Chemistry Olympiad - Kolack

Stoichiometry, chemical calculations

Solution chemistry

Gases

How can we represent the law of conservation of mass?

- CHEMICAL EQUATIONS are the shorthand used.
- Don’t forget, chemistry is a second language! Look up any words you don’t understand, and get a FULL, CONCEPTUAL understanding of them.

Molecular mass

- The sum of the atomic masses of the atoms in a compound
- Ex- CO_2 is 12.011 + 2(15.9994) AMU
- Ex- $Mg(NO_3)_2$ is 24.3050 + 2(14.0067 + 3(15.9994))
- FORMULA MASS is not a topic we will discuss in detail yet as it refers to ionic (as opposed to molecular) compounds

The mole

- Just a number, like “pair,” “dozen” or “gross”
- Abbreviated “mol” NOT “m” or “M” which are the abbreviations for meter and molarity, respectively

Moles

mole

molé

The mole

- Number of atoms in exactly 12g of carbon-12 ...same number as in 16g of oxygen-16, 1g of hydrogen, etc.
- 6.02×10^{23} = Avogadro's number = HUGE number (six hundred two sextillion)
- 602,214,000,000,000,000,000,000
- How huge is it?......

Why do we use the mole?

- 1 dozen cars = 12 cars
- 1 mole of cars = 6.02×10^{23} cars

- 1 dozen Al atoms = 12 Al atoms
- 1 mole of Al atoms = 6.02×10^{23} atoms

- The NUMBER is always the same...
  - The MASS is very different!

- Chemistry often deals with extraordinarily big or small numbers.
- We use numbers we can deal with in everyday life.

A mole is BIG

- If everyone on Earth bought stuff off the dollar menu (with 1 mole of dollars for the whole planet), everyone could order approximately 100 trillion items

- We could do the $700B bailout 700 billion times and still have only used 80% of 1 mole of dollars

- If a mole of pumpkins is split into 16 piles, each is the size of Earth

- Assuming 1 rat per person in NYC (disproven), it would take 73 billion million cities to get a mole of rats

How big is it?

The mole – more fun

- If you spent $1billion/sec your whole life, you'd have spent less than 0.001% of a mole of dollars
- A mole of pennies distributed equally to everyone on Earth gives everyone approximately $1trillion
- A mole of peas would cover the Earth to a depth of 100m
- A mole of marshmallows would cover the Earth to a depth of 12 miles
- A mole of oranges weighs as much as the Earth
- A mole of papers would stack from the Earth to the moon and back 80,000,000 times

How do we use the mole?

- UNITS, UNITS, UNITS!!!!
- If your units are correct, the answer will be correct.
- Use dimensional analysis, factor labeling, whatever you want to call it, to convert what you are given into what you are asked for.

Problem #1

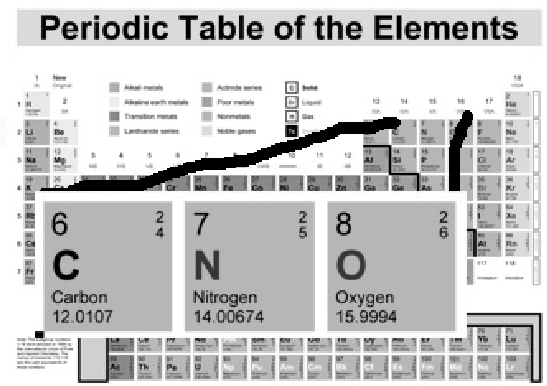
- How many light years is a mole of miles?

6.02×10^{23} mi

- 1.02×10^{11} light years (102 billion)

Molecular mass – a review

- The sum of the atomic masses (from the periodic table) of the atoms in a compound
- CO_2 is 12.0107 + 2(15.9994) ≈ 44 AMU



- Why use the mole?
- If you have one mole's worth of atomic mass units, you have one gram...

$$(1.66\times10^{-27}\text{ kg}) \times (6.02\times10^{23}) = 1.00\text{ gram}$$

Problem #2

- Prove that $6.02x10^{23}$ MOLECULES of CO_2 is 12 + 2(16) GRAMS

$$\frac{6.02x10^{23}\ \cancel{CO_2}}{} \cdot \frac{44\ \cancel{AMU}}{1\ \cancel{CO_2}} \cdot \frac{1.66x10^{-27}\ \cancel{kg}}{1\ \cancel{AMU}} \cdot \frac{1000g}{\cancel{kg}} = 44g\ CO_2$$

- The MASS of one MOLE of atoms or molecules is equal to the numbers from the periodic table added together in GRAMS
- N_A = number of atoms in exactly 12g of carbon-12 ...same number as in 16g of oxygen-16, 1g of hydrogen, etc...

Problem #3

- How many moles of Cu are present in 22 pennies with a mass of 60.0 g, assuming the penny is 100% Cu?

$$\frac{60.0\ \cancel{\text{g Cu}}}{} \left|\ \frac{1\ \text{mol Cu}}{63.5\ \cancel{\text{g Cu}}}\right. = 0.945\ \text{mol Cu}$$

Molar mass

- The mass of one mole of atoms or molecules
- Ex- CO_2 is 12.011 + 2(15.9994) GRAMS = 6.02×10^{23} molecules of CO_2

Percent composition

- What is the mass composition of C in CO_2?
  - Not just a calculation of one mole of C per 3 moles of atoms in one mole of CO_2...must calculate the percent by weight (mass) of the 12g carbon per mole in the 44g per mole CO_2
  - 5-10-5 fertilizer is a good practical example
    - 5%N, 10%P_2O_5, 5%K_2O
    - Empirical formula?

