

Name: Solutions

Date: _____

Period: _____

Chemistry 30: Acids and Bases Practice Problems

Properties of Acids and Bases

1. List four characteristic properties of acids and of bases.

Acids: sour taste, react with metals & carbonates, turns litmus red
Bases: slippery feel, bitter taste, react with acids, turns litmus blue

2. Classify each of the following as either an acid or a base:

- | | | | |
|--|------|------------------------|------|
| a. The substance has a bitter taste | BASE | f. NH_3 | BASE |
| b. H_2SO_4 | ACID | g. has a slippery feel | BASE |
| c. litmus paper dipped in this turns red | ACID | h. has a sour taste | ACID |
| d. reacts with active metals to produce hydrogen gas | ACID | i. a proton donor | ACID |
| e. KOH | BASE | j. a proton acceptor | BASE |

3. Copy the chart and fill it in with definitions.

	Acid	Base
Arrhenius	contains H and dissolves to produce H^+	contains OH and dissolves to produce OH^-
Brønsted-Lowry	H^+ donor in rxns	H^+ acceptor in rxns

4. Which of the following could be considered Brønsted-Lowry bases?

- | | | | | | |
|------------------|-----|----------------------------|----|-------------------------|-----|
| a. Br^- | yes | c. H_3PO_4 | no | e. H_2O | yes |
| b. Li^+ | no | d. NH_4^+ | no | f. NH_2^- | yes |

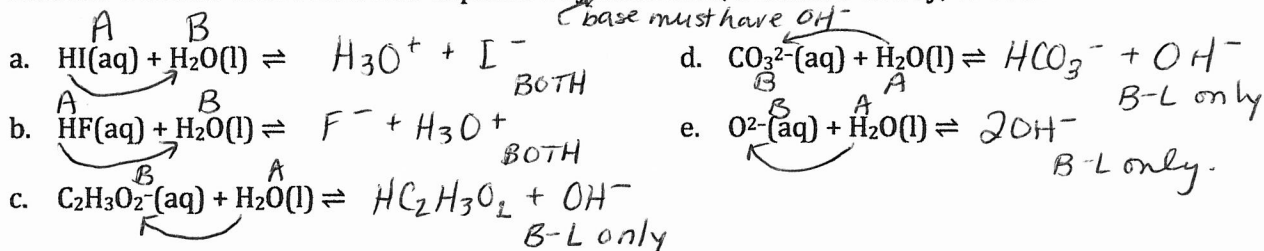
→ must be able to get an H^+

Conjugate Acid-Base Pairs

5. Identify the acid, base, conjugate acid and conjugate base for each of the following.

- | | | | | | | | |
|----|--|-----|--------------------------------|----------------------|-----------------------------------|-----|---|
| a. | A | B | CA | CB | | | |
| | $\text{HClO}_4(\text{aq})$ | $+$ | $\text{H}_2\text{O}(\text{l})$ | \rightleftharpoons | $\text{H}_3\text{O}^+(\text{aq})$ | $+$ | $\text{ClO}_4^-(\text{aq})$ |
| b. | A | B | CA | CB | | | |
| | $\text{H}_2\text{SO}_3(\text{aq})$ | $+$ | $\text{H}_2\text{O}(\text{l})$ | \rightleftharpoons | $\text{H}_3\text{O}^+(\text{aq})$ | $+$ | $\text{HSO}_3^-(\text{aq})$ |
| c. | A | B | CA | CB | | | |
| | $\text{HC}_2\text{H}_3\text{O}_2(\text{aq})$ | $+$ | $\text{H}_2\text{O}(\text{l})$ | \rightleftharpoons | $\text{H}_3\text{O}^+(\text{aq})$ | $+$ | $\text{C}_2\text{H}_3\text{O}_2^-(\text{aq})$ |
| d. | A | B | CA | CB | | | |
| | $\text{H}_2\text{S}(\text{g})$ | $+$ | $\text{H}_2\text{O}(\text{l})$ | \rightleftharpoons | $\text{H}_3\text{O}^+(\text{aq})$ | $+$ | $\text{HS}^-(\text{aq})$ |
| e. | A | B | CA | CB | | | |
| | $\text{HSO}_3^-(\text{aq})$ | $+$ | $\text{H}_2\text{O}(\text{l})$ | \rightleftharpoons | $\text{H}_3\text{O}^+(\text{aq})$ | $+$ | $\text{SO}_3^{2-}(\text{aq})$ |
| f. | B | A | CA | CB | | | |
| | $\text{NH}_3(\text{g})$ | $+$ | $\text{H}_2\text{O}(\text{l})$ | \rightleftharpoons | $\text{NH}_4^+(\text{aq})$ | $+$ | $\text{OH}^-(\text{aq})$ |
| g. | A | B | CB | CA | | | |
| | $\text{HF}(\text{aq})$ | $+$ | $\text{HSO}_3^-(\text{aq})$ | \rightleftharpoons | $\text{F}^-(\text{aq})$ | $+$ | $\text{H}_2\text{SO}_3(\text{aq})$ |
| h. | A | B | CB | CA | | | |
| | $\text{HNO}_2(\text{aq})$ | $+$ | $\text{HS}^-(\text{aq})$ | \rightleftharpoons | $\text{NO}_2^-(\text{aq})$ | $+$ | $\text{H}_2\text{S}(\text{aq})$ |

