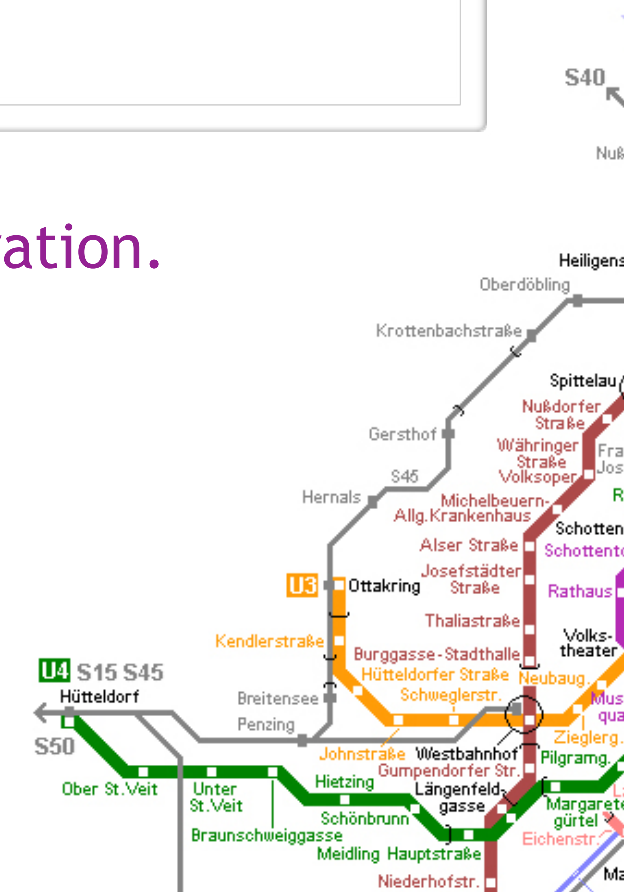
Ch10

Concentration

Understanding molarity and concentration.

"Crowdedness" of a Mixture



version 1.5

Ch10

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- Solution concentration.
  - What concentration means?
  - Measures of concentration.
    - Molarity and others.
    - Using molarity as a conversion factor.
    - Solving for molarity.
- Solution techniques in the lab.
  - Using volumetric glassware.
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    - Calculating volumes
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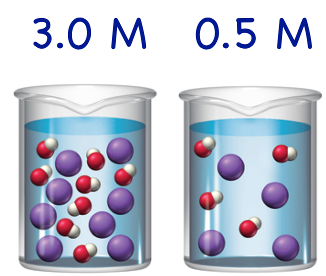
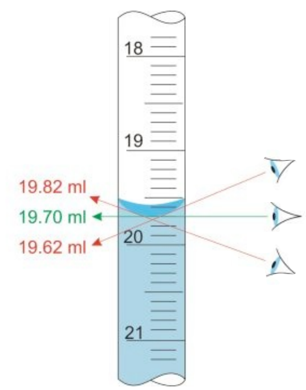
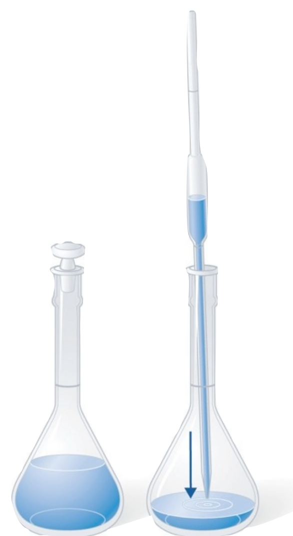
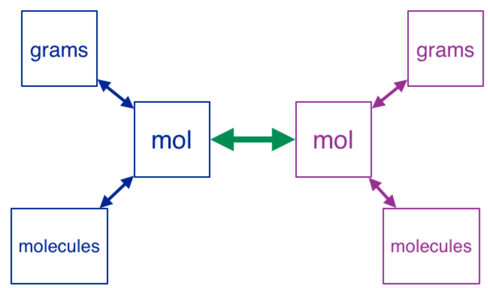
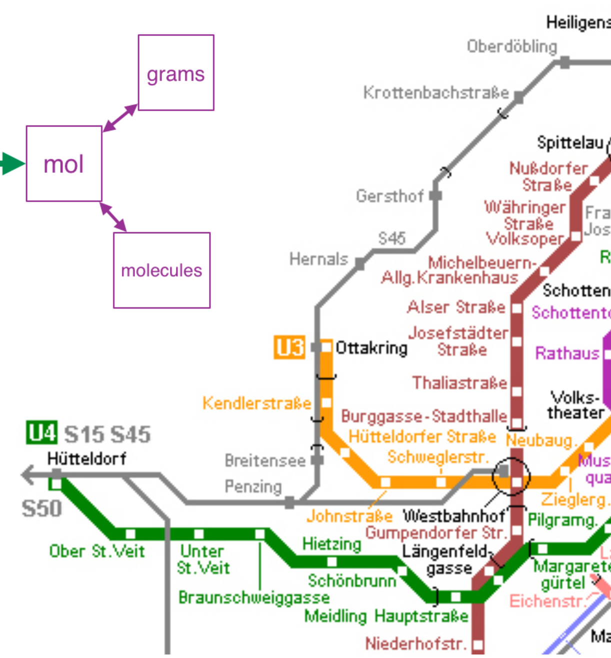
    - A technique to find concentration.









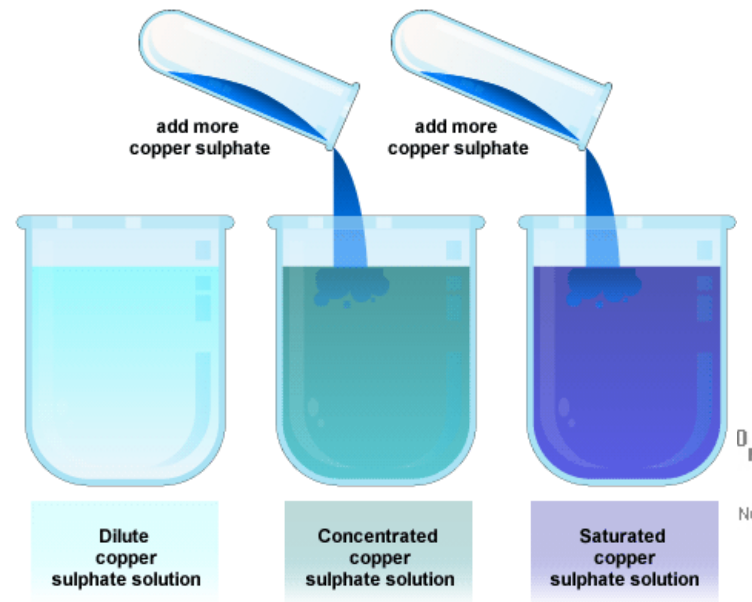


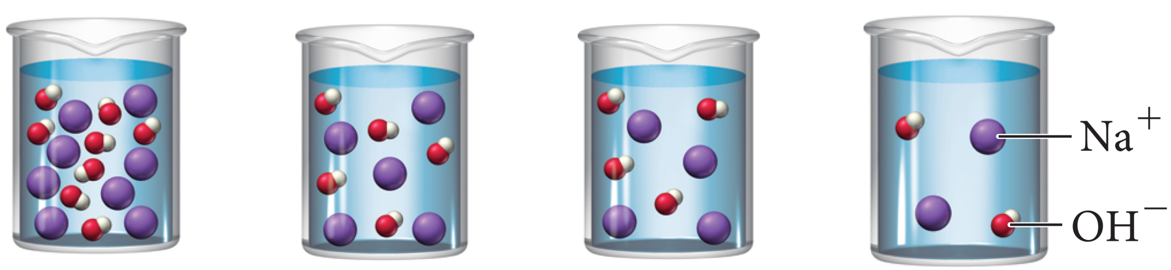
Solutions & Concentration

- Solutions are homogeneous mixtures.
- We know mixtures have tunable properties.
- The properties vary with the ratio of the pure substances that make up that mixture.

We describe that ratio as concentration.

- Concentration is the relationship between amount of a minor component of the mixture (a solute) to the major component of the mixture (the solvent).
- Concentration is how "crowded" the mixture is in a substance.
- Concentration is the amount of a solute in a given quantity of solvent.
- Solutions that contain greater amounts of solute are said to be more concentrated.
- Solutions that contain lesser amounts of solute are said to be more dilute.
- Solutions that contain the maximum amount of solute a solution can hold are said to be saturated.





A solution is a homogenous mixture.

A solvent is the largest component of the mixture.

A solute is a smaller components of the mixture.

Concentration

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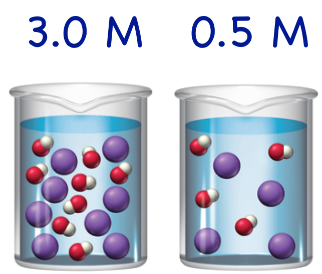
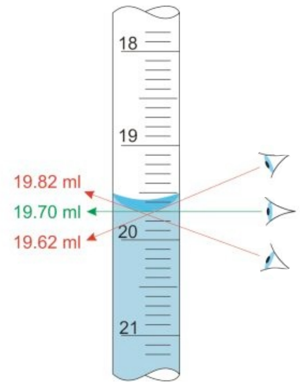
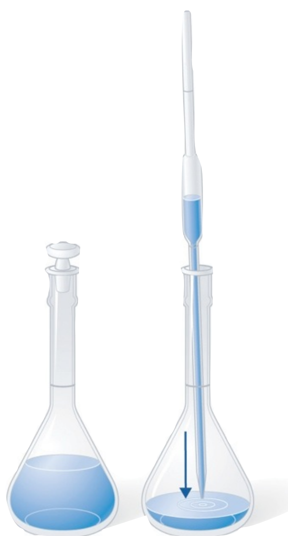
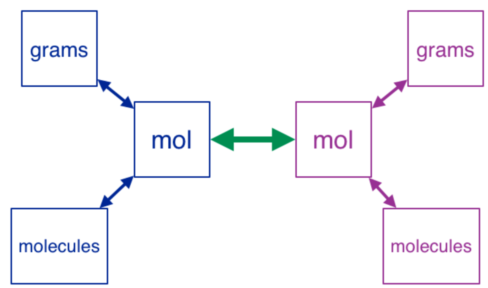
    - A technique to find concentration.





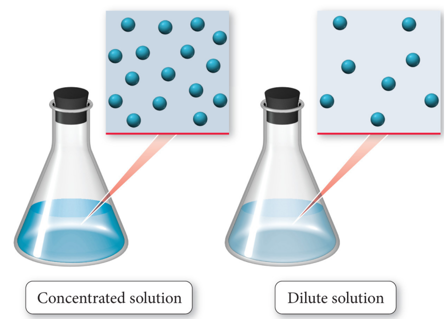




Measures of Concentration

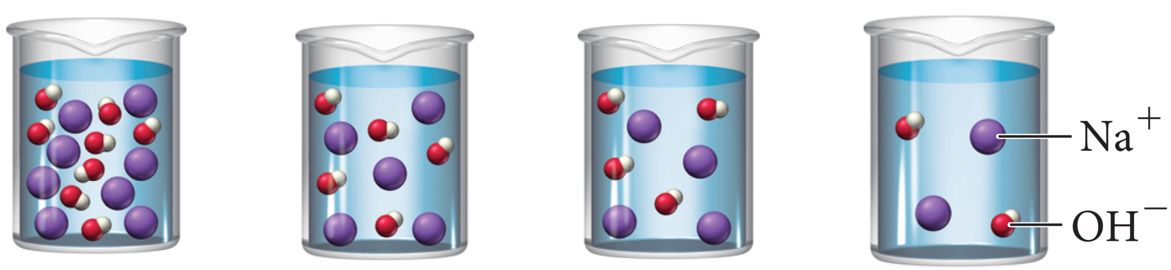
- There are a lot of ways we measure concentration.
- Three common ones are:
  - Mole Fraction (X)
    - Moles of solute per mole of solution.
    - We'll use this when we discuss gases, it's less useful for liquids.
  - Mass Percent
    - Mass of solute in mass of solution.
  - Molarity (M)
    - Moles of solute per liter of solution.
    - We'll use this <u>**a lot**</u> for liquids.

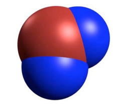
$$X = \frac{\text{moles of solute}}{\text{moles of solution}}$$



$$mass\ perc = \frac{\text{grams of solute}}{\text{grams of solution}}$$

$$M = \frac{\text{moles of solute}}{\text{liters of solution}}$$



- A molecule is a particle. 

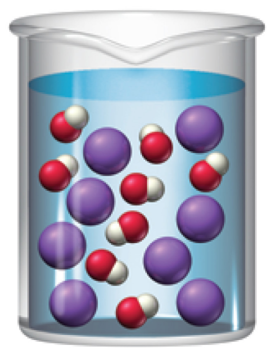
  4 molecules means 4 particles.

- A mole is 6.022×10^{23} particles.

  4 mols means $4 \times 6.022 \times 10^{23}$ particles

- Molarity is how many moles (of particles) are dissolved in a 1 L solution.

  4 M means in each liter of solution there are $4 \times 6.022 \times 10^{23}$ particles.

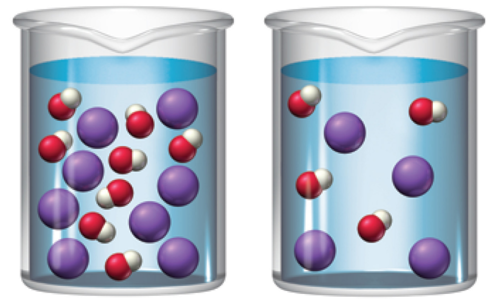


$$\frac{\text{mol solute}}{\text{L solution}}$$

Molarity

$$\frac{\text{mol solute}}{\text{L solution}}$$

- Molarity is a measure of concentration.
- The units of molarity are mol/L. We abbreviate mol/L as “M”
- Molarity is the moles of a solute divided by the volume of the solution.
  - Don’t confuse volume of solution with volume of solvent.
  - Because the solute(s) also add to the volume of the solution Molarity is not the same thing as dividing the moles of solute by volume of solvent.
- It is easier to calculate concentration if we know the total volume of the solution rather than the volume of the solvent.



