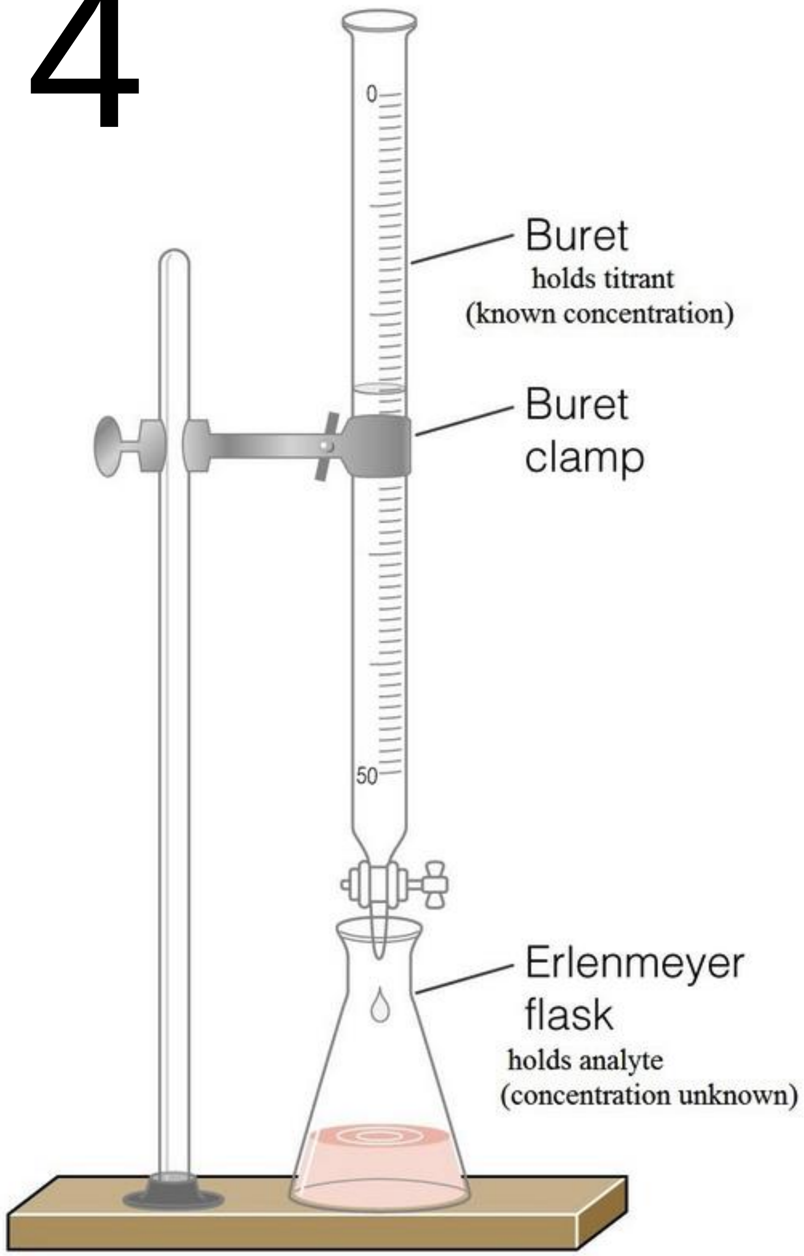
Chapter 4

Molarity and Titration
Dr. Stone
CHEM 1100



Molarity, M

Molarity is the moles of solute per liter of solution.

$$\frac{\text{Moles}}{\text{L}} = \text{M}$$

Moles = Molarity x vol (make sure volume is in L)

Volume = moles/Molarity

What is the molarity of a solution made by adding 11 grams of sodium chloride to 500 mL of water?

A. 3.8×10^{-1} B. 5.0×10^{-2} C. 4.27×10^{-1} D. 2.9×10^{1}

$$11\text{ g NaCl} \times \frac{1\text{ mole NaCl}}{58.5\text{g}} \times \frac{1}{500\text{ mL}} \times \frac{1000\text{ mL}}{\text{L}} = 3.8 \times 10^{-1}$$

1. What volume (in mL) of 0.15M solution of glucose ($C_6H_{12}O_6$) has 3×10^{-3} moles of glucose?

a. 2×10^{1} mL

b. 2×10^{-2} mL

c. 5×10^{1} mL

d. 5×10^{4} mL

e. None of these

Volume = moles/Molarity

$$\frac{3.0 \times 10^{-3} \text{ moles of glucose}}{0.15 \text{ moles/L}} \times \frac{1000\text{mL}}{\text{L}} = 2 \times 10^{1} \text{ mL}$$

2. How many moles of potassium phosphate are in 23.45 mL of a 0.143 M solution of potassium phosphate?

a. 3.35 moles
b. 3.35×10^{-3} moles
c. 6.10×10^{-3} moles
d. 6.1 moles
e. None of these

Molarity x volume = moles

$$23.45 \text{ mL} \times \frac{1\text{L}}{1000\text{mL}} \times \frac{0.143 \text{ moles}}{\text{L}} = 3.35 \times 10^{-3} \text{ moles}$$

Titration of KHP with NaOH

$KC_8H_5O_{4(aq)}$ + $NaOH_{(aq)}$ —> $H_20_{(l)}$ + $KNaC_8H_4O_{4(aq)}$
acid + base —> water + salt

<u>Balanced Ionic equation:</u>
$K^+_{(aq)} + C_8H_5O_4-_{(aq)} + Na^+_{(aq)} + OH^-_{(aq)}$ —> $H_20_{(l)} + K^+_{(aq)} + Na^+_{(aq)} + C_8H_4O_4^{-2}{}_{(aq)}$

What is the same for both the reactants and the products?
$K^+_{(aq)} + C_8H_5O_4-_{(aq)} + Na^+_{(aq)} + OH^-_{(aq)}$ —> $H_20_{(l)} + K^+_{(aq)} + Na^+_{(aq)} + C_8H_4O_4^{-2}{}_{(aq)}$

What is different? What changes?
$K^+_{(aq)} + C_8H_5O_4-_{(aq)} + Na^+_{(aq)} + OH^-_{(aq)}$ —> $H_20_{(l)} + K^+_{(aq)} + Na^+_{(aq)} + C_8H_4O_4^{-2}{}_{(aq)}$

<u>Net ionic equation (remove spectators)</u>
$C_8H_5O_4-_{(aq)} + OH^-_{(aq)}$ —> $H_20_{(l)} + C_8H_4O_4^{-2}{}_{(aq)}$

Titration of KHP with NaOH

It takes 32.56 mL of a sodium hydroxide solution to reach the end point of a titration of 25.00 mL of KHP. The concentration of KHP is 40.84g/L. What is the molarity of a sodium hydroxide solution?

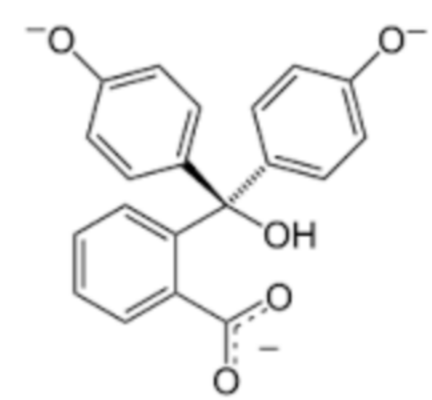
$KC_8H_5O_{4(aq)}$ + $NaOH_{(aq)}$ —> $NaKC_8H_5O_{4(aq)}$ + $H_20_{(l)}$

End point is when the moles of KHP = moles of NaOH

Use an indicator to detect a very slight excess of hydroxide ions.

Phenolphthalein turns
pink with excess base
Use volume of NaOH at
The end point to determine
The molarity of NaOH.

Phenolphthalein is a chemical compound with the formula $C_{20}H_{14}O_4$ and is often written as "HIn" or "phph" in shorthand notation. **Phenolphthalein** is often used as an indicator in acid–base titrations. For this application, it turns colorless in acidic solutions and pink in basic solutions.



Phenolphthalein - Wikipedia
https://en.wikipedia.org/wiki/Phenolphthalein

Titration of KHP with NaOH

It takes 32.56 mL of a sodium hydroxide solution to reach the end point of a titration of 25.00 mL of KHP. The concentration of KHP is 40.84g/L. What is the molarity of a sodium hydroxide solution?

$KC_8H_4O_{(aq)}$ + $NaOH_{(aq)}$ —> $NaKC_8H_4O_{(aq)}$ + $H_20_{(l)}$

End point is when the moles of KHP = mole of NaOH

Need: $\frac{\text{moles of NaOH}}{\text{volume of NaOH}}$

Have:

1. moles of NaOH = moles of KHP at end point
2. Volume of NaOH at the endpoint

Determine

1. moles of KHP in the flask (= moles of NaOH)
2. Moles NaOH/vol NaOH at endpoint = Molarity of NaOH

Moles of KHP = volume x Molarity KHP

Convert 40.84g/L to moles per liter:

$$\frac{40.84\ \text{g KHP}}{\text{L}} \times \frac{1\ \text{mole}}{204.2\ \text{g}} = 2.000 \times 10^{-1}\ \text{M KHP}$$

Volume KHP x M KHP = moles KHP

$$25.00\ \text{mL KHP} \times \frac{1\ \text{L}}{1000\ \text{mL}} \times \frac{2.000 \times 10^{-1}\ \text{moles KHP}}{\text{L}} = 5.000 \times 10^{-3}\ \text{moles KHP}$$

At the End point: 5.000×10^{-3} moles KHP = 5.000×10^{-3} moles NaOH

Volume of NaOH at endpoint = 32.56 ml

$$\text{Molarity of NaOH} = \frac{5.000 \times 10^{-3}\ \text{moles NaOH}}{32.56\ \text{mL}} \times \frac{1000\ \text{mL}}{\text{L}} = 1.536 \times 10^{-1}\ \text{M}$$

Titration of KHP with NaOH

It takes 22.12 mL of a sodium hydroxide solution to reach the end point of a titration of 20.00 mL of KHP. The concentration of KHP is 20.11g/L. What is the molarity of a sodium hydroxide solution?

