Chapter 18

Acids and Bases

Warm Up

- Name any acids that you have at home.
- What are they usually used for?

- Name any bases that you have at home.
- What are they usually used for?

Today's Agenda

- QOTD: What is an acid and a base and three theories that describe them.

- Arrhenius Model
- Brønsted-Lowry Model
- Lewis Model

- Homework due Friday : Chapter 18, 56-64 evens, and 85, 86, 87, 89, 92, 93
- Lab reports due tomorrow!

Acids and Bases

- Acids
  - Carbonic acid and phosphoric acid – soda
  - Acetic acid – vinegar
  - Citric acid – oranges and grapefruit
- Bases
  - Antacid medications
  - Soap, cleaning products

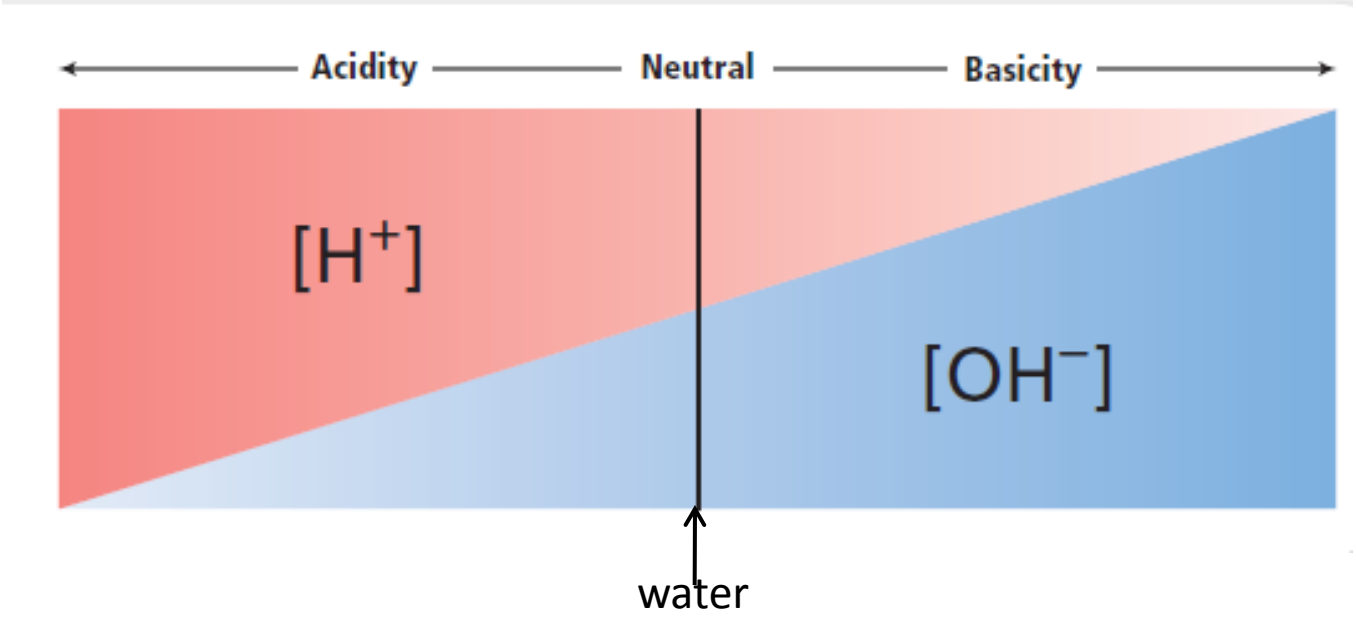
What is an Acid?

- Acids result in a high concentration of H^+ ions in solution
- Usually ionic compounds with H^+
- Turn blue litmus paper red
- Strong Acids –
- HCl H_2SO_4 HNO_3
- HBr HI $HClO_4$

What is a Base?

- Bases result in a high concentration of OH^- ion in solution.
- Ionic compounds that *usually* contain OH^-
- Turn red litmus paper blue.
- Strong Bases –
- NaOH $Ca(OH)_2$
- KOH $Ba(OH)_2$

Hydronium and Hydroxide



- Autoionization of water:

$H_2O_{(l)} + H_2O_{(l)} \rightarrow H_3O^+ + OH^-$ is the same as…

$H_2O_{(l)} \rightarrow H^+ + OH^-$

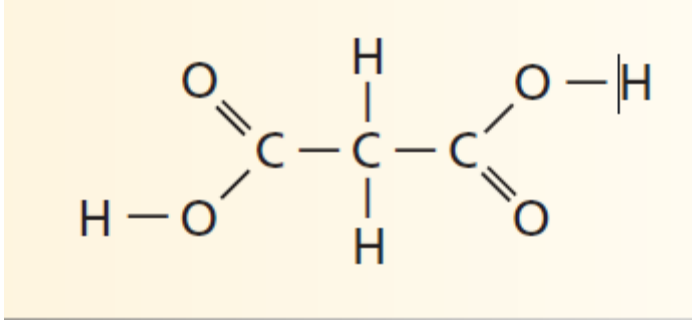
Arrhenius Model

- An acid contains hydrogen and ionizes to produce H^+ ions in aqueous solution.
- $HCl_{(g)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$

- A base contains a hydroxide group and ionizes to produce OH^- ions in aqueous solution.
- $NaOH_{(s)} \rightarrow Na^+_{(aq)} + OH^-_{(aq)}$

Which H atoms are ionizable?

- What does ionizable mean?
- Which hydrogen atoms can be ionized in water, creating an acidic aqueous solution?



- Only H atoms that are attached to N atoms or O atoms can be ionized!

But…

- The Arrhenius model does not explain NH_3 and Na_2CO_3 (both bases)!

- Although they do not contain OH^-, they DO in fact increase the concentration of OH^- ions in aqueous solution.

Brønsted-Lowry Model

- Acids are hydrogen ion (proton) donors.
- Bases are hydrogen ion (proton) acceptors.

- Generic chemical equation:

$$HX_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+ + X^-$$

acid base conjugate acid conjugate base

Conjugate Acids and Bases

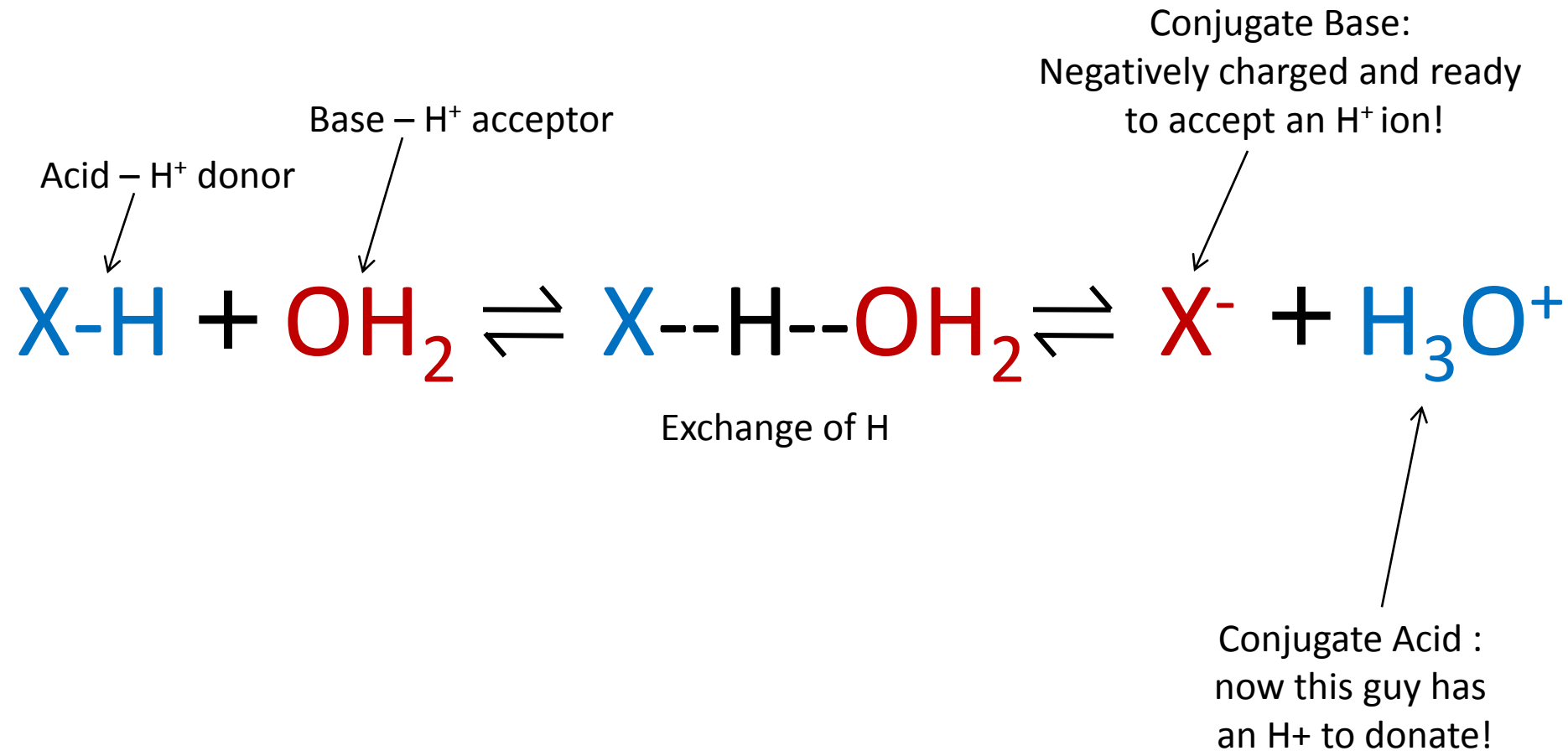
- The acid and base species in the products of an acid/base reaction.

