but weak acids and bases ionize only partially.



New Vocabulary

strong acid

weak acid

acid ionization constant

strong base

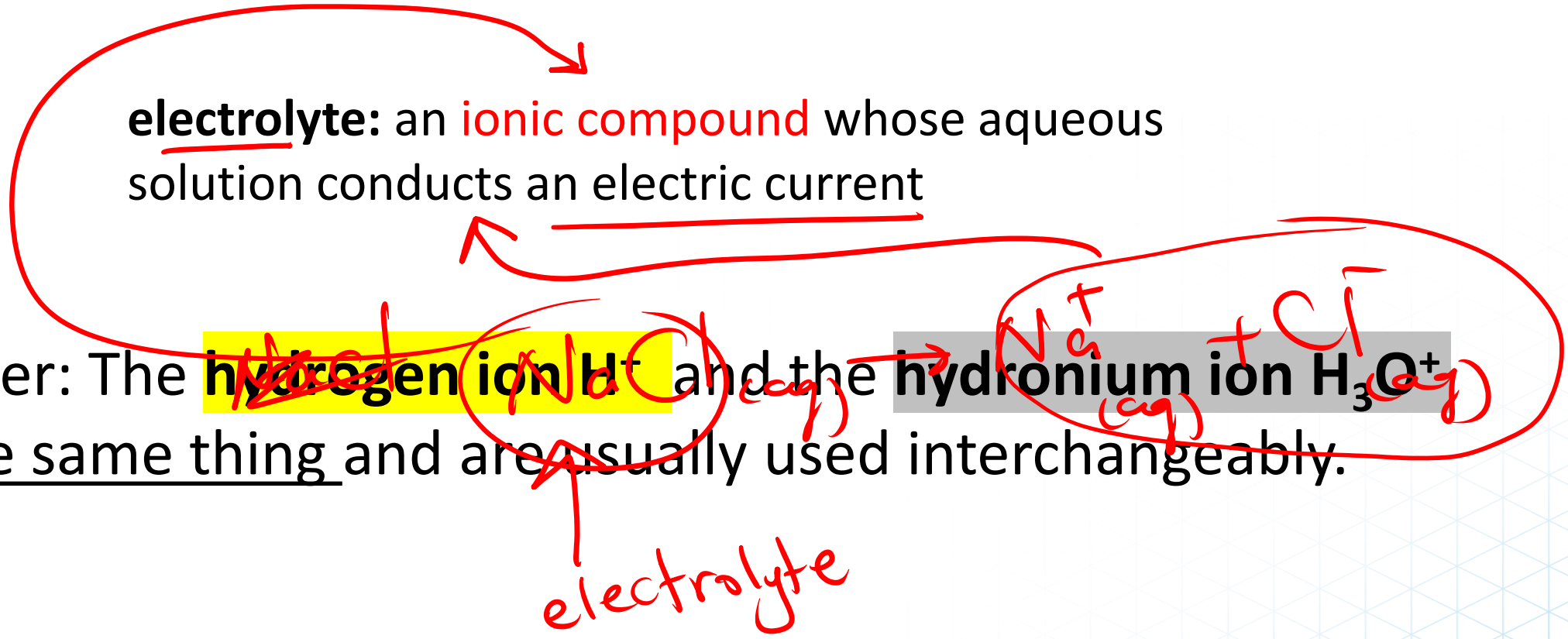
weak base

base ionization constant

Review Vocabulary

electrolyte: an ionic compound whose aqueous solution conducts an electric current

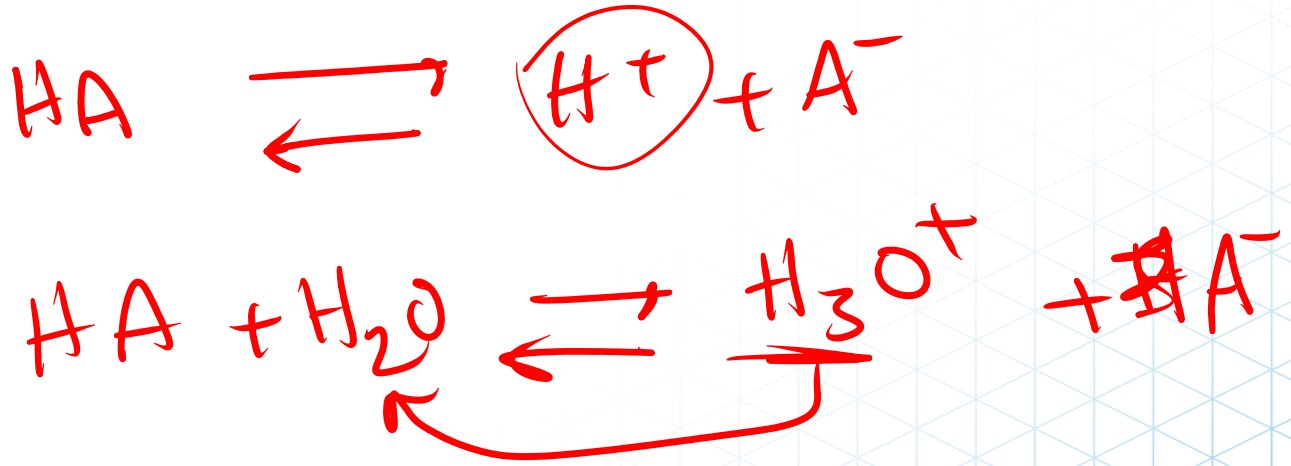
Remember: The **hydrogen ion H^+** and the **hydronium ion H_3O^+** mean the same thing and are usually used interchangeably.



Review Vocabulary

electrolyte: an ionic compound whose aqueous solution conducts an electric current

Remember: The **hydrogen ion H^+** and the **hydronium ion H_3O^+** mean the same thing and are usually used interchangeably.



Starter Activity

What is the K_{eq} for the following equilibrium?

$AB \rightleftharpoons A^+ + B^-$

$$\frac{[A^+][B^-]}{[AB]}$$

If the K_{eq} is **3.4×10^{-9}** or reactants?

At equilibrium, which is favored: products

Reactants (A^+ and B^-), because **$K_{eq} < 1$**

!!REMEMBER!!

The Equilibrium Constant (K_{eq})

- A value that relates the position of a reaction at equilibrium
- Calculated by inserting values into the equilibrium constant expression
- Keq does NOT have units
- Keq > 1
  - Product favored
- Keq ≤1
  - Reactant favored

More products > reactants

// reactants > products

Quick Revision on K_{eq}

we dont write (s) and (l)

$K_{eq} = [C_2H_5OH_{(g)}]$

$$C_2H_5OH(l) \rightleftharpoons C_2H_5OH(g)$$

$$K = \frac{[C_2H_5OH(g)]}{[C_2H_5OH(l)]}$$

$$K[C_2H_5OH(l)] = [C_2H_5OH(g)] = K_{eq}$$

constant

(s) constant

$$K_{eq} = [C_2H_5OH(g)]$$

Strengths of Acids Pages 98 & 99

$HCl + H_2O \rightarrow H_3O^+ + Cl^-$

Strong Acid = More ions = High electrical conductivity

in solution

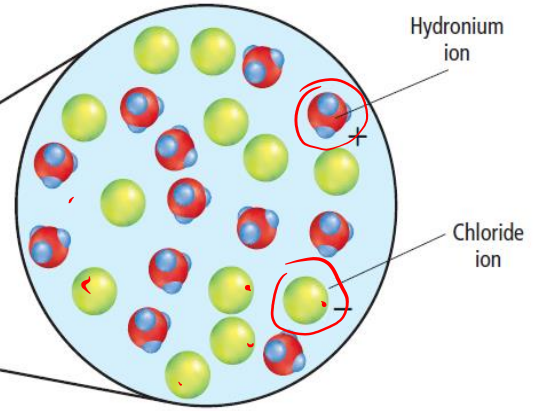


Figure 11 The light glows brightly when electrodes are placed in 0.10*M* hydrochloric acid solution because all of the HCl is in the form of hydronium ions and chloride ions.

Weak Acid = Less ions = Low electrical conductivity

$HC_2H_3O_2$ (aq) $+ H_2O \rightleftharpoons H_3O^+ + CH_3COO^-$

CH_3COOH

$HC_2H_3O_2$

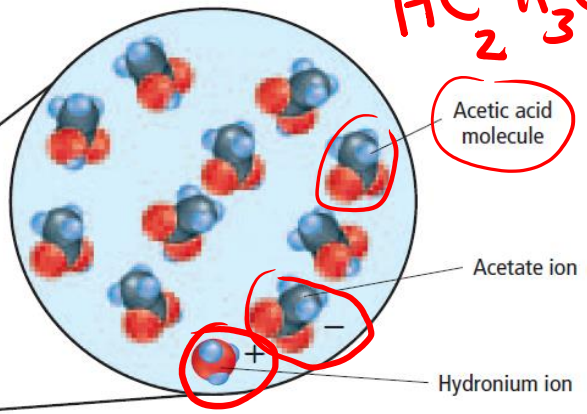


Figure 12 When electrodes are placed in 0.10*M* acetic acid solution, the light is dim. Compare this illustration with **Figure 18.11.**

Explain *the difference in the brightness of the bulbs in terms of the concentration of ions in solution.*

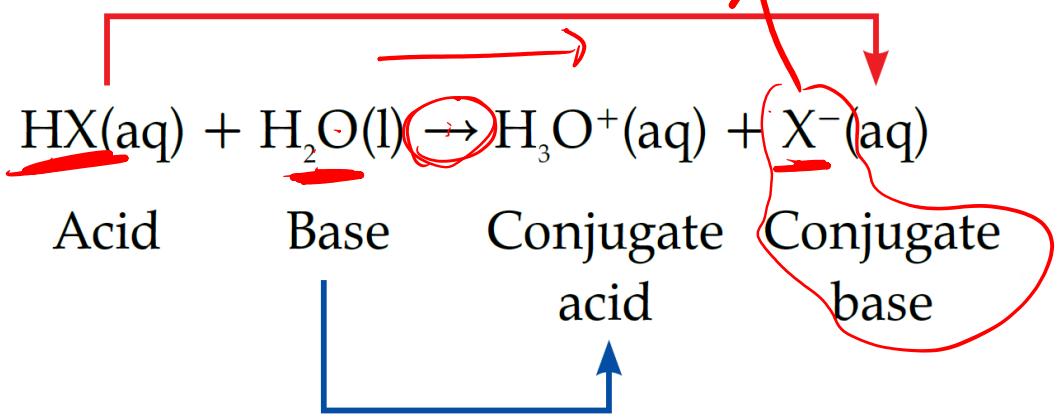
Strengths of Acids

- Acids that ionize completely are called **strong acids.**
- Because they produce the maximum number of hydrogen ions, strong acids are good conductors of electricity.
- Acids that ionize only partially in dilute aqueous solutions are called **weak acids.**

Strengths of Acids

Acid strength and the Brønsted-Lowry model

- With a **strong acid**, the conjugate base is a **weak base**.



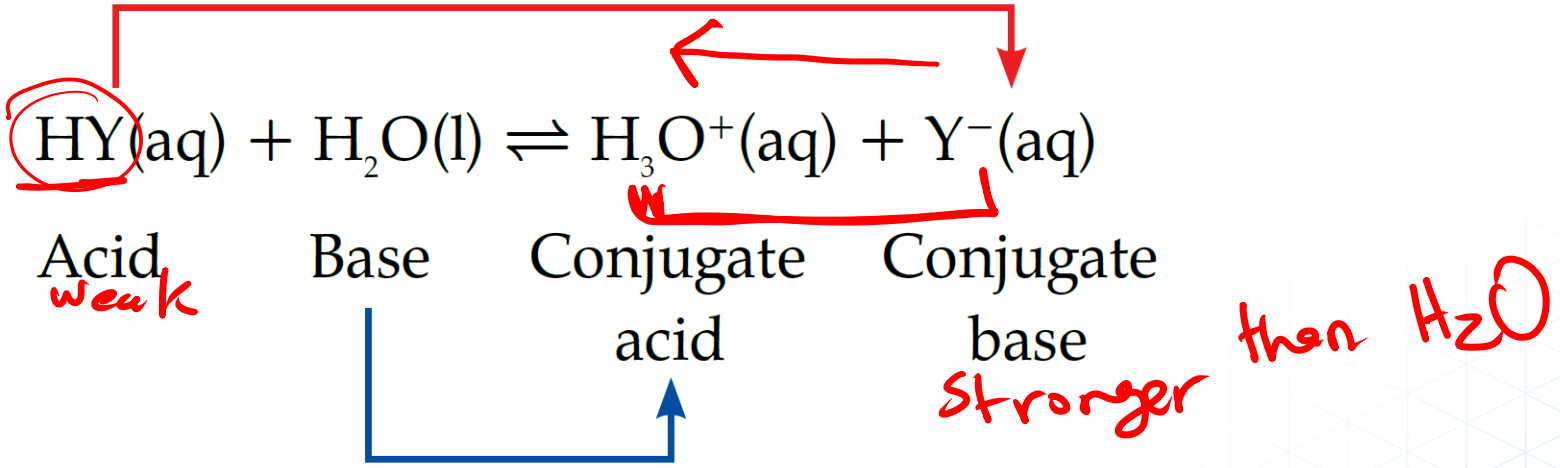
- Equilibrium lies almost completely **to the right**, because the conjugate base has a weaker attraction for the H^+ ion than does the base in the forward reaction.
- Notice that the equation is **shown with a single arrow** to the right for **strong acids**. The reaction goes to completion (right).

Strengths of Acids

weak acid makes a stronger conjugate base

Acid strength and the Brønsted-Lowry model

- In a weak acid, the ionization equilibrium lies to the far left because the conjugate base has a greater attraction for H^+ ions than does the base in the forward reaction.



- Notice that **the equation is shown with equilibrium arrows for weak acids**.

Strengths of Acids

Try to Memorize them

CH_3COOH

Table 3 Ionization Equations

Strong Acids		Weak Acids	
Name	Ionization Equation	Name	Ionization Equations
Hydrochloric	$HCl \rightarrow H^+ + Cl^-$	Hydrofluoric	$HF \rightleftharpoons H^+ + F^-$
Hydroiodic	$HI \rightarrow H^+ + I^-$	Acetic	$HC_2H_3O_2 \rightleftharpoons H^+ + C_2H_3O_2^-$
Perchloric	$HClO_4 \rightarrow H^+ + ClO_4^-$	Hydrosulfuric	$H_2S \rightleftharpoons H^+ + HS^-$
Nitric	$HNO_3 \rightarrow H^+ + NO_3^-$	Carbonic	$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$
Sulfuric	$H_2SO_4 \rightarrow H^+ + HSO_4^-$	Hypochlorous	$HClO \rightleftharpoons H^+ + ClO^-$

Quiz

1. _____ acids **dissociate completely** in aqueous solutions.

A Only strong

B Only weak

C Both strong and weak

D Neither strong nor weak

Strengths of Acids

- The equilibrium constant, K_{eq}, provides a measure of the degree of ionization of an acid.

$$HCN(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CN^-(aq)$$

$$K_{eq} = \frac{[H_3O^+][CN^-]}{[HCN][H_2O]}$$

- The **acid ionization constant, K_a**, is the value of the equilibrium constant expression for the ionization of a weak acid.

$$K_a = K_{eq}[H_2O] = \frac{[H_3O^+][CN^-]}{[HCN]} = 6.2 \times 10^{-10}$$

Strengths of Acids

- K_a indicates whether **products (Ions)** or **reactants(Acid)** are favored (**more**) at equilibrium.
- For weak acids, the products tend to be smaller compared to the un-ionized molecules (reactant).
- Weaker acids have a smaller K_a. < 1 (More Acid and less ions)

Ka → 1 strong Acid

Table 4 Ionization Constants for Weak Acids

Acid	Ionization Equation	K_a (298 K)
Hydrosulfuric, first ionization	$H_2S \rightleftharpoons H^+ + HS^-$	8.9×10^{-8} <1
Hydrosulfuric, second ionization	$HS^- \rightleftharpoons H^+ + S^{2-}$	1×10^{-19} <1
Hydrofluoric	$HF \rightleftharpoons H^+ + F^-$	6.3×10^{-4} $\ll 1$
Hydrocyanic	$HCN \rightleftharpoons H^+ + CN^-$	6.2×10^{-10} $\ll\ll 1$
Acetic	$CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$	1.8×10^{-5} $\ll\ll 1$
Carbonic, first ionization	$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$	4.5×10^{-7} $\ll 1$
Carbonic, second ionization	$HCO_3^- \rightleftharpoons H^+ + CO_3^{2-}$	4.7×10^{-11} $\ll\ll 1$

Quiz

2. In the equation below, **CH_3COOH** is a _____.

$$CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$$

A strong acid

B weak acid

C strong base

D weak base

Practice Problems:

APPLICATIONS

lesson 1 — Ka

12. Write ionization equations and acid ionization constant expressions for each acid.

a. $HClO_2$ **b.** HNO_2 **c.** HIO

13. Write the first and second ionization equations for H_2SeO_3.

14. Challenge Given the expression $K_a = \frac{[AsO_4^{3-}][H_3O^+]}{[HAsO_4^{2-}]}$, write the balanced equation for the corresponding reaction.

12 a.) $HClO_2 \rightleftharpoons H^+ + ClO_2^-$ → $K_a = \frac{[H^+][ClO_2^-]}{[HClO_2]}$

or $HClO_2 + H_2O \rightleftharpoons H_3O^+ + ClO_2^-$ → $K_a = \frac{[H_3O^+][ClO_2^-]}{[HClO_2]}$

Answers: Applications

12. Write ionization equations and acid ionization constant expressions for the following acids.

a. $HClO_2$

$$HClO_2(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + ClO_2^-(aq)$$

$$K_a = \frac{[H_3O+][ClO_2]}{[HClO_2]}$$

b. HNO_2

$$HNO_2(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + NO_2^-(aq)$$

$$K_a = \frac{[H_3O^+]\,[NO_2^-]}{[HNO_2]}$$

c. HIO

$$HIO(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + IO^+(aq)$$

$$K_a = \frac{[H_3O^+][IO^-]}{[HIO]}$$

13. Write the first and second ionization equations for H_2SeO_3.

$$H_2SeO_3(aq) + H_2O(l) \leftrightarrow HSeO_3^-(aq) + H_3O^+(aq)$$

$$HSeO_3^-(aq) + H_2O(l) \leftrightarrow SeO_3^{2-}(aq) + H_3O^+(aq)$$

14. Challenge Given the expression

$$K_a = \frac{[ASO_4^{3-}]\,[H_3O^+]}{[HAsO_4^{2-}]}$$

, write the balanced equation for the corresponding reaction.

$$HAsO_4^{2-}(aq) + H_2O(l) \leftrightarrow H_3O^+(aq) + AsO_4^{3-}$$

Part 2

Module 17: Acids and Bases
Lesson 2: Strengths of acids and bases

Learning Objectives

Define **strong** and **weak** bases using “Bronsted-Lowery model”.

Use ionization equations of bases to wrote the **basicity constant** equation K_b.

Strengths of Bases_Self Study_102

- A base that dissociates completely into metal ions and hydroxide ions is known as a **strong base.**
- A **weak base** ionizes only partially in dilute aqueous solution.

Table 5 Dissociation Equations for Strong Bases

$NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$
$KOH(s) \rightarrow K^+(aq) + OH^-(aq)$
$RbOH(s) \rightarrow Rb^+(aq) + OH^-(aq)$
$CsOH(s) \rightarrow Cs^+(aq) + OH^-(aq)$
$Ca(OH)_2(s) \rightarrow Ca^{2+}(aq) + 2OH^-(aq)$
$Ba(OH)_2(s) \rightarrow Ba^{2+}(aq) + 2OH^-(aq)$

Strengths of Bases_103

Kb
Ka
Keq
} we don't put (s) or (l)

- The **base ionization constant, K_b,** is the value of the equilibrium constant expression for the ionization of a base.
- For example, for Methylamine (CH_3NH_2) **(Reaction is below in Table 6):**

base — gain H+ — lose H+

$$CH_3NH_2(aq) + H_2O(l) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$$

CH_3NH_2 is a base

$$K_b = \frac{[CH_3NH_3^+][OH^-]}{[CH_3NH_2]}$$

- The smaller the value of K_b, the weaker the base. $<<< 1$

Table 6 Ionization Constants of Weak Bases

Small

Base	Ionization Equation	K_b (298 K)
Ethylamine	$C_2H_5NH_2(aq) + H_2O(l) \rightleftharpoons C_2H_5NH_3^+(aq) + OH^-(aq)$	5.0×10^{-4}
Methylamine	$CH_3NH_2(aq) + H_2O(l) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$	4.3×10^{-4}
Ammonia	$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$	2.5×10^{-5}
Aniline	$C_6H_5NH_2(aq) + H_2O(l) \rightleftharpoons C_6H_5NH_3^+(aq) + OH^-(aq)$	4.3×10^{-10}