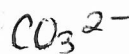
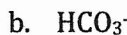
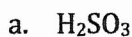
6. Complete the equation for the reaction of each of the following with water. Then:
- Indicate whether the ion or molecule is an acid or base; and,
 - Indicate whether each reaction is explained by Arrhenius, Brønsted-Lowry, or both.



7. Define the term **amphoteric**. Give an example of an amphoteric compound.

amphoteric compounds can act as either an acid or a base, depending on what they are combined with (e.g. H₂O, HCO₃⁻, H₂PO₄⁻)

8. Write the formula for the conjugate base of:



1. What are the conjugate bases of these acids?

remove one H⁺

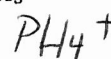
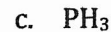
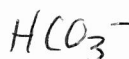
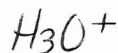
original acid	conjugate base
HNO ₃	<i>NO₃⁻</i>
H ₂ O	<i>OH⁻</i>
H ₃ O ⁺	<i>H₂O</i>
H ₂ SO ₄	<i>HSO₄⁻</i>
HBr	<i>Br⁻</i>
HCO ₃ ⁻	<i>CO₃²⁻</i>

9. What are the conjugate acids of these bases?

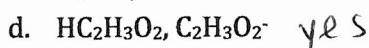
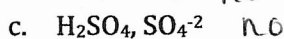
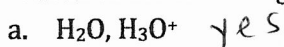
add one H⁺

original base	conjugate acid
OH ⁻	<i>H₂O</i>
H ₂ O	<i>H₃O⁺</i>
HCO ₃ ⁻	<i>H₂CO₃</i>
SO ₄ ²⁻	<i>HSO₄⁻</i>
ClO ₄ ⁻	<i>HClO₄</i>

10. Write the formula for the conjugate acid of:



11. Which of the following represent conjugate acid-base pairs?



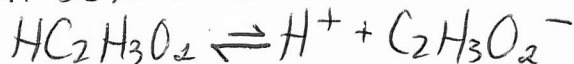
↳ different by ONE H⁺

Strength of Acids and Bases

12. What is the difference between a strong acid and a weak acid? Give an example of both.

A strong acid ionizes completely in a solution HCl → H⁺ + Cl⁻

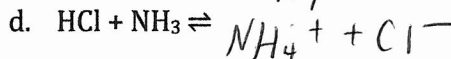
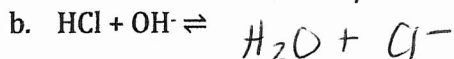
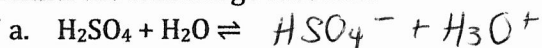
A weak acid ionizes less than 50% in solution



13. Explain the difference between the terms "concentrated" and "dilute" with respect to both strong and weak acids.

Concentrated $\left\{ \begin{array}{l} \text{strong} \rightarrow \text{lots of } H^+ \text{ and } A^- \text{ ions} \\ \text{weak} \rightarrow \text{lots of HA molecules and } H^+ \text{ and } A^- \text{ ions} \end{array} \right.$
 Weak $\left\{ \begin{array}{l} \text{strong} \rightarrow \text{a few } H^+ \text{ and } A^- \text{ ions} \\ \text{weak} \rightarrow \text{a few HA molecules and even fewer } H^+ \text{ and } A^- \text{ ions} \end{array} \right.$

14. Finish the following reactions:

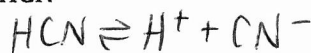


15. Write a dissociation equation for each acid or base in an aqueous solution. Remember to use a single arrow (\rightarrow) for strong acids and bases and a double arrow (\rightleftharpoons) for weak acids and bases.