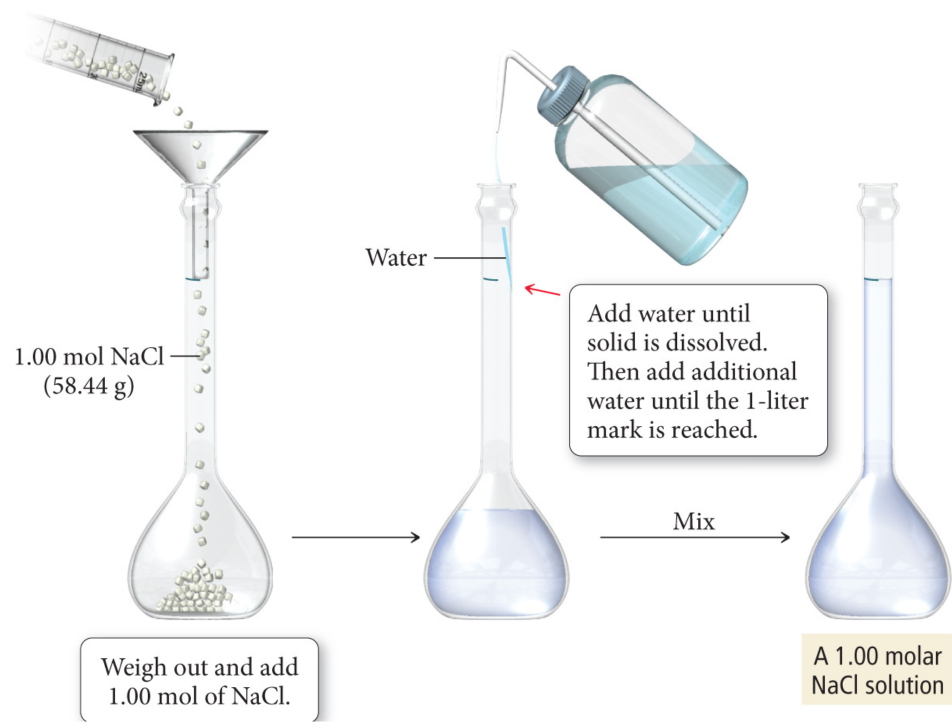
3.0 mol H_2SO_4 dissolved in 1.0 L water is:

$$\frac{3.0\text{ mol } H_2SO_4}{1.0\text{ L water} + 160\text{ mL } H_2SO_4} = \frac{3.0\text{ mol } H_2SO_4}{1.16\text{ L solution}} =$$

2.6 molar or 2.6 M

3.0 mol H_2SO_4 diluted to 1.0 L in water is:

$$\frac{3.0\text{ mol } H_2SO_4}{1.0\text{ L solution}} = 3.0\text{ molar or } 3.0\text{ M}$$



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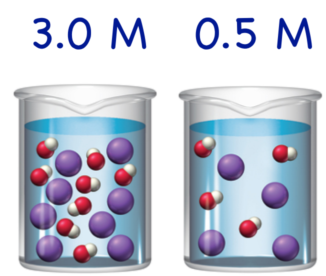
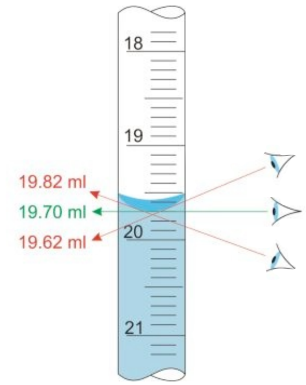
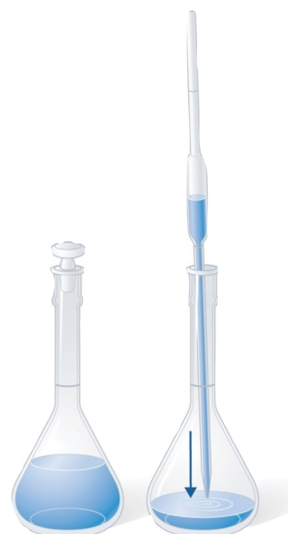
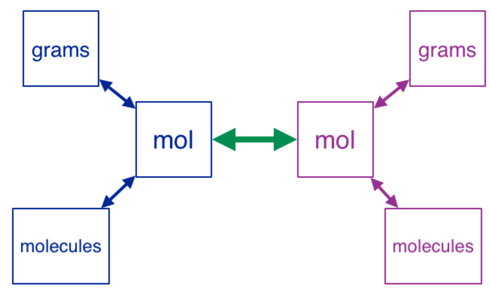
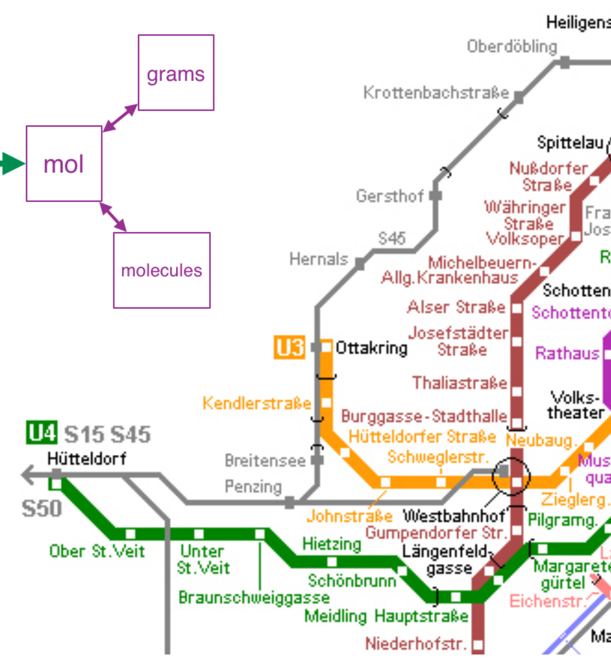










Molarity

mol solute / L solution

- Molarity is the number of moles of a solute divided by the total volume of
- Molarity makes it easy to interconvert between volumes of a solution and mols of solute.
- e.g. if I have 3.0 M H_2SO_4
  - How many mols H_2SO_4 in 0.150 L?

$$L \xrightarrow{1} mol \qquad 1\;\; 3.0\,mol = 1\,L$$

$$0.150\,L \cdot \frac{3.0\,mol}{1\,L} = 0.45\,mol\ H_2SO_4$$

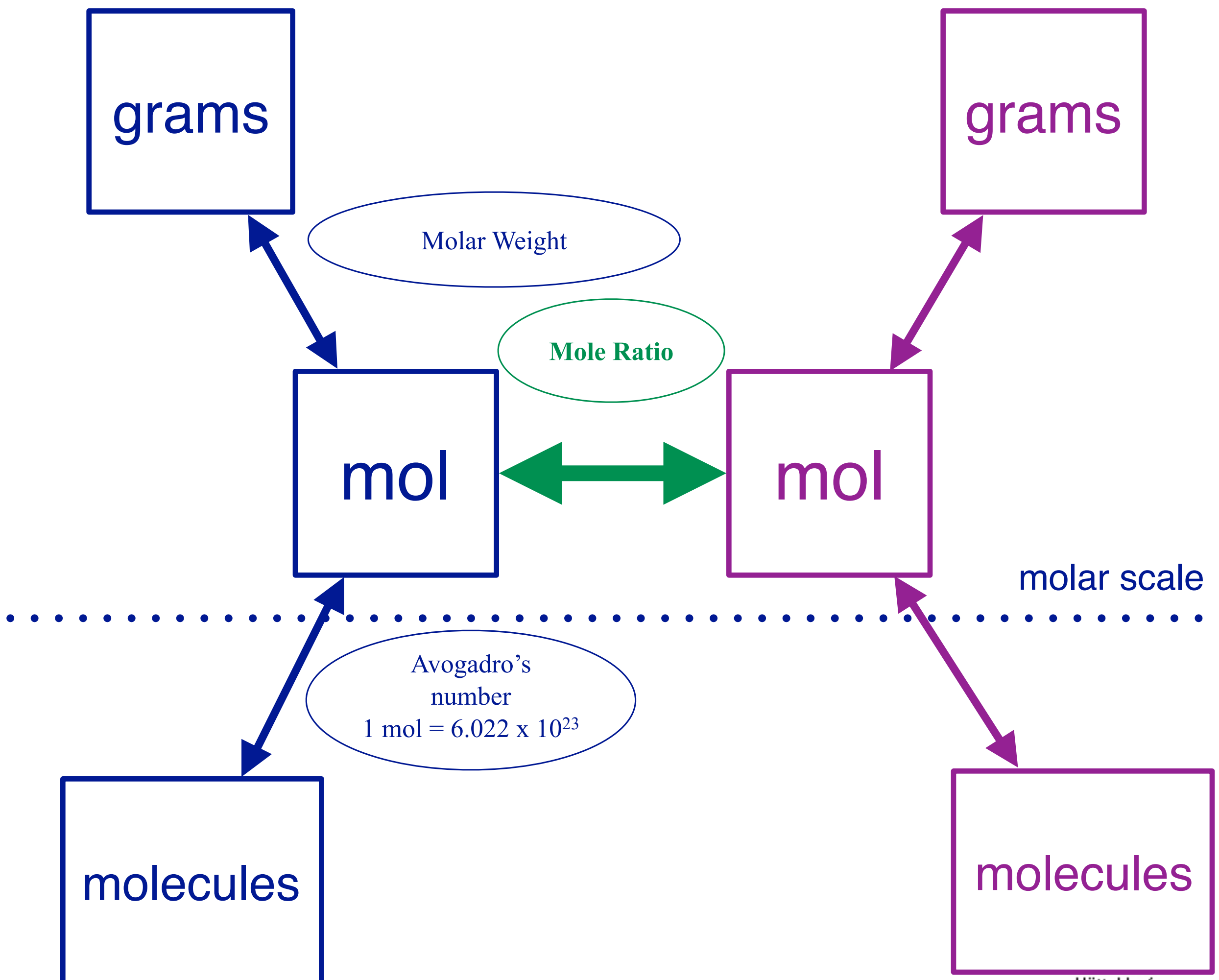
$$L\ (\text{sol'n}) \xleftrightarrow{\text{Molarity}} \text{mol}$$

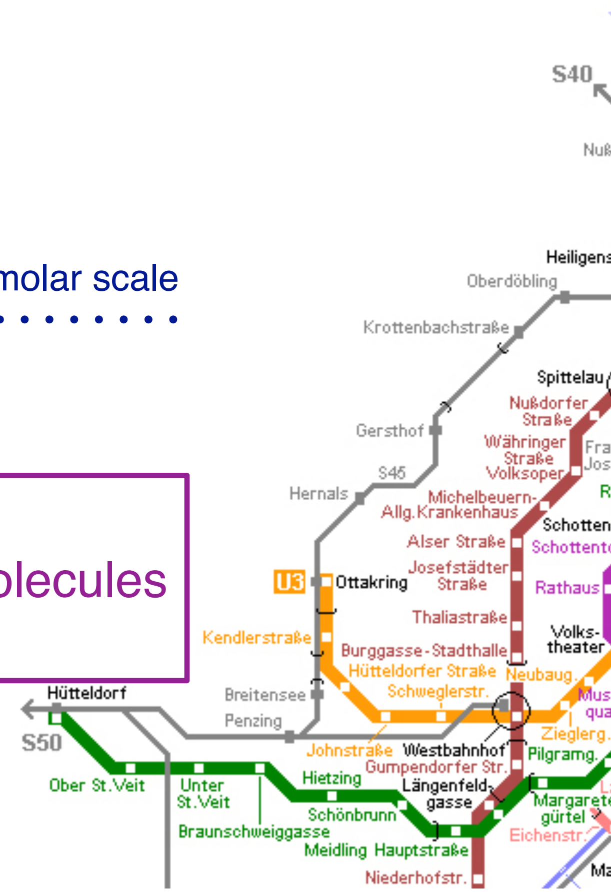
  - What volume do I need to get 0.42 mol?

$$mol \xrightarrow{1} L \qquad 1\;\; 3.0\,mol = 1\,L$$

$$0.42\,mol \cdot \frac{1\,L}{3.0\,mol} = 0.14\,L \quad (140\,mL)$$

The Molar Subway



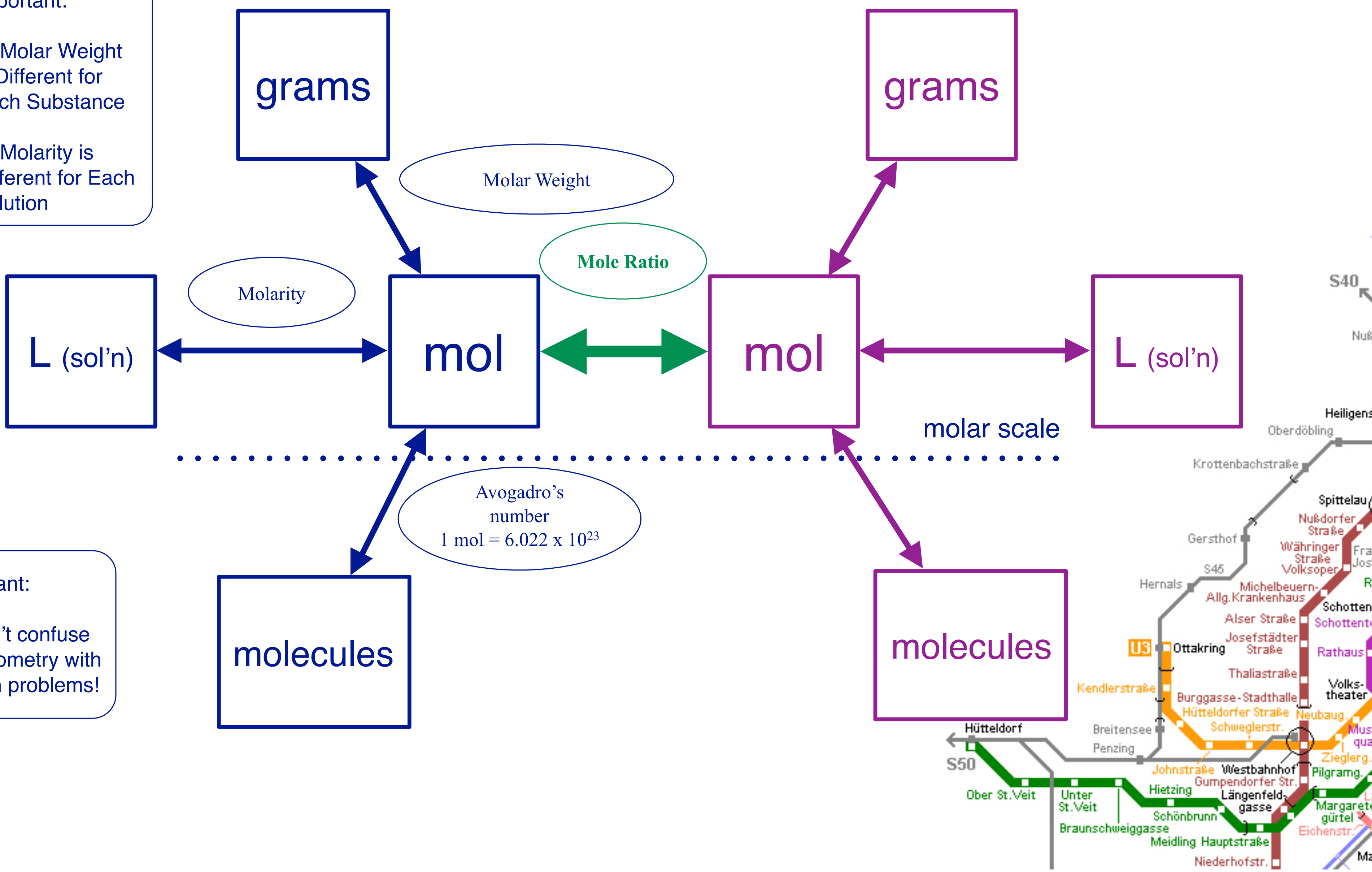


The Molar Subway

Important:

— Molar Weight is Different for Each Substance

— Molarity is Different for Each Solution

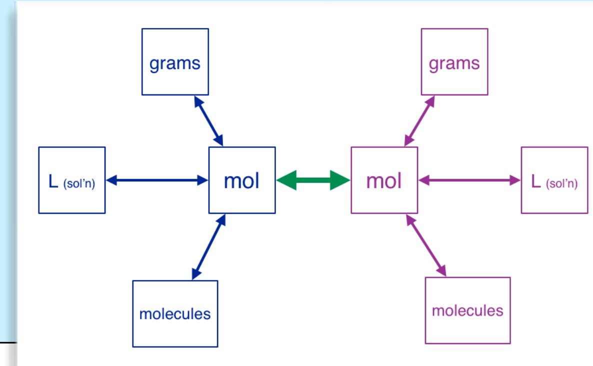


Important:

— Don't confuse stoichiometry with dilution problems!

Problem:

How many grams of $CaCl_2$ are needed to completely react with 25.0 mL of 0.100 M $AgNO_3$?



Solution

$$CaCl_{2\,(s)} + 2\ AgNO_{3\,(aq)} \rightarrow Ca(NO_3)_{2\,(aq)} + 2\ AgCl_{(s)}$$

$$\underbrace{mL \xrightarrow{1} L \xrightarrow{2} mol}_{AgNO_3} \xrightarrow{3} \underbrace{mol \xrightarrow{4} g}_{CaCl_2}$$

1. $1000\ mL = 1\ L$
2. $0.100\ mol = 1\ L$
3. $2\ AgNO_3 = 1\ CaCl_2$
4. 1 (Ca) 40.078
   2 (Cl) 70.906
   110.984

$110.984\ g = 1\ mol$

3 s.f. ∞ 3 s.f. ∞ 6 s.f.

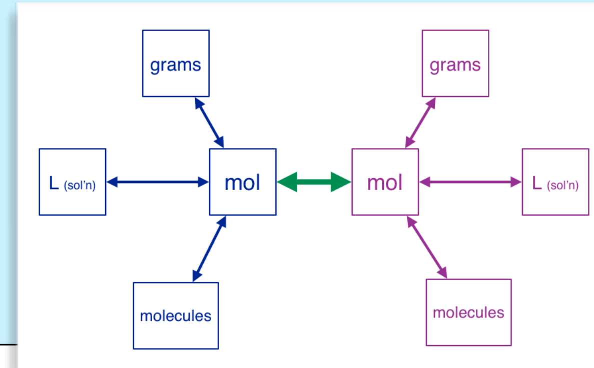
$$25.0\ mL \cdot \frac{1\ L}{1000\ mL} \cdot \frac{0.100\ mol}{1\ L} \cdot \frac{1\ CaCl_2}{2\ AgNO_3} \cdot \frac{110.984\ g}{1\ mol} =$$

$$0.13873\ g$$

$$= \boxed{0.139\ g\ CaCl_2}$$

Problem:

How many mL of 3.0 M HNO_3 are needed to completely consume 2.7 g Mg?



Solution

$$Mg_{(s)} + 2\ HNO_{3\,(aq)} \rightarrow Mg(NO_3)_{2\,(aq)} + H_{2(g)}$$

$$\underbrace{g\,Mg \xrightarrow{①} mol\ Mg}_{Mg} \xrightarrow{②} \underbrace{mol \xrightarrow{③} L \xrightarrow{④} mL}_{HNO_3}$$

① 24.3050 g = 1 mol

② 1 Mg = 2 HNO_3

③ 3.0 M HNO_3

④ 1 L = 1000 mL

$$2.7\,g \cdot \frac{1\,mol}{24.3050\,g} \cdot \frac{2\,HNO_3}{1\,Mg} \cdot \frac{1\,L}{3.0\,mol} \cdot \frac{1000\,mL}{1\,L} = \boxed{74\,mL}$$

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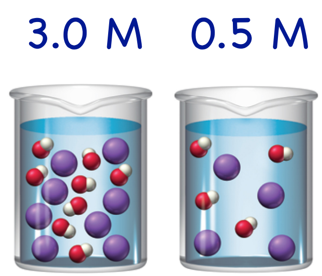
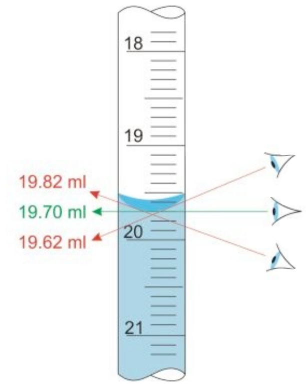
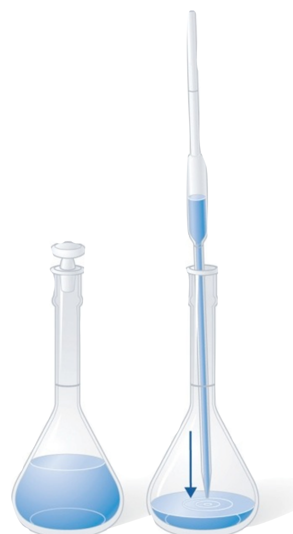
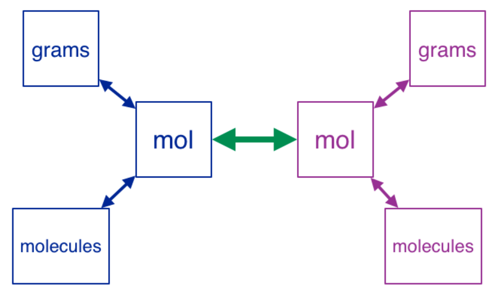


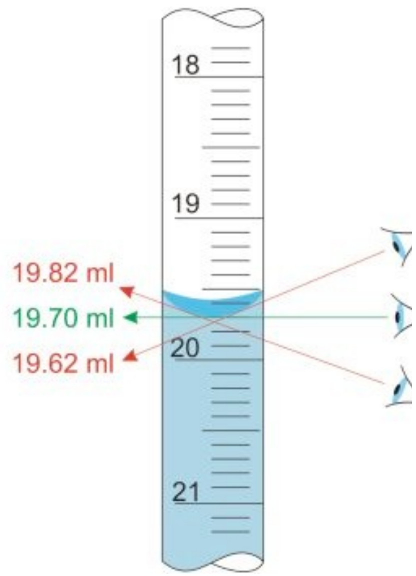


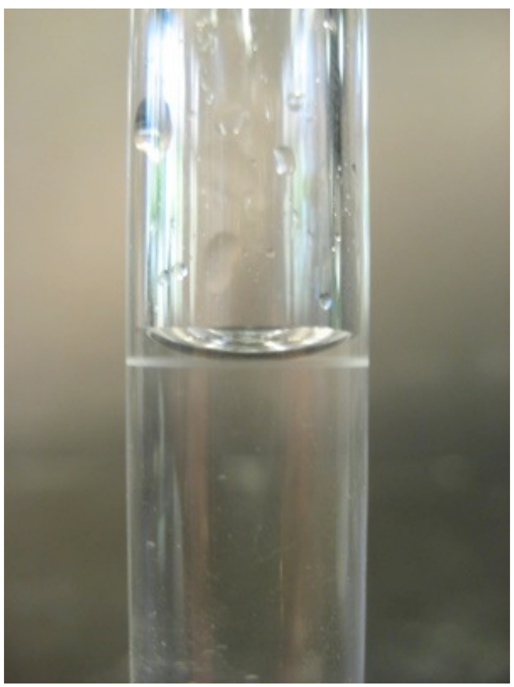


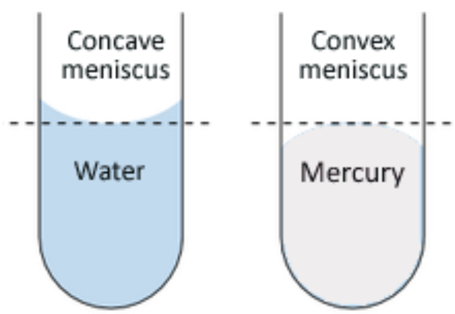


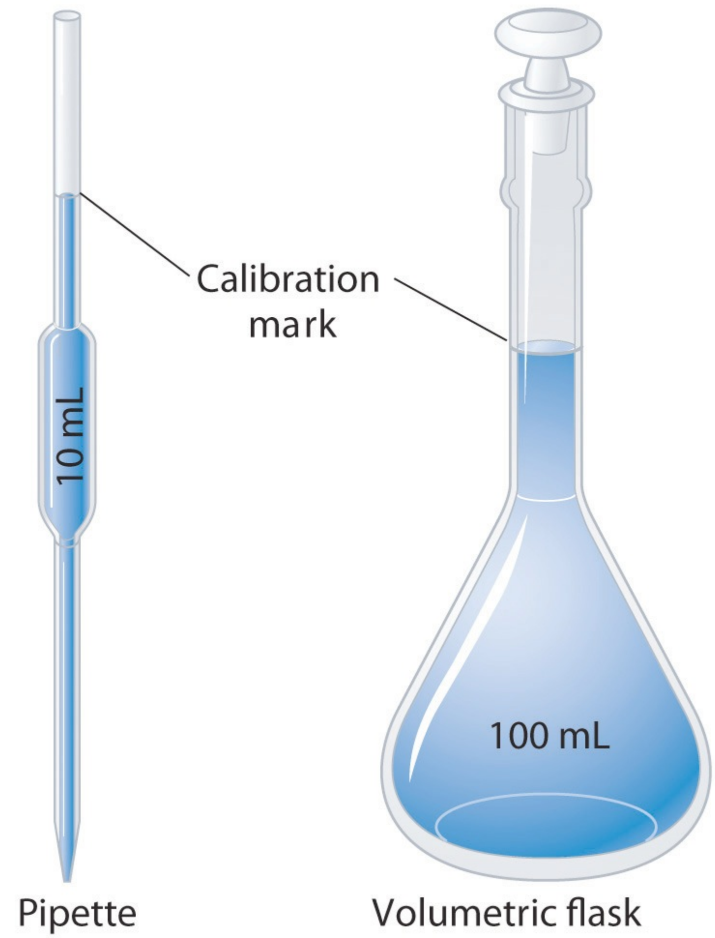
Volumetric Glassware

- Volumetric Pipets and Volumetric Flasks have a long thin neck and with a calibration mark.
- Small changes in volume make big changes in the level of the liquid allowing you to precisely measure the volume for which the device is calibrated.
- The volume is right when the meniscus of the liquid meets the calibration mark.









Dilution

- Stock solutions are solutions of known concentration.
- Most solutions are made by diluting a stock solution to a new molarity.
- Dilution just means adding more solvent.
- Dilution never changes the number of mols dissolved in the solution.
  - just the volume of the solution around them.
- Molarity and volume change with dilution, but because the mols don't change…
  - the ratio of volume to molarity is constant.

moles before = moles after

$$v_{before} M_{before} = v_{after} M_{after}$$

only when diluting!

molarity × volume = moles

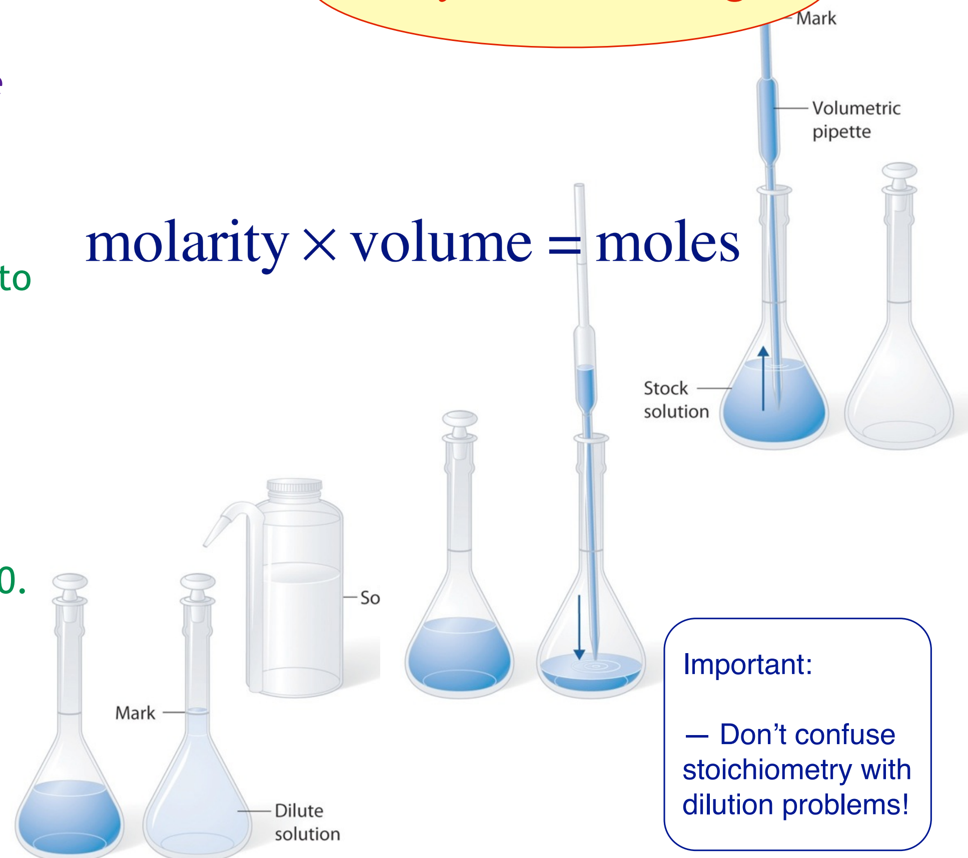
- What volume must you dilute 25 mL of 8.0 M $Ca(NO_3)_2$ to make a 2.0 M solution?

$$V_A = \frac{V_B M_B}{M_A} = \frac{8.0\,M \cdot 25\,mL}{2.0\,M} = 100\,mL$$

$$(1.0 \times 10^2\,mL)$$

- How many mL of 6.0 M HCl $_{(aq)}$ do you need to make 200. mL of 2.0 M HCl $_{(aq)}$?

$$V_B = \frac{V_A M_A}{M_B} = \frac{200.\,mL \cdot 2.0\,M}{6.0\,M} = 67\,mL$$



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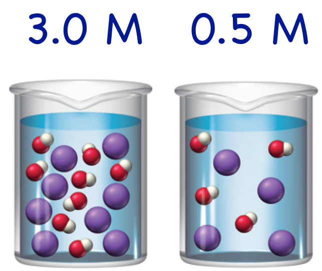
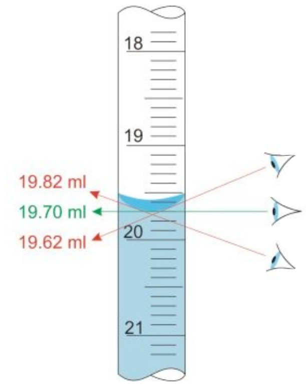
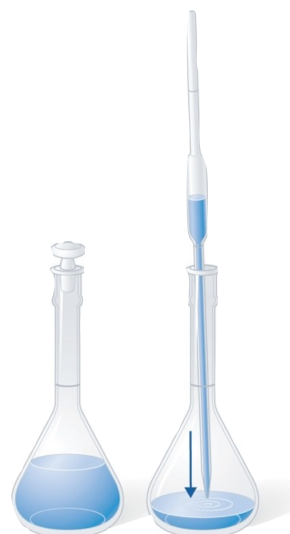
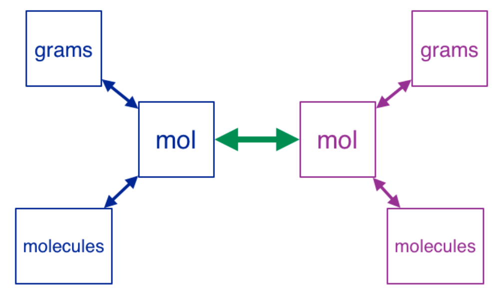
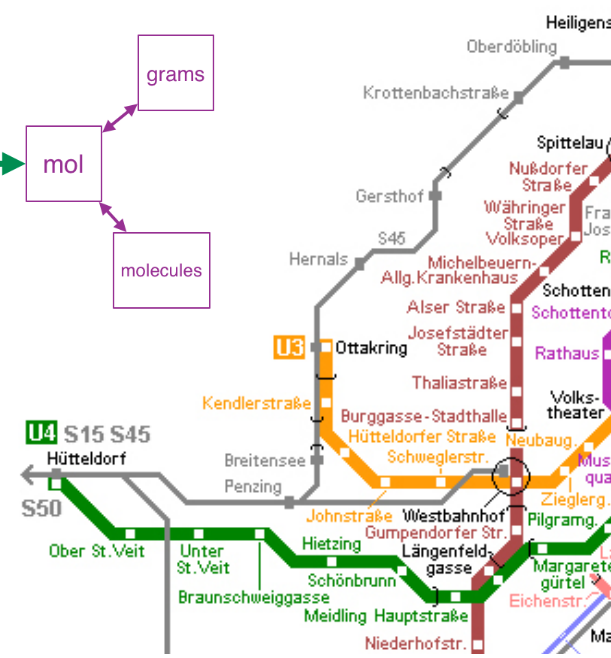






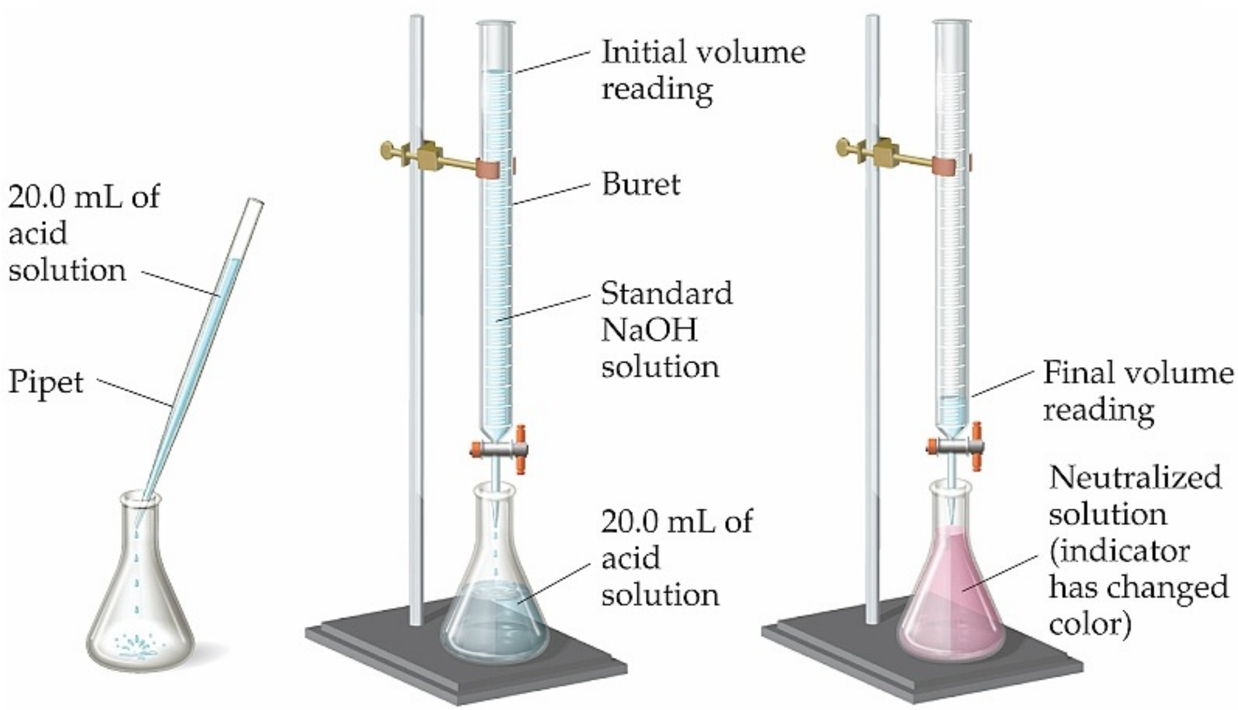




Titration

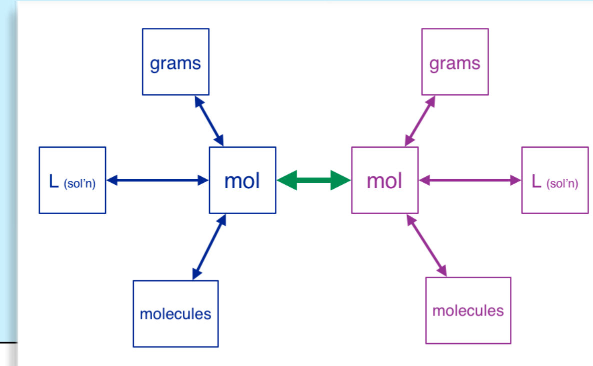
$HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(l)} + NaCl_{(aq)}$