Percent composition (cont'd)

Molecular formula of butane	C_4H_{10}
Mass of C in 1 mol C_4H_{10}	$4 \text{ mol C} \times 12.011 \text{ g C/mol C} = 48.044 \text{ g C}$
Mass of H in 1 mol C_4H_{10}	$10 \text{ mol H} \times 1.0079 \text{ g H/mol H} = 10.079 \text{ g H}$
Molar mass of C_4H_{10}	$48.044 \text{ g C} + 10.079 \text{ g H} = 58.123 \text{ g/mol } C_4H_{10}$
Mass percent C in C_4H_{10}	$\frac{48.044 \text{ g C}}{58.123 \text{ g } C_4H_{10}} \times 100\% = 82.66\% \text{ C}$
Mass percent H in C_4H_{10}	$\frac{10.079 \text{ g C}}{58.123 \text{ g } C_4H_{10}} \times 100\% = 17.34\% \text{ H}$

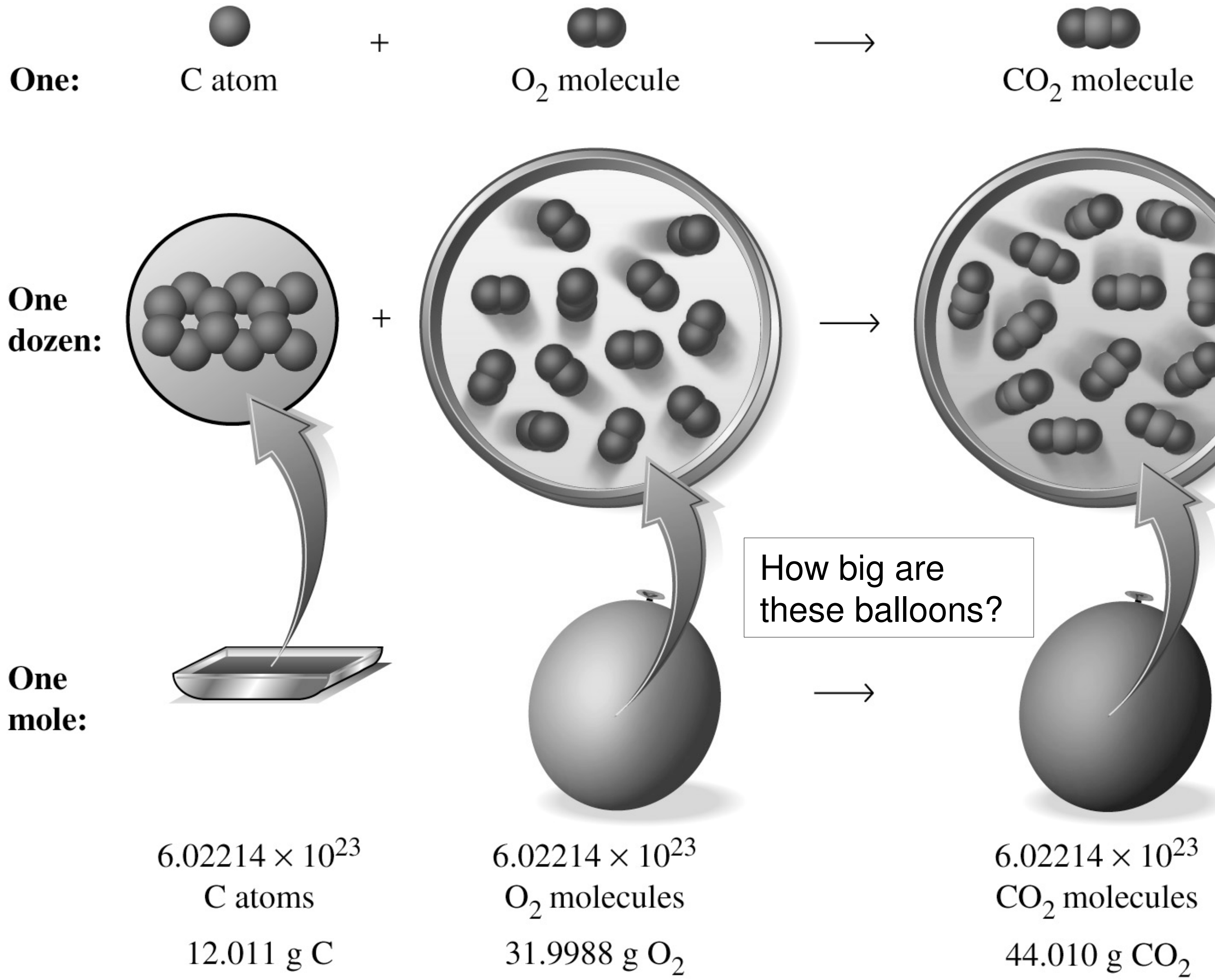
Percent composition (cont'd)

- Given the mass percents, you should be able to determine the empirical formula...given the molecular mass, you should be able to determine the chemical formula
- UNITS, UNITS, UNITS
- Determined experimentally by a technique called ELEMENTAL ANALