Chapter 8.7
Acid-Base Titration

Learning Goals: I will be able to **Calculate** the pH during various stages of acid-base titration

Acid-Base Titration

- **Titration** is used to determine the concentration of acid/base by adding base/acid of known concentration (**titrant)**.

- For most titration, the titrant is slowly added from a burette into a known volume of sample solution in a receiving flask.

- The titrant is added just until all the reactant in the sample is consumed (**equivalence point**).

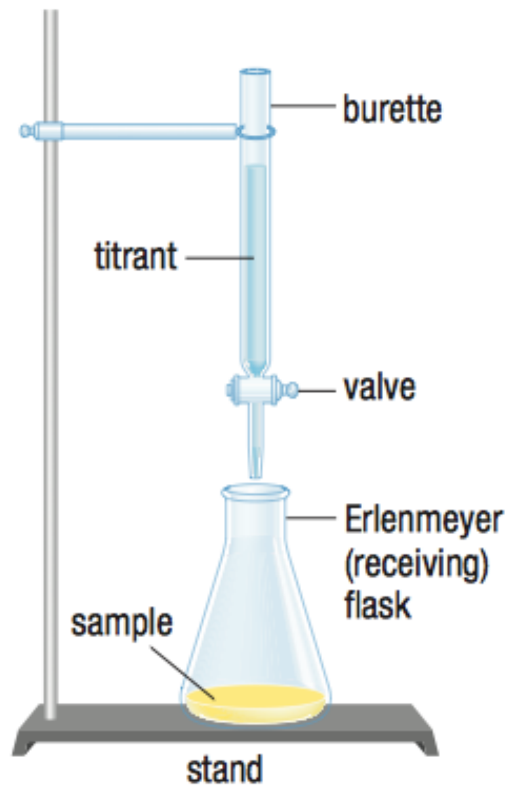


Figure 1 The burette contains the titrant. The Erlenmeyer flask contains the sample.

How do you know the equivalence point is reached?

- Before beginning an acid-base titration, we mix an appropriate acid-base indicator (substance that changes colour at a certain pH) with the sample.
- The **endpoint** of a titration occurs just as the indicator changes colour.