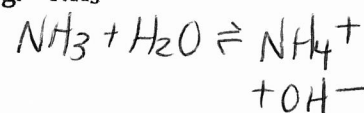
a. HCl



d. HCN



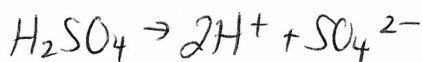
g. NH_3



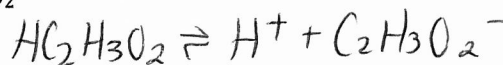
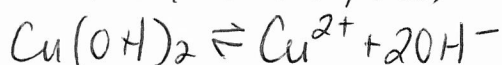
b. NaOH



e. H_2SO_4



c. $Cu(OH)_2$ (not technically weak) f. $HC_2H_3O_2$



16. Write balanced equations for:

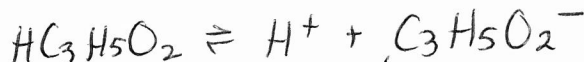
a. The dissociation of calcium hydroxide



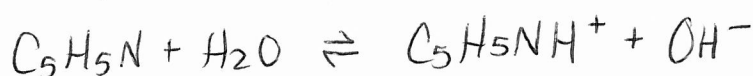
b. The ionization of nitric acid



c. The ionization of propionic acid



d. The dissociation of pyridine



K_a and K_b

17. Given the following balanced ionization reactions for the following weak acids and bases, write the K_a or K_b expressions for each.

a. ascorbic acid: $HC_6H_7O_6(aq) \rightleftharpoons H^+(aq) + C_6H_7O_6^-(aq)$

$$K_a = \frac{[H^+][C_6H_7O_6^-]}{[HC_6H_7O_6]}$$

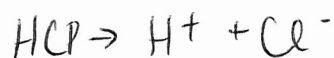
b. boric acid: $H_3BO_3(aq) \rightleftharpoons H^+(aq) + H_2BO_3^-(aq)$

$$K_a = \frac{[H^+][H_2BO_3^-]}{[H_3BO_3]}$$

c. methylamine: $CH_3NH_2(aq) + H_2O(l) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$

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

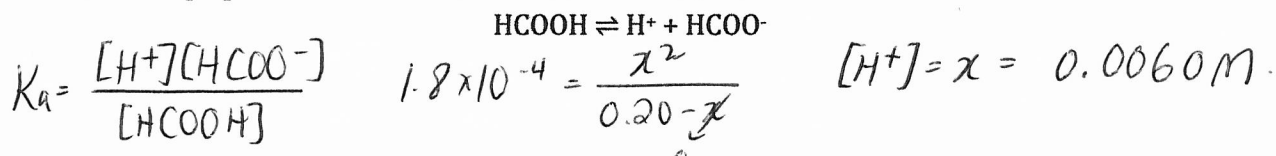
18. Calculate $[H^+]$ for a $1.0 \times 10^{-3} M$ solution of hydrochloric acid.



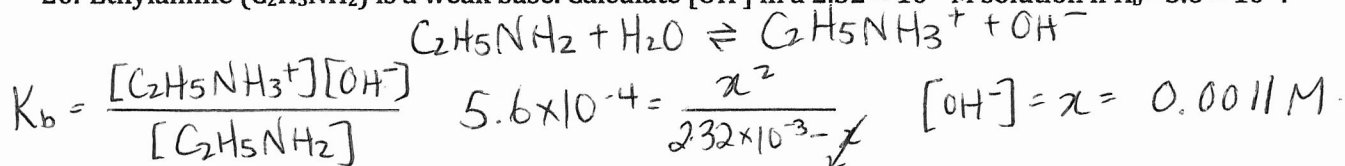
$$1.0 \times 10^{-3} \quad 1.0 \times 10^{-3} \quad 1.0 \times 10^{-3}$$

$$[H^+] = 1.0 \times 10^{-3} M$$

19. Calculate $[H^+]$ in a 0.20 M solution of formic acid. $K_a = 1.8 \times 10^{-4}$



20. Ethylamine ($C_2H_5NH_2$) is a weak base. Calculate $[OH^-]$ in a 2.32×10^{-3} M solution if $K_b = 5.6 \times 10^{-4}$.



21. Calculate $[OH^-]$ in a solution containing 100.0 g of potassium hydroxide in 2.50 L solution.

Potassium hydroxide is a strong base.

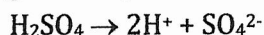
$$M_{KOH} = 56.11 \text{ g/mol}$$

$$n = \frac{m}{M} = \frac{100.0}{56.11} = 1.78 \text{ mol}$$

$$C = \frac{n}{V} = \frac{1.78}{2.50} = 0.712 M$$

$$[KOH] = [OH^-] = 0.712 M$$

22. A solution is prepared that contains 0.0445 mole of sulfuric acid in a total solution volume of 12.1 L. Sulfuric acid typically undergoes complete ionization according to the equation:

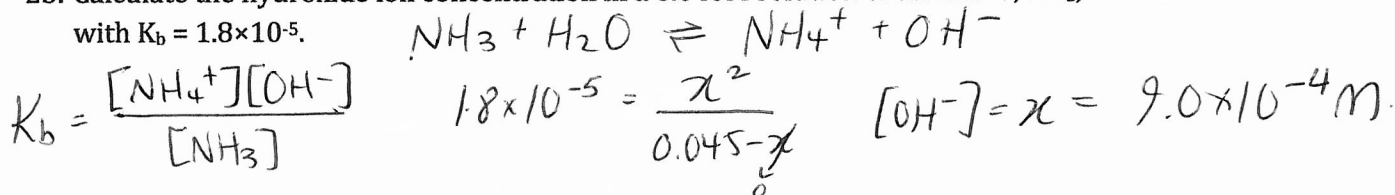


Calculate $[H^+]$. Sulfuric acid is a strong acid.

$$[H_2SO_4] = \frac{n}{V} = \frac{0.0445}{12.1} = 0.00368 M$$

$$[H^+] = 2[H_2SO_4] = 0.00736 M$$

23. Calculate the hydroxide ion concentration in a 0.045 M solution of ammonia, NH_3 , a weak base with $K_b = 1.8 \times 10^{-5}$.



pH and pOH

24. Determine pH and pOH for each concentration.

a. $[H^+] = 0.023 M$

$$pH = 1.6 \quad pOH = 12.4$$

b. $[H^+] = 6.6 \times 10^{-6} M$

$$pH = 5.2 \quad pOH = 8.8$$

c. $[OH^-] = 0.0334 M$

$$pOH = 1.48 \quad pH = 12.52$$

d. $[OH^-] = 9.01 \times 10^{-4} M$

$$pOH = 3.05 \quad pH = 10.95$$

e. $[H^+] = 8.96 \times 10^{-3} M$

$$pH = 2.05 \quad pOH = 11.95$$

25. Determine $[H^+]$ and $[OH^-]$ for each pH value.

a. pH = 2.5

$$[H^+] = 0.0032 M \quad [OH^-] = 3.2 \times 10^{-12} M$$

b. pH = 11.3

$$[H^+] = 5.0 \times 10^{-12} M \quad [OH^-] = 2.0 \times 10^{-3} M$$

c. pOH = 4.6

$$[OH^-] = 2.5 \times 10^{-5} M \quad [H^+] = 4.0 \times 10^{-10} M$$

d. pOH = 8.7

$$[OH^-] = 2.0 \times 10^{-9} M$$

$$[H^+] = 5.0 \times 10^{-6} M$$

e. pH = 7.65

$$[H^+] = 2.2 \times 10^{-8} M$$

$$[OH^-] = 4.5 \times 10^{-7} M$$

26. 4.52 g of calcium hydroxide, a strong base, is dissolved in 1.00 L of water. What is the pH of the resulting solution?

$$M_{Ca(OH)_2} = 74.10 \text{ g/mol}$$

$$C = \frac{m}{M \cdot V} = \frac{4.52}{(74.10)(1.00)} = 0.0610 M$$



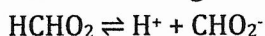
$$[OH^-] = 2[Ca(OH)_2] = 0.122 M$$

$$pOH = -\log[OH^-] = 0.914$$

$$pH = 13.0$$

27. Methanoic acid ($HCHO_2$) is a weak acid that undergoes the following ionization reaction:

FORMIC



If 25.0 g of methanoic acid is dissolved to make 0.500 L of solution, what is the pH?