- Titration is an analytic technique for determining the concentration in one solution by carefully adding a measured quantity of a known solution and observing a clear end point.
- The unknown is called an analyte.
- The standard solution is called a titrant or titrator.
- The end point is the point in the experiment where an indicator suggests the quantities of analyte and titrant are equal.
- The equivalence point is the point where they actually are.
  - With a good chemical indicator, the two should be close, but your equivalence point is almost always reached before you see the end point.
- An indicator is a chemical added to the mixture that changes color close to the equivalence point.
- Finding the end point with a chemical indicator requires some skill.



Problem:

A 20.0 mL sample of $NaOH_{(aq)}$ is titrated to an end point with 45.7 mL of 0.500 M H_2SO_4 $_{(aq)}$, what is concentration of the NaOH solution?



Solution

$$2\ NaOH_{(aq)} + H_2SO_4\,_{(aq)} \rightarrow Na_2SO_4\,_{(aq)} + 2\ H_2O_{(l)}$$

$$\underbrace{mL \xrightarrow{1} L \xrightarrow{2} mol}_{H_2SO_4} \xrightarrow{3} mol\ NaOH \; ; \quad \frac{mol}{vol} = molarity$$

1. $1000\,mL = 1\,L$
2. $0.500\,mol = 1\,L$
3. $2\,NaOH = 1\,H_2SO_4$

Part A

$$45.7\,mL \cdot \frac{1\,L}{1000\,mL} \cdot \frac{0.500\,mol}{1\,L} \cdot \frac{2\,NaOH}{H_2SO_4} = 4.57 \times 10^{-2}\,mol$$

Part B

$$20.0\,mL = 0.0200\,L$$

$$\frac{4.57 \times 10^{-2}\,mol}{0.0200\,L} = \boxed{2.29\,M}$$

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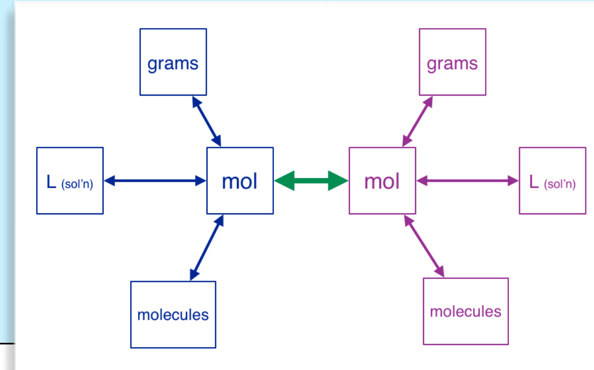


Solution

$$2\ NaOH_{(aq)} + H_2SO_{4\,(aq)} \rightarrow Na_2SO_{4\,(aq)} + 2\ H_2O_{(l)}$$

① ② ③

$\underbrace{\text{mL} \rightarrow \text{L} \rightarrow \text{mol}}_{H_2SO_4} \rightarrow \text{mol NaOH}$; $\frac{\text{mol}}{\text{vol}} = \text{molarity}$

① 1000 mL = 1 L

② 0.500 mol = 1 L

③ 2 NaOH = 1 H_2SO_4

Part A

$$45.7\,\text{mL} \cdot \frac{1\,\text{L}}{1000\,\text{mL}} \cdot \frac{0.500\,\text{mol}}{1\,\text{L}} \cdot \frac{2\,NaOH}{H_2SO_4} = 4.57\times10^{-2}\,\text{mol}$$

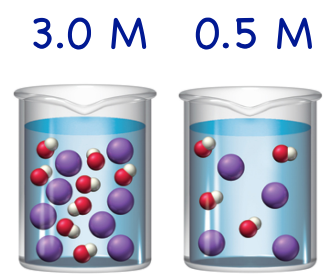
Part B

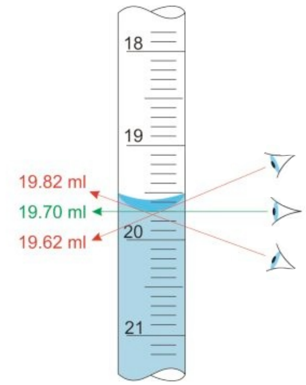
20.0 mL = 0.0200 L

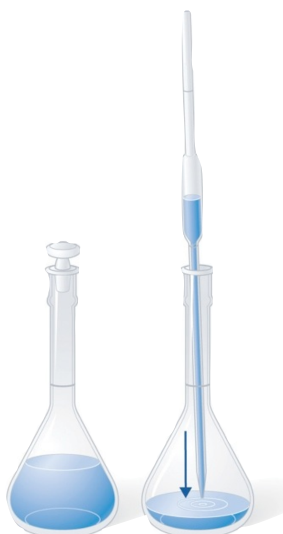
$$\frac{4.57\times10^{-2}\,\text{mol}}{0.0200\,\text{L}} = \boxed{2.29\ M}$$

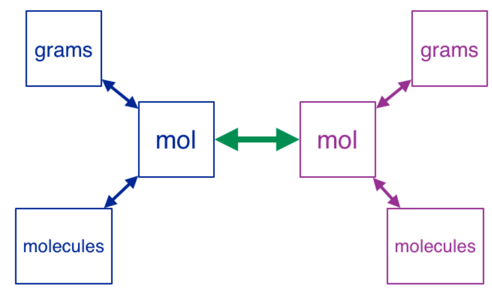
Concentration

- Solution concentration.
  - What concentration means?
  - Measures of concentration.
    - Molarity and others.
    - Using molarity as a conversion factor.
    - Solving for molarity.
- Solution techniques in the lab.
  - Using volumetric glassware.
  - Dilution
    - Calculating volumes
    - Calculating concentrations.
  - Titration
    - A technique to find concentration.









Questions?


S40
Oberdöbling
Krottenbachstraße
Spittelau
Nußdorfer Straße
Gersthof
Währinger Straße Volksoper
S45
Hernals
Michelbeuern-Allg.Krankenhaus
Alser Straße
Josefstädter Straße
U3
Ottakring
Rathaus
Thaliastraße
Volks-theater
Kendlerstraße
Burggasse-Stadthalle
Hütteldorfer Straße
Neubaug.
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Breitensee
Schweglerstr.
Penzing
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Zieglerg.
Johnstraße
Westbahnhof
Pilgramg.
Gumpendorfer Str.
Ober St.Veit
Unter St.Veit
Hietzing
Längenfeld-gasse
Schönbrunn
Braunschweiggasse
Eichenstr.
Meidling Hauptstraße
Niederhofstr.