0.0005

Strengths of Bases_Page 103

0 + 1 = +1 or (+) 0 − 1 = (−1) = (−)

APPLICATIONS

15. Write ionization equations and base ionization constant expressions for the following bases.

a. hexylamine ($C_6H_{13}NH_2$)
b. propylamine ($C_3H_7NH_2$)
c. carbonate ion (CO_3^{2-})
d. hydrogen sulfite ion (HSO_3^-)

16. **Challenge** Write an equation for a base equilibrium in which the base in the forward reaction is PO_4^{3-} and the base in the reverse reaction is OH^-.

Kb

base

gain H+ ✓ lose H+ ✓

15a.

$$C_6H_{13}NH_{2(aq)} + H_2O_{(l)} \rightleftharpoons C_6H_{13}NH_3^{+}{}_{(aq)} + OH^-_{(aq)}$$

$$K_b = \frac{[C_6H_{13}NH_3^+][OH^-]}{[C_6H_{13}NH_2]}$$

Strengths of Bases_Page 103

+1 -2 = -1

⊖ = -1

APPLICATIONS

15. Write ionization equations and base ionization constant expressions for the following bases.

a. hexylamine ($C_6H_{13}NH_2$)

b. propylamine ($C_3H_7NH_2$)

c. carbonate ion (CO_3^{2-})

d. hydrogen sulfite ion (HSO_3^-)

16. Challenge Write an equation for a base equilibrium in which the base in the forward reaction is PO_4^{3-} and the base in the reverse reaction is OH^-.

15 (c)

gain H+ loses H+

$CO_3^{2-} + H_2O \rightleftharpoons HCO_3^{-} + OH^-$

$$K_b = \frac{[HCO_3^-][OH^-]}{[CO_3^{2-}]}$$

Strengths of Bases_Page 103

APPLICATIONS

15. Write ionization equations and base ionization constant expressions for the following bases.

a. hexylamine ($C_6H_{13}NH_2$)

b. propylamine ($C_3H_7NH_2$)

c. carbonate ion (CO_3^{2-})

d. hydrogen sulfite ion (HSO_3^-)

16. Challenge Write an equation for a base equilibrium in which the base in the forward reaction is PO_4^{3-} and the base in the reverse reaction is OH^-.

Strengths of Bases_Page 103

15. Write ionization equations and base ionization constant expressions for the following bases.

a. hexylamine ($C_6H_{13}NH_2$)

$$C_6H_{13}NH_2(aq) + H_2O(l) \leftrightarrow C_6H_{13}NH_3^+(aq) + OH^-(aq)$$

$$K_b = \frac{[C_6H_{13}NH_3^+]\,[OH^-]}{[C_6H_{13}NH_2]}$$

b. propylamine ($C_3H_7NH_2$)

$$C_3H_7NH_2(aq) + H_2O(l) \leftrightarrow C_3H_7NH_3^+(aq) + OH^-(aq)$$

$$K_b = \frac{[C_3H_7NH_3^+]\,[OH^-]}{[C_3H_7NH_2]}$$

c. carbonate ion (CO_3^{2-})

$$CO_3^{2-}(aq) + H_2O(l) \leftrightarrow HCO^{3-}(aq) + OH^-(aq)$$

$$K_b = \frac{[HCO_3^-]\,[OH^-]}{[CO_3^{2-}]}$$

d. hydrogen sulfite ion (HSO_3^-)

$$HSO_3^-(aq) + H_2O(l) \leftrightarrow H_2SO_3(aq) + OH^-(aq)$$

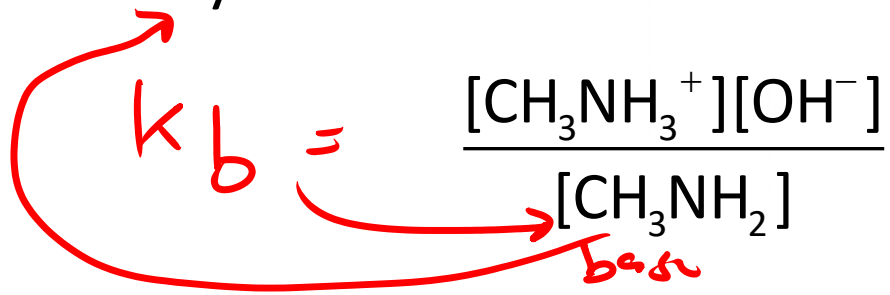
$$K_b = \frac{[H_2SO_3]\,[OH^-]}{[HSO_3^-]}$$

16. Challenge Write an equation for a base equilibrium in which the base in the forward reaction is PO_4^{3-} and the base in the reverse reaction is OH^-

$$PO_4^{3-}(aq) + H_2O(l) \leftrightarrow HPO_4^{2-}(aq) + OH^-(aq)$$

Quiz

3. The expression shown below is the _____ for methylamine.



A equilibrium constant

B acid ionization constant

C base ionization constant

D ionization equation

Strongest = highest K

Quiz

lowest K_b

4. Which is the weakest base shown in the table below?

Table 6 Ionization Constants of Weak Bases

Base	Ionization Equation	K_b(298 K)
Ethylamine	$C_2H_5NH_2(aq) + H_2O(l) \rightleftharpoons C_2H_5NH_3^+(aq) + OH^-(aq)$	5.0×10^{-4}
Methylamine	$CH_3NH_2(aq) + H_2O(l) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$	4.3×10^{-4}
Ammonia	$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$	2.5×10^{-5}
Aniline	$C_6H_5NH_2(aq) + H_2O(l) \rightleftharpoons C_6H_5NH_3^+(aq) + OH^-(aq)$	4.3×10^{-10}

A ethylamine

B methylamine

C ammonia

D analine

SECTION 2 REVIEW

Section Summary

- Strong acids and strong bases are completely ionized in a dilute aqueous solution. Weak acids and weak bases are partially ionized in a dilute aqueous solution.
- For weak acids and weak bases, the value of the acid or base ionization constant is a measure of the strength of the acid or base.

17. **MAINIDEA** **Describe** the contents of dilute aqueous solutions of the strong acid HI and the weak acid HCOOH.
18. **Relate** the strength of a weak acid to the strength of its conjugate base.
19. **Identify** the conjugate acid-base pairs in each equation.

    a. $HCOOH(aq) + H_2O(l) \rightleftharpoons HCOO^-(aq) + H_3O^+(aq)$

    b. $NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$
20. **Explain** what the K_b for aniline ($C_6H_5NH_2$) tells you ($K_b = 4.3 \times 10^{-10}$).
21. **Interpret Data** Use the data in **Table 4** to put the seven acids in order according to increasing electrical conductivity.

SECTION 2 REVIEW

Answers

17. Describe the contents of dilute aqueous solutions of the strong acid HI and the weak acid HCOOH.

The solution of HI contains only H_3O^+ and I^- ions and water molecules. The solution of HCOOH contains H_3O^+ and $HCOO^-$ ions, and HCOOH and H_2O molecules.

18. Relate the strength of a weak acid to the strength of its conjugate base.

The stronger the acid is, the weaker its conjugate base. The weaker the acid is, the stronger its conjugate base.

19. Identify the conjugate acid-base pairs in each equation.

a. $HCOOH(aq) + H_2O(l) \leftrightarrow HCOO^-(aq) + H_3O^+(aq)$

acid: HCOOH; conjugate base: $HCOO^-$; base: H_2O; conjugate acid: H_3O^+;

b. $NH_3(aq) + H_2O(l) \leftrightarrow NH_4^+(aq) + OH^-(aq)$

acid: H_2O; conjugate base: OH^-; base: NH_3; conjugate acid: NH_4^+

20. Explain what the K_b for aniline tells you. ($K_b = 4.3 \times 10^{-10}$).

The size of aniline's K_b indicates that aniline is a weak base.

21. Interpret Data Use the data in **Table 18.4** to put the seven acids in order according to increasing electrical conductivity.

HS^-, HCO_3^-, H_2S, H_2CO_3, CH_3COOH, HCOOH, HF