$$[HCHO_2] = 1.09 M$$

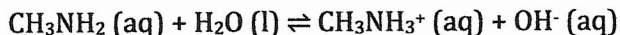
$$K_a = \frac{[H^+][CHO_2^-]}{[HCHO_2]}$$

$$[H^+] = x = 0.014 M$$

$$1.7 \times 10^{-4} = \frac{x^2}{1.09}$$

$$pH = 1.9$$

28. A weak base, methylamine, is dissolved in water according to the following dissociation reaction:



If 0.00355 moles of methylamine is present in 1.25 L of solution, what is the pH?

$$[CH_3NH_2] = 0.00284 M$$

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

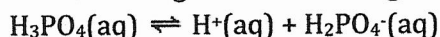
$$[OH^-] = x = 0.0011 M$$

$$4.4 \times 10^{-4} = \frac{x^2}{0.00284}$$

$$pOH = 3.0$$

$$pH = 11.0$$

29. Phosphoric acid is a weak acid that undergoes the following ionization reaction:



If there is 1.32×10^{-2} mol of phosphoric acid present in 875 mL of solution, calculate the concentration of hydrogen ions, H^+ , in solution. K_a for phosphoric acid is 7.0×10^{-3} .

$$[H_3PO_4] = 0.0151 M$$

$$K_a = \frac{[H^+][H_2PO_4^-]}{[H_3PO_4]}$$

$$[H^+] = x = 1.1 \times 10^{-4} M$$

$$7.0 \times 10^{-3} = \frac{x^2}{0.0151}$$

30. A solution of acetic acid contains 12.0 g of $HC_2H_3O_2$ in 500 mL of solution. Calculate $[H^+]$.

$$[HC_2H_3O_2] = 0.400 M$$

$$K_a = \frac{[H^+][C_2H_3O_2^-]}{[HC_2H_3O_2]}$$

$$[H^+] = x = 0.0026 M$$

$$1.7 \times 10^{-5} = \frac{x^2}{0.400}$$

31. Why would the pH be different for a 0.05 M solution of HCl and a 0.05 M solution of acetic acid?

What is the difference in pH?

HCl
 $[H^+] = 0.05 M$

$HC_2H_3O_2$
 $1.7 \times 10^{-5} = \frac{x^2}{0.05}$ $[H^+] = x = 9.2 \times 10^{-4} M$

$K_a = \frac{[H^+][C_2H_3O_2^-]}{[HC_2H_3O_2]}$

one is strong (completely ionizes) and the other is weak (ionizes very little)

32. Calculate the pH of a 0.00345 M solution of aniline, $C_6H_5NH_2$, a weak base.

$K_b = \frac{[C_6H_5NH_3^+][OH^-]}{[C_6H_5NH_2]}$
 $4.2 \times 10^{-10} = \frac{x^2}{0.00345}$

$[OH^-] = x = 1.2 \times 10^{-6} M$
 $pOH = 5.9$ $pH = 8.1$

33. Calculate the $[H^+]$ in a solution in which $[OH^-] = 2.0 \times 10^{-2} M$. Is this solution acidic, neutral, or basic?

$[H^+] = \frac{K_w}{[OH^-]} = \frac{10^{-14}}{2.0 \times 10^{-2}} = 5.0 \times 10^{-13} M$
basic

34. Find pH of each of the following. Identify each as an acidic, neutral, or basic.

a. $[H^+] = 0.0015 M$ $pH = 2.8$ acidic

b. $[H^+] = 5.0 \times 10^{-9} M$ $pH = 8.3$ basic

c. $[OH^-] = 3.27 \times 10^{-4} M$ $pOH = 3.49$ basic
 $pH = 10.51$

d. $[OH^-] = 1.00 \times 10^{-12} M$ $pOH = 12$ acidic
 $pH = 2$

35. What is the pH, pOH, $[H^+]$, and $[OH^-]$ for a $3.2 \times 10^{-4} M$ solution of sodium hydroxide? NaOH

$[OH^-] = 3.2 \times 10^{-4} M$ $pOH = 3.5$

$[H^+] = 3.2 \times 10^{-11} M$ $pH = 10.5$

36. What is the pH, pOH, $[H^+]$, and $[OH^-]$ for a $9.20 \times 10^{-3} M$ solution of sulfuric acid? H_2SO_4

$[H^+] = 0.0184 M$ $pH = 1.74$

$[OH^-] = 5.43 \times 10^{-13} M$ $pOH = 12.26$

Neutralization

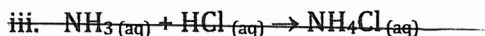
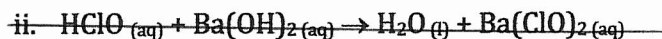
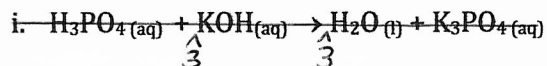
37. For each reaction:

a. Balance the reaction;

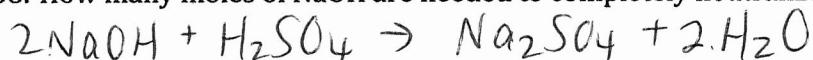
b. Write the complete ionic equation and the net ionic equation; and,

c. List the spectator ions.

Remember that if an acid or base is not strong, it is written as a molecule, not as an ion.

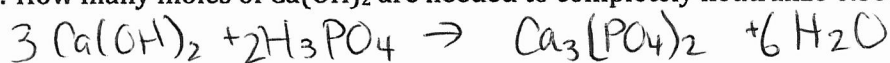


38. How many moles of NaOH are needed to completely neutralize 0.432 mol of H_2SO_4 ?



$$0.432 \text{ mol H}_2\text{SO}_4 \times \frac{2 \text{ mol NaOH}}{1 \text{ mol H}_2\text{SO}_4} = 0.864 \text{ mol NaOH}$$

39. How many moles of $\text{Ca}(\text{OH})_2$ are needed to completely neutralize 0.530 mol of H_3PO_4 ?



$$0.530 \text{ mol H}_3\text{PO}_4 \times \frac{3 \text{ mol Ca}(\text{OH})_2}{2 \text{ mol H}_3\text{PO}_4} = 0.795 \text{ mol Ca}(\text{OH})_2$$

40. It takes 38 mL of 0.75 M NaOH solution to completely neutralize 155 mL of a sulfuric acid solution (H_2SO_4). What is the concentration of the H_2SO_4 solution?

$$n_{\text{NaOH}} = CV = (0.75)(0.038) = 0.0285 \text{ mol}$$

$$[\text{H}_2\text{SO}_4] = \frac{n}{V}$$

$$n_{\text{H}_2\text{SO}_4} = 0.0285 \text{ mol NaOH} \times \frac{1 \text{ mol H}_2\text{SO}_4}{2 \text{ mol NaOH}} = 0.0143 \text{ mol}$$

$$= \frac{0.0143}{0.155}$$

$$= 0.0923 \text{ M}$$

41. It takes 12.5 mL of a 0.30 M CH_3COOH solution to completely neutralize 285 mL of NaOH solution. What is the concentration of the NaOH solution?

$$[\text{NaOH}] = 0.013 \text{ M}$$

42. It takes 50 mL of 0.500 M KOH solution to completely neutralize 125 mL of sulfuric acid solution. What is the pH of the sulfuric acid solution?

$$[\text{H}_2\text{SO}_4] = 0.10 \text{ M}$$

$$\text{pH} = 0.70$$

43. What is the pH of a NaOH solution if it takes 100.0 mL to neutralize 150.0 mL of 3.00 M H_2CO_3 solution?

$$[\text{NaOH}] = 9.0 \text{ M} \quad \text{pOH} = -0.95$$
$$\text{pH} = 14.95$$

44. Titration reveals that 11.6 mL of 3.0 M sulfuric acid are required to neutralize the sodium hydroxide in 25.00 mL of NaOH solution. What is the molarity of the NaOH solution?

$$[\text{NaOH}] = 2.78 \text{ M}$$

45. When 34.2 mL of a 1.02 M NaOH solution is added from a buret to 25.00 mL of a phosphoric acid solution that contains phenolphthalein, the solution changes from colorless to pink. What is the molarity of the phosphoric acid?

$$[\text{H}_3\text{PO}_4] = 0.465 \text{ M}$$