A. 8.904×10^{-2}M B. 1.123×10^{1}M C. 1.089×10^{-1}M
D. 9.18M E. None of these

Titration of KHP with NaOH

It takes 22.12 mL of a sodium hydroxide solution to reach the end point of a titration of 20.00 mL of KHP. The concentration of KHP is 20.11g/L. What is the molarity of a sodium hydroxide solution?

A. 1.089×10^{-1}M   B. 1.123×10^{1}M   C. 8.904×10^{-2}M D. 9.18M   E. None of these

$KC_8H_4O_{(aq)}$ + $NaOH_{(aq)}$ —> $NaKC_8H_4O_{(aq)}$ + $H_20_{(l)}$

End point is when the moles of KHP = mole of NaOH

Need: $\frac{\text{moles of NaOH}}{\text{volume of NaOH}}$

Have: moles of NaOH = moles of KHP at end point

Moles of KHP = volume x Molarity KHP

Convert 20.11g/L to moles per liter:

$\frac{\_\_\_\_\_\_\,g}{L} \times \frac{1\ \text{mole}}{204.2\ g} = \_\_\_\_\_\_\_\_\_\_\_\_$ M KHP

Volume KHP x M KHP = moles KHP

$\times \frac{1\ L}{1000\ mL} \times \frac{\_\_\_\_\_\_\ \text{moles KHP}}{L} = 5.000 \times 10^{-3}$ moles KHP = 5.000×10^{-3} moles NaOH

Volume of NaOH at endpoint =   .

Molarity of NaOH = $\frac{\text{moles NaOH}}{\text{Endpoint mL}} \times \frac{1000\ mL}{L}$ =

Titration of KHP with NaOH

It takes 22.12 mL of a sodium hydroxide solution to reach the end point of a titration of 20.00 mL of KHP. The concentration of KHP is 20.11g/L. What is the molarity of a sodium hydroxide solution?

$KC_8H_4O_{(aq)}$ + $NaOH_{(aq)}$ —> $NaKC_8H_4O_{(aq)}$ + $H_20_{(l)}$

End point is when the moles of KHP = mole of NaOH

Need: $\frac{\text{moles of NaOH}}{\text{volume of NaOH}}$

Have: moles of NaOH = moles of KHP at end point

Moles of KHP = volume x Molarity KHP

Convert 20.11g/L to moles per liter:

$\frac{20.11\ g}{L} \times \frac{1\ mole}{204.2\ g}$ = __0.09848____M KHP

Volume KHP x M KHP = moles KHP

$20.00mL \times \frac{1\ L}{1000\ mL} \times \frac{0.09848\ moles\ KHP}{L} = 1.9696 \times 10^{-3}$ moles KHP $= 1.9696 \times 10^{-3}$ moles NaOH

Volume of NaOH at endpoint = 22.12 mL

Molarity of NaOH $= \frac{1.9696 \times 10^{-3}\ moles/L\ NaOH}{22.12\ mL} \times \frac{1000\ mL}{L} = 8.904 \times 10^{-2}M$

A. 1.089×10^{-1}M B. 1.123×10^{1}M C. 8.904×10^{-2}M D. 9.18M E. None of these

Always soluble	Soluble with exceptions	Insoluble Except	Always Insoluble
Alkali earth metal ions	Halides except Mercury(I) Lead(II) Silver	Hydroxides except Barium, Calcium and Strontium	All other ions
Ammonia	Sulfates except Calcium, Barium, Strontium, Lead (II), Mercury(I)		
Nitrates, nitrites			
Chlorate, perchlorate			
Acetates			

Naming can be a challenge

Ammonium ion: NH_4^+

Ammonia (the molecule) NH_3

Mercury(I) is Hg_2^{+2}

Mercury(II) is Hg^{+2}

Silver is only Ag^+ so we don’t use Roman numerals

Zinc is only Zn^{+2}, so we don’t use Roman numerals.

Always soluble	**Soluble with exceptions**	**Insoluble Except**	**Always Insoluble**
Alkali earth metal ions Li^+, Na^+, K^+, Rb^+ ,Cs^+, Fr^+	Halides except Mercury(I) Lead(II) Silver	Hydroxides except Calcium, Ca^{+2} Barium, Ba^{+2} Strontium, Sr^{+2}	All other ions Phosphate, PO_4^{-3} Sulfite, SO_3^{-2} Carbonate, CO_3^{-2}
Ammonia NH_4^+	Sulfates except Calcium, Ca^{+2} Barium, Ba^{+2} Strontium, Sr^{+2} Lead (II), Pb^{+2} Mercury(I) Hg_2^{+2}		
Nitrates, nitrites NO_3^-, NO_2^-			
Chlorate, perchlorate ClO_3^-, ClO_4^-			
Acetate $C_2H_3O_2^-$ CH_3COO^-			