Titrations Involving Strong Acids and Strong Bases

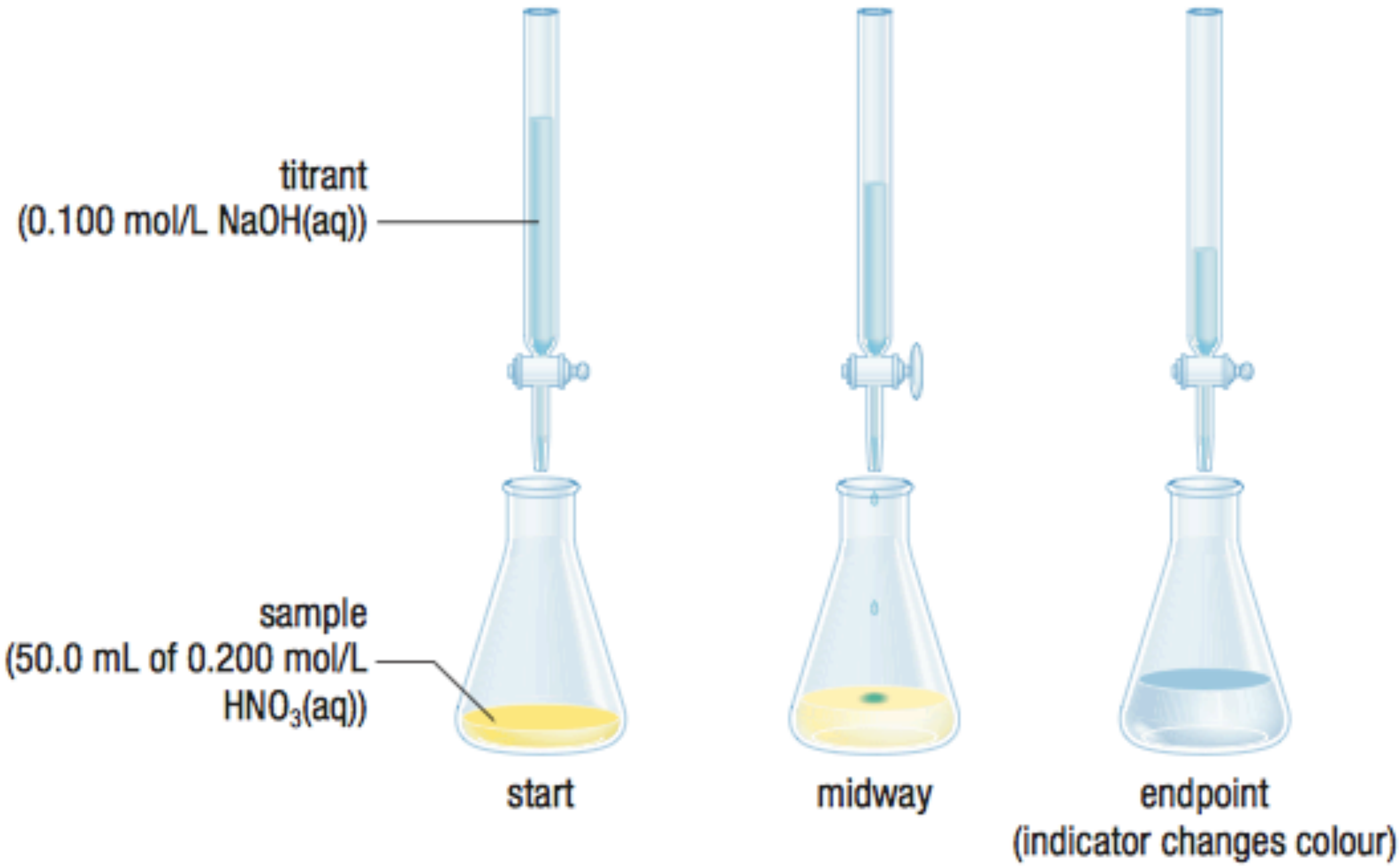
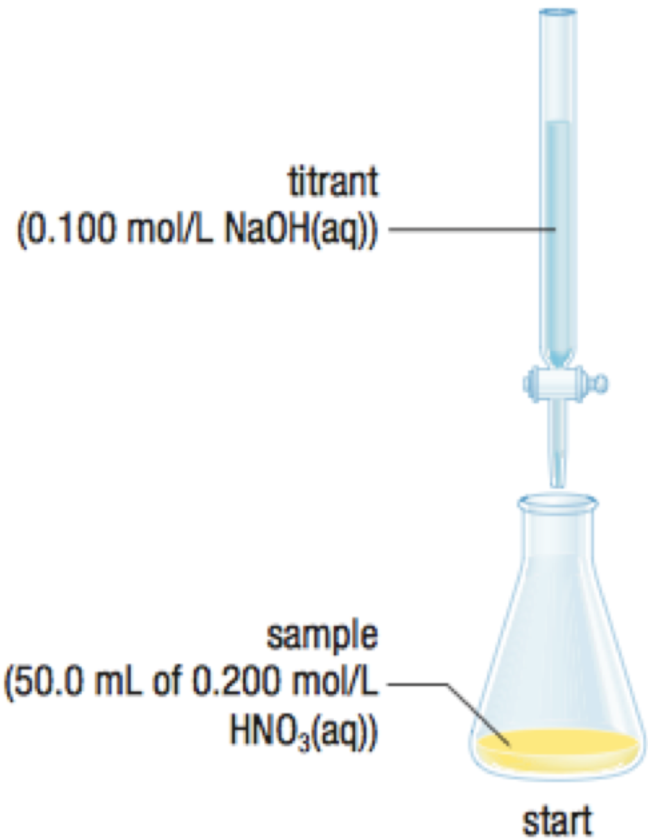


Figure 2 A typical titration of a strong acid with a strong base. The chosen indicator is yellow in an acidic solution and becomes blue in a basic solution.