$$HX_{(aq)} + H_2O_{(l)} \rightleftharpoons H_3O^+ + X^-$$

acid base conjugate acid conjugate base

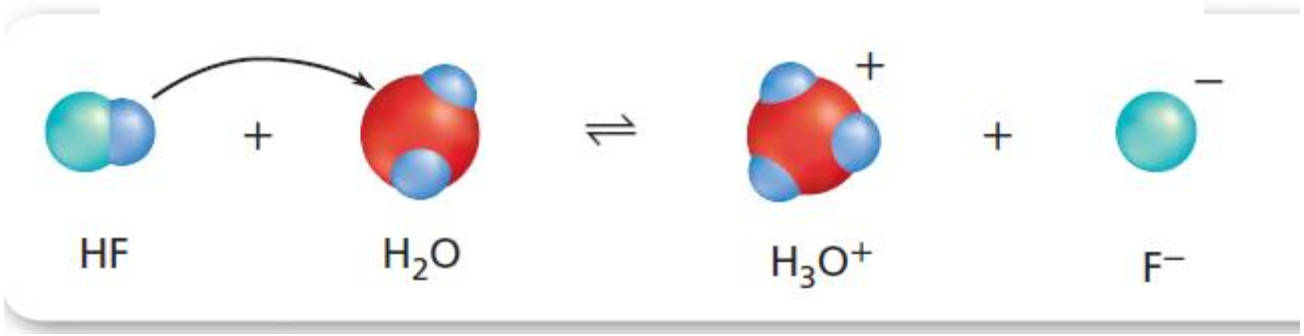
- Conjugate acid-base pairs consist of two substances related to each other by the exchange of a hydrogen ion (H^+).

Conjugate Acids and Bases



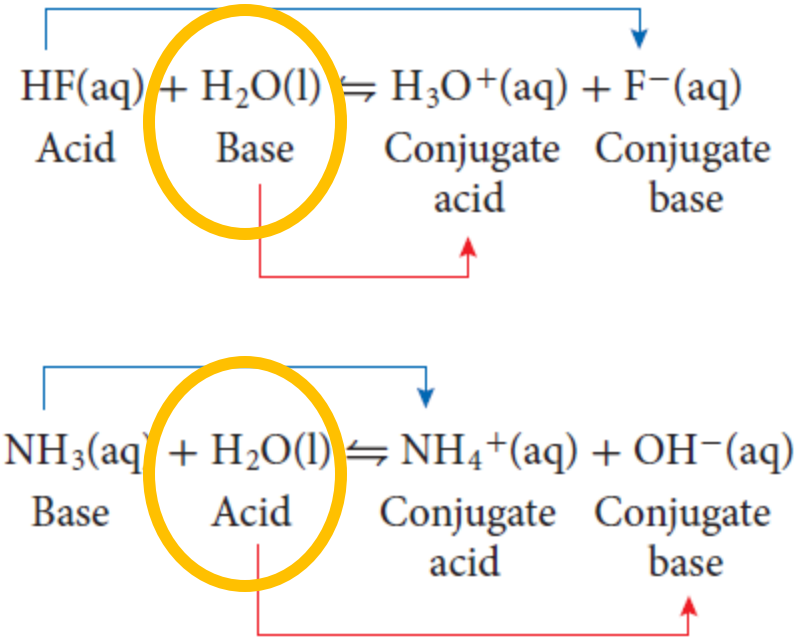
Label the acid, base, and conjugates

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



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

Water is AMPHOTERIC



- Amphoteric substances can act as BOTH acids AND bases. Examples: H_2O, HCO_3^-, and HSO_4^-

Label acids, bases, and conjugates

$$HCO_3^- + H_2O \rightleftharpoons CO_3^{2-} + H_3O^+$$

$$HCO_3^- + H_2O \rightleftharpoons H_2CO_3 + OH^-$$

$$HBr + H_2O \rightleftharpoons H_3O^+ + Br^-$$

$$HSO_4^- + H_2O \rightleftharpoons SO_4^{2-} + H_3O^+$$

Which of the above are amphoteric?

The Lewis Model

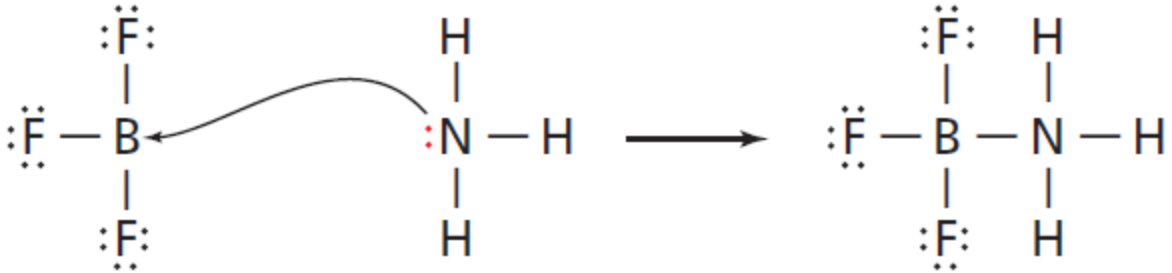
- Remember electron dot diagrams (Lewis structures)?? Same dude here!

- Lewis acid – electron acceptor
- Lewis base – electron donor

- Does not clash with Brønsted-Lowry model, just broadens the definition to include more!

Lewis Acids and Bases

Which is donating electrons, which species is accepting electrons?
Which is Lewis base and which is Lewis acid?



Which is donating electrons, which species is accepting electrons?
Which is Lewis base and which is Lewis acid?

Models for Acid/Base Theory

Table 18.2 **Three Models for Acids and Bases**

Interactive Table
Explore acids and bases at glencoe.com.

Model	Acid Definition	Base Definition
Arrhenius	H^+ producer	OH^- producer
Brønsted-Lowry	H^+ donor	H^+ acceptor
Lewis	electron-pair acceptor	electron-pair donor

Warm Up

- List the three models for acid/base chemistry and the definitions of acids and bases for each.

- Identify acid, base, and conjugates.

$CH_3NH_{2\,(aq)} + H_2O_{(l)} \rightarrow CH_3NH_3^{+}{}_{(aq)} + OH^{-}{}_{(aq)}$

$CH_3COOH_{\,(aq)} + H_2O_{(l)} \rightarrow CH_3COO^{-}{}_{(aq)} + H_3O^{+}{}_{(aq)}$

Today's Agenda

- QOTD: What is a neutralization reaction and how do you do a titration?

- Polyprotic acids
- Review of neutralization reactions
- Acid-base titrations
- Indicators

- Lab reports due TODAY!

Polyprotic Acids

$$H_3PO_4(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + H_2PO_4^-(aq)$$

$$H_2PO_4^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HPO_4^{2-}(aq)$$

$$HPO_4^{2-}(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + PO_4^{3-}(aq)$$

- Polyprotic acids have more than one acidic H^+
- These acids lose one H^+ at a time in a step-wise series of acid base reactions.
- Intermediate species are amphoteric.
- Label acids, bases, and conjugates.
- Which species are acting amphoterically?

Write the H^+ dissociation steps for H_2SO_4 in water.

Neutralization Reactions

- Double replacement reaction of an acid and base.

Acid + Base → Salt + Water

$HCl_{(aq)} + NaOH_{(aq)} \rightarrow NaCl_{(aq)} + H_2O_{(l)}$

Remember that a salt is any ionic compound made up of a cation and anion.

Net Ionic Review

- Remember when ionic compounds (and some acids/bases) are dissolved in water, they dissociate into their cation and anion.

- Acids and bases that break up into ions in water are **STRONG** only (see list from yesterday)!

- Strong acid/base – an acid/base that dissociates COMPLETELY in water (always breaks up in a net ionic eqn!)

Net Ionic for Neutralization

$H^+ + \cancel{Cl^-} + \cancel{Na^+} + OH^- \rightarrow \cancel{Na^+} + \cancel{Cl^-} + H_2O$

cross out samesies on both sides

Final net ionic eqn for ALL strong acid/strong base neutralization reactions:

$H^+ + OH^- \rightarrow H_2O$

(some may have stoich differences)

Practice

- Write complete and net ionic chemical equation for the neutralization reaction of KOH and HNO_3 (strong/strong).

- $H^+ + \cancel{NO_3^-} + \cancel{K^+} + OH^- \rightarrow \cancel{K^+} + \cancel{NO_3^-} + H_2O$
- $H^+ + OH^- \rightarrow H_2O$

Neutralization Stoichiometry

- In order for a neutralization to be complete, you must have an **equal number of moles** of acid to base.

(ALL acid must react with ALL base without any extra left over…hence neutral)

$HCl + NaOH \rightarrow NaCl + H_2O$ 1:1 acid to base

$2HCl + Mg(OH)_2 \rightarrow MgCl_2 + 2H_2O$ 2:1 acid to base

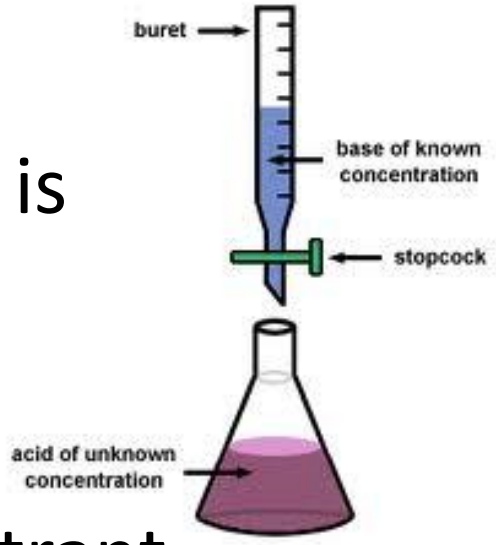
Acid-Base Titration

- ***Titration*** – experimental method for determining the concentration of an unknown solution of acid or base.

- It is important to think about acid/base stoichiometry when doing a titration experiment (neutralization)!
- You need ***equimolar*** amounts of H^+ to OH^- for a complete titration.

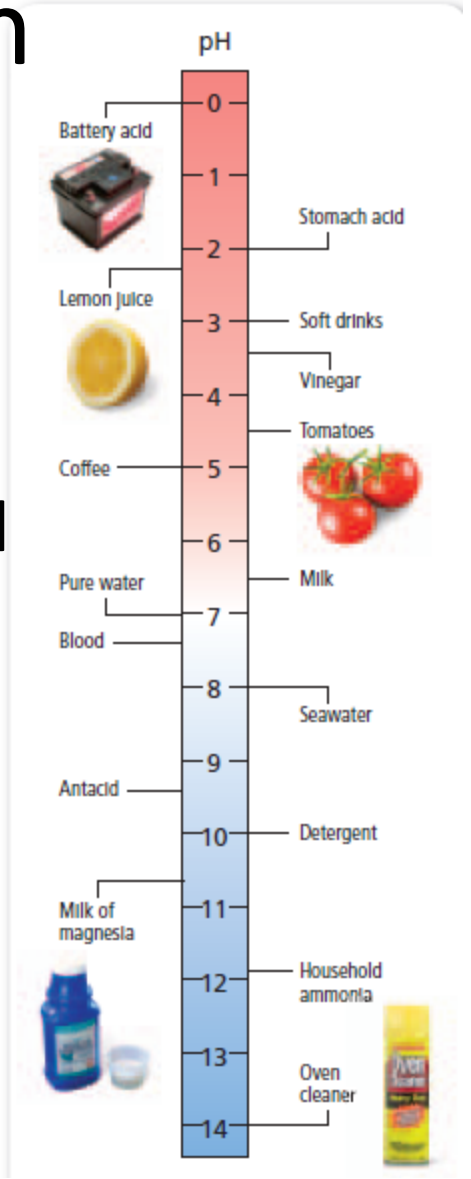
Titration Methodology

- You start with a solution of unknown concentration of acid in a beaker or flask.
- You then place a solution of known concentration of base in a *buret*. This is your *titrant*!
- You then add *titrant* into your acid slowly and monitor the VOLUME of titrant added.
- Titration is complete when moles of acid equals the moles of base.



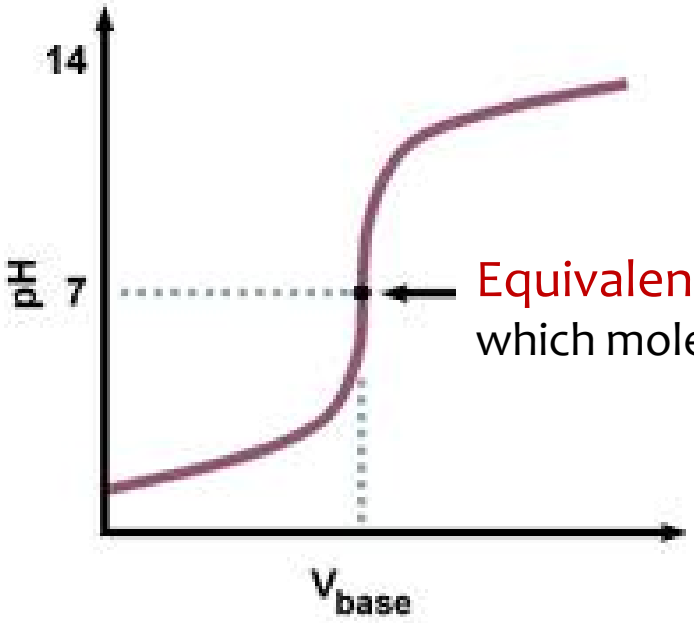
How do we know when it's done? : monitoring a titration

- pH meters
  - pH measures the hydrogen ion concentration in a solution.
  - more H^+ = stronger acid = lower pH (we'll talk about this more later).
  - Using a pH meter allows you to measure the pH as you add base to your acid. You get a digital reading of pH.



Monitoring a Titration: pH meter

- Strong acid with strong base titrant starts at a low pH and ends at a high pH.
- Sigmoidal curve with inflection point (a.k.a. *equivalence point*.)



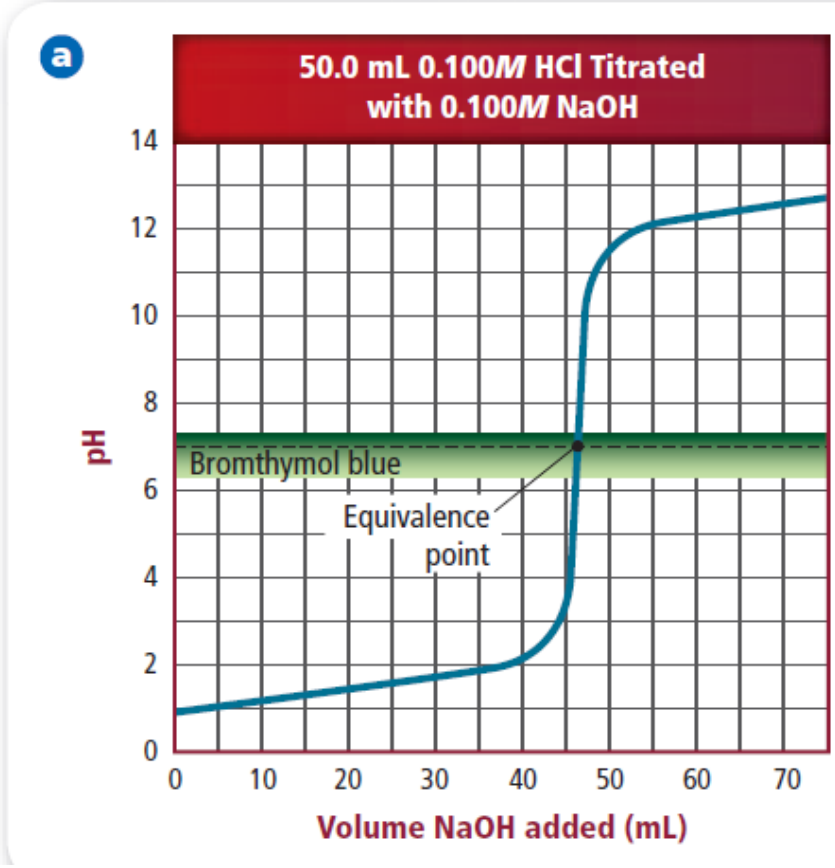
Equivalence point - volume at which moles of acid = moles of base

Strength of acids/bases in Titrations

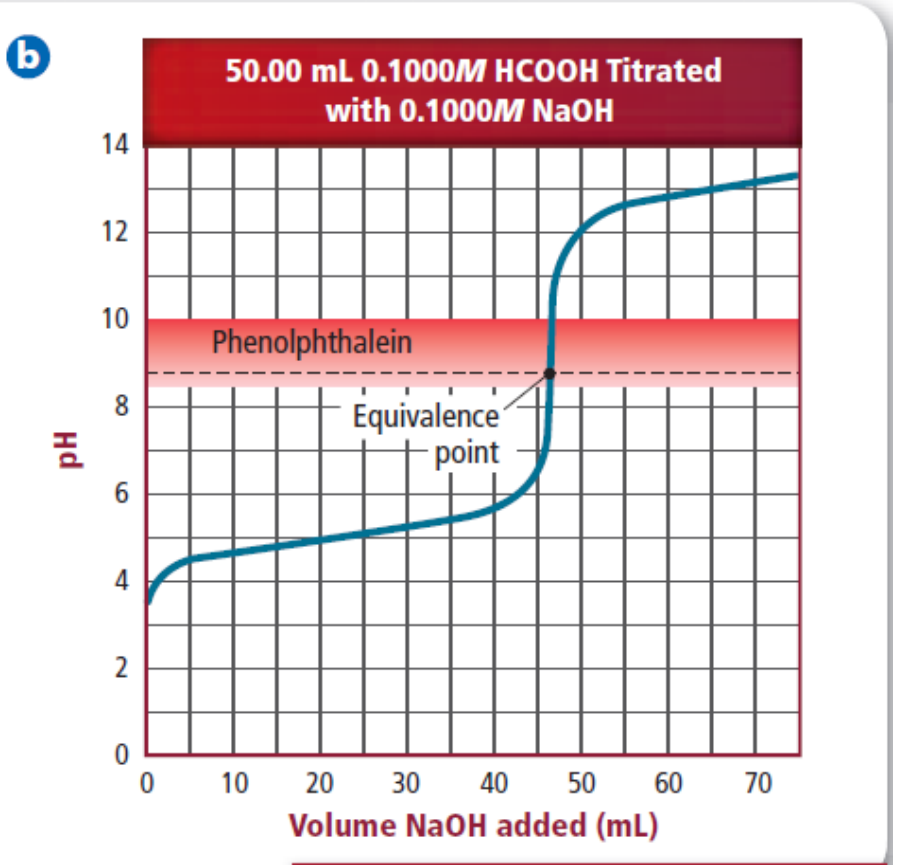
- Equivalence point of strong acid/strong base is always at pH = 7.

- Not all titrations are strong/strong! You can titrate a weak acid with strong base and vice versa.
  - With weak/strong (or strong/weak) the equivalence point is **NOT** at pH = 7.

Titration Curves!



Strong/Strong



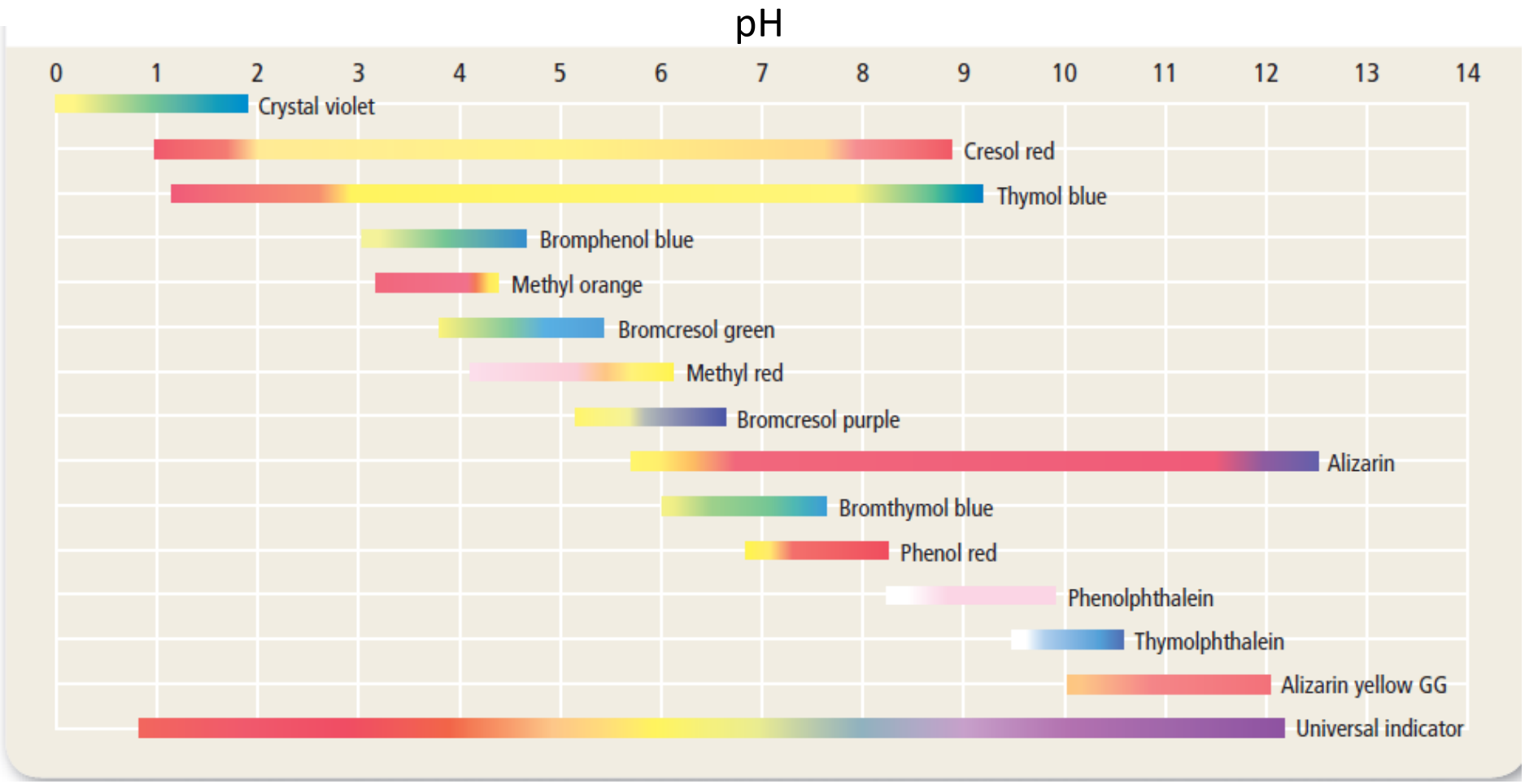
Weak/Strong

Monitoring Titrations : Indicators

- Indicators - chemical dyes whose colors change depending on acidity or basicity of solutions.

Fun (chemistry) fact: Tea contains chemicals that act as indicators, and by adding lemon (citric acid) you change the color of your black tea by changing the $[H^+]$!

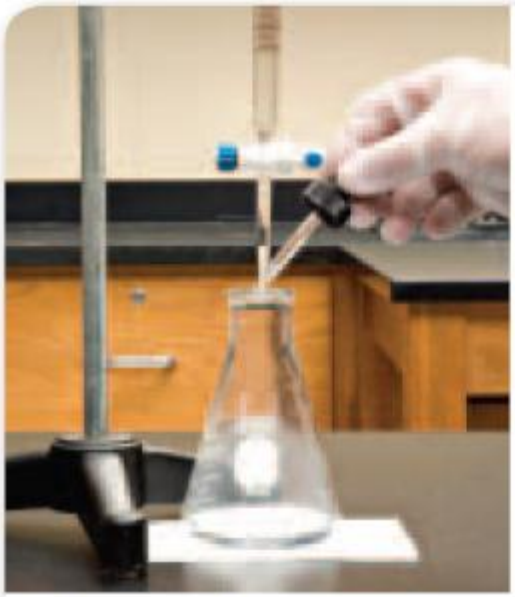
Indicators


pH
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Crystal violet
Cresol red
Thymol blue
Bromphenol blue
Methyl orange
Bromcresol green
Methyl red
Bromcresol purple
Alizarin
Bromthymol blue
Phenol red
Phenolphthalein
Thymolphthalein
Alizarin yellow GG
Universal indicator

Titration with Phenolphthalein

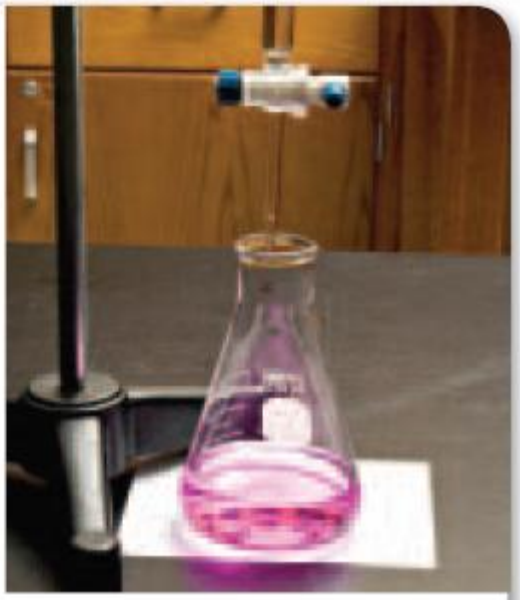
Weak acid/strong base titration

Phenolphthalein turns pink at pH = 8.5-10 and indicates the *endpoint* of the titration.



The buret contains the standard solution (0.1000*M* NaOH), and the flask contains 25.00 mL HCOOH solution along with a small amount of phenolphthalein indicator.

The standard solution is added slowly to the acid solution. The phenolphthalein indicator turns pink, but the color disappears upon mixing, until the end point is reached.



The end point of the titration is marked by a permanent, but very light, pink color. A careful reading of the buret reveals that 18.28 mL 0.1000*M* NaOH has been added.

Warm Up

- What are the two ways to monitor a titration

- Write the balanced neutralization reaction between HNO_3 and NaOH

Todays Agenda

- QOTD: How do you calculate molarity from a titration?

- Titration Calcs
- Practice

- Homework due tomorrow – small quiz tomorrow!
- Acid/Base Test next Friday!

Titration Calculations

- You must be able to write and balance the neutralization reaction! Write and balance:

Sulfuric acid is titrated with sodium hydroxide.

- $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2HOH$

- What type of titration is this? (strong/strong or weak strong)
- What should you expect for a pH at the equivalence point?

$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2HOH$

- You titrate 150 mL of sulfuric acid with 1.5 M sodium hydroxide and your indicator changes color after 30 mL of titrant was added.

1. How many moles of NaOH were added to the acid?
   - 0.045 moles NaOH
2. How many moles of H_2SO_4 were neutralized?
   - 0.0225 moles H_2SO_4
3. What was the molarity of the acid?
   - 0.15 M H_2SO_4

Titration Problems

1. Write and balance the chemical equation.
2. Calculate the moles of titrant used.

   $M_b \times V_b$
3. Use the mole ratio to determine moles of acid.
4. Calculate the molarity of the acid using moles from #3.

   n_a/V_a

Your turn!

- A volume of 18.28 mL of 0.1M NaOH was required to neutralize 25 mL of HCOOH (formic acid). What is the molarity of the formic acid?

- What is the molarity of a nitric acid solution if 43.33 mL of 0.1M KOH solution is needed to neutralize 20 mL of the acid solution?

Review Questions

- Why are there 3 legitimate models that describe acids and bases?
- Identify acids, bases, and conjugates:

$$HNO_2 + H_2O \rightleftharpoons NO_2^- + H_3O^+$$

- How do you determine the appropriate indicator for a titration?
- If 42 mL of a 3 M NaOH solution is used to titrate 200 mL of HNO_3, what is the molarity of HNO_3?