Different Stages



Stage 1: Before Titrant is Added

- **pH = ? In receiving flask?**

Stage 2: After 10.0 mL of Titrant is Added

- **pH = ?**

Stage 3: After 50.0 mL of Titrant is Added

- **pH = ?**

Stage 4: After 100.0 mL of Titrant is Added
-- The Equivalence Point

- **pH = ?**

Stage 5: After 150.0 mL of Titrant is Added

- **pH = ?**

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pH Curves

- The results of these calculations may be illustrated in a graph of pH plotted against volume of titrant added (**pH curve**)
- A strong acid-strong base titration has equivalence point at pH 7

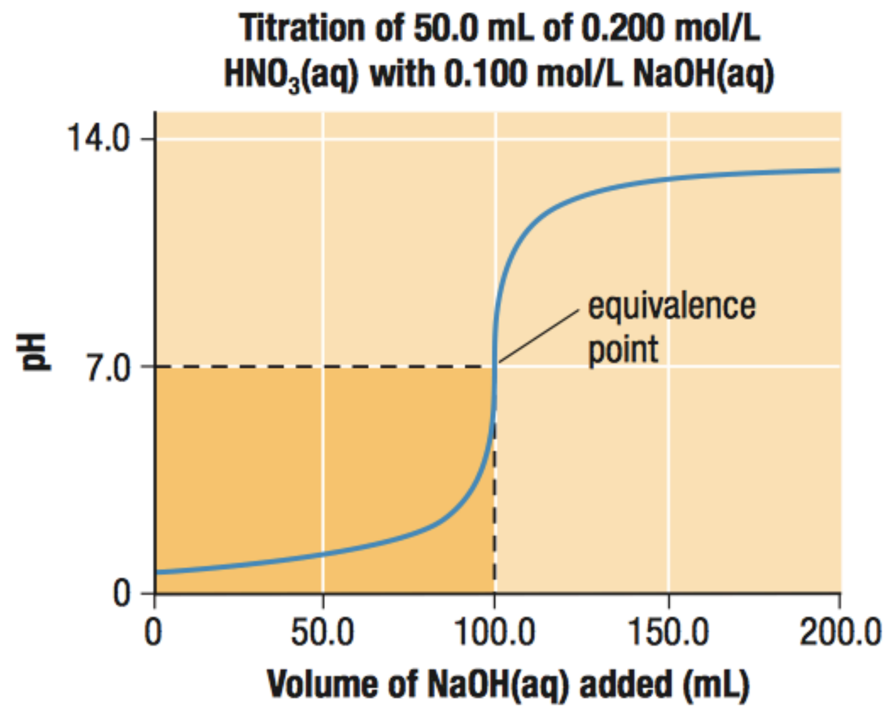


Figure 3 The pH curve for the titration of nitric acid with sodium hydroxide solution. Note that the equivalence point occurs when 100.0 mL NaOH(aq) has been added, the point where there is exactly enough OH^-(aq) to react with all the H^+(aq) originally present.

Strong acid-Strong Base Titration

- Before equivalence point, you may calculate $[H^+_{(aq)}]$ (and hence the pH) by dividing the remaining amount of hydrogen ions by the total volume of the solution in the receiving flask (in mL).
- At the equivalence point, the pH is always equal to 7.
- After the equivalence point, you may calculate $[OH^-_{(aq)}]$ by dividing the amount of excess hydroxide ions by the total volume of the solution in the receiving flask. Then obtain $[H^+_{(aq)}]$ from K_w, and calculate pH.

Strong Base-Strong Acid Titration

- Similar to that used in strong acid-strong base titration except that hydroxide ions are in excess before the equivalence point and hydrogen ions are in excess after the equivalence point.

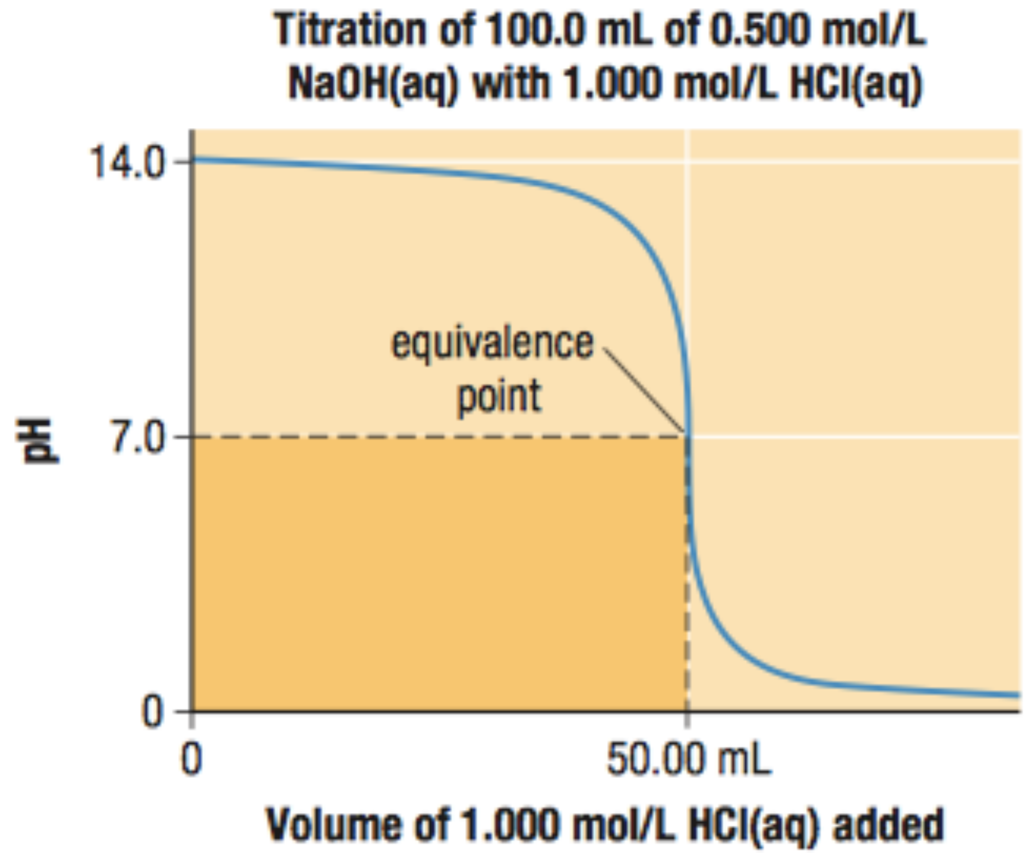


Figure 4 The pH curve for the titration of sodium hydroxide solution with hydrochloric acid.

Titrations Involving
Weak Acids and Strong Bases

- To calculate the $[H^+_{(aq)}]$, and pH after a certain amount of strong base has been added, we must deal with the weak acid ionization equilibrium.

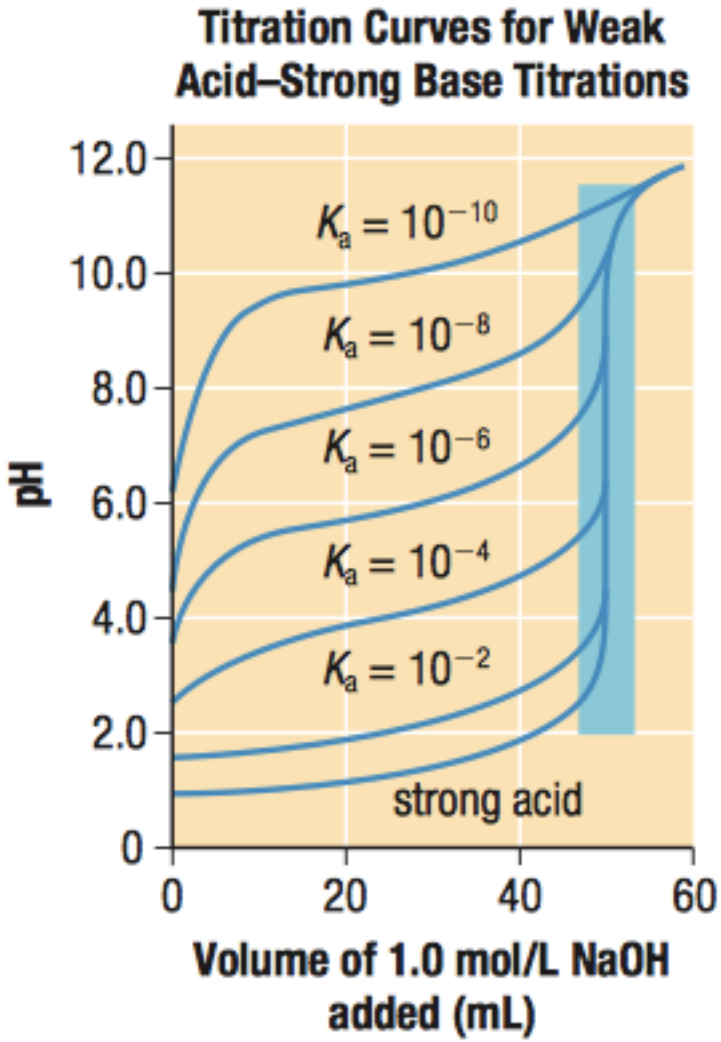
Practice:

A 20.00 mL sample of 0.600 mol/L ethanoic acid, $HC_2H_3O_{2(aq)}$ (a weak acid), is titrated with a standardized 0.300 mol/L solution of sodium hydroxide, $NaOH_{(aq)}$ (a strong base). Predict the amount of unreacted ethanoic acid and the pH of the solution

a) before titration begins
b) Before equivalentce point when 20.00mL of NaOH as been added
c) At the equivalence point when 40.00 mL of $NaOH_{(aq)}$ has been added
d) Beyond the equivalence point when a total of 60.00 mL of $NaOH_{(aq)}$ has been added

pH Curves for Weak Acid-Strong Base Titrations

- The equivalence point occurs when the same mole (n = cV) of titrant has been added.
- The weaker the acid, the higher the pH (pH > 7) value at the equivalence point.



Independent Practice

In a titration, 50.00 mL of 0.100 mol/L ethanoic acid, $HC_2H_3O_2(aq)$, is titrated with standardized 0.100 mol/L potassium hydroxide solution, KOH(aq). K/U T/I

(a) What is the amount of unreacted $HC_2H_3O_2(aq)$ and the pH of the sample before titration?

(b) What is the amount of unreacted ethanoic acid and the pH of the solution after 10.0 mL of base is added?

(c) What is the pH when 30.0 mL of base is added?

(d) What amount and volume of titrant must be added to reach the equivalence point?

(e) What is a good indicator for this titration? Why?

a) 2.873 b) 4.745 or 4.145 c) 4.569 d) 50.00 mL
e) pH = 8.72 Thymol blue (8.0 – 9.6) Yellow to blue

Weak Bases-Strong Acids Titrations

- The calculations are similar to those of weak acid-strong base titrations.

- The major difference is that the strong acid titrant is completely ionized and we have to consider the equilibrium of the weak base sample.

Weak base-Strong Acid Titrations

- Before titration begins, calculate the pH of the sample using the K_b of the weak base.

- At the equivalence point, hydrogen ions in the solution are the result of hydrolysis caused by the conjugate acid of the weak base.
  - Calculate the pH using the K_a of the conjugate acid.
  - The solution will be acidic: $pH < 7$

- Beyond the equivalence point, determine the pH of the solution by the amount of excess strong acid provided by the titrant.
  - Determine the pH from the $[H^+_{(aq)}]$ produced by the ionization of the strong acid.

Acid-Base Indicators

- We can make the equivalence point more visible by adding a few drops of an acid-base indicator to the sample.
- There are many different acid-base indicators that change colour (have endpoints) at different pH levels.
- Ideally, we want the endpoint of a titration to coincide with the equivalence point, thus alerting us that the equivalence point has been reached.

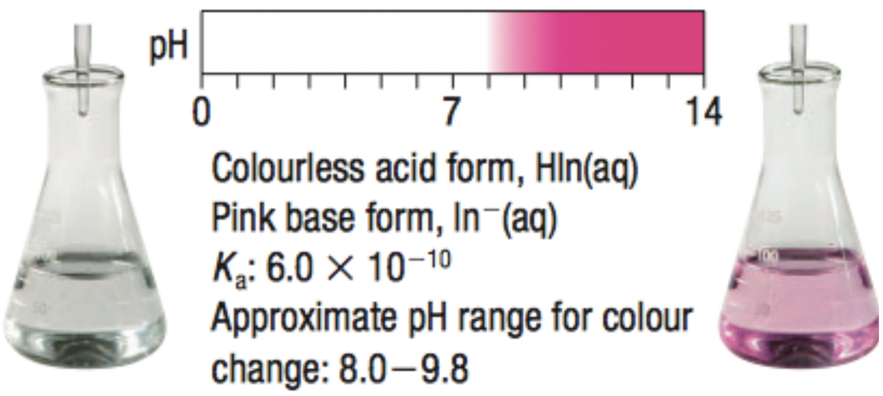


Figure 8 In an acid solution phenolphthalein indicator, HIn(aq), is colourless. When hydrogen ions are removed to give the base form, $In^-(aq)$, the colour changes to pink.

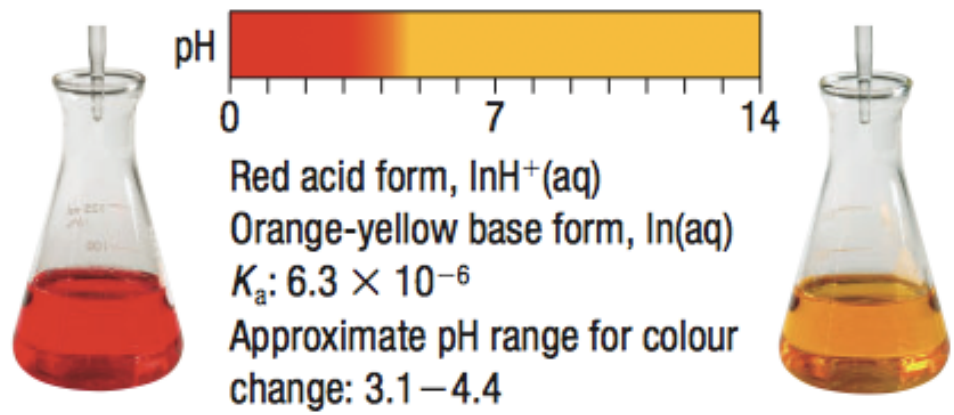


Figure 9 Methyl orange indicator is red in highly acidic solution.

Indicator	Low pH color	Transition pH range	High pH color
Gentian violet (Methyl violet 10B)	yellow	0.0–2.0	blue-violet
Leucomalachite green (first transition)	yellow	0.0–2.0	green
Leucomalachite green (second transition)	green	11.6–14	colorless
Thymol blue (first transition)	red	1.2–2.8	yellow
Thymol blue (second transition)	yellow	8.0–9.6	blue
Methyl yellow	red	2.9–4.0	yellow
Bromophenol blue	yellow	3.0–4.6	purple
Congo red	blue-violet	3.0–5.0	red
Methyl orange	red	3.1–4.4	yellow
Screened methyl orange (first transition)	red	0.0–3.2	grey
Screened methyl orange (second transition)	grey	3.2–4.2	green
Bromocresol green	yellow	3.8–5.4	blue
Methyl red	red	4.4–6.2	yellow
Azolitmin	red	4.5–8.3	blue
Bromocresol purple	yellow	5.2–6.8	purple
Bromothymol blue	yellow	6.0–7.6	blue
Phenol red	yellow	6.4–8.0	red
Neutral red	red	6.8–8.0	yellow
Naphtholphthalein	colorless to reddish	7.3–8.7	greenish to blue
Cresol Red	yellow	7.2–8.8	reddish-purple
Phenolphthalein	colorless	8.3–10.0	fuchsia
Thymolphthalein	colorless	9.3–10.5	blue
Alizarine Yellow R	yellow	10.2–12.0	red

Did You Learn?

- The progress of a titration is represented by plotting a pH curve showing the pH of the solution against the volume of titrant added.
- Strong acid-strong base titrations show a sharp change in pH near the equivalence point.
- In strong acid-strong base titrations, pH = 7 at the equivalence point because the pH is determine solely by the autoionization of water:
  - $[H^+_{(aq)}] = 1.0 \times 10^{-7}$ mol/L
- In weak acid-strong base titrations, pH > 7 at the equivalence point because of hydrolysis caused by the conjugate base of the weak acid.
- In weak base-strong acid titration, pH < 7 at the equivalence point because of hydrolysis caused by the conjugate acid of the weak base.
- When calculating pH values for a strong base-weak acid titration, perform stoichiometry first and then equilibrium.
- Indicators are often used to mark the equivalence point of an acid-base titration.
  - An indicator changes colour at its endpoint.
  - The goal is to have the endpoint and the equivalence point be as close as possible.

HOMEWORK

Required Reading:

p. 540 – 557

(remember to supplement your notes!)

Questions:

P. 547 #1, 2

P. 554 #1, 2

P. 557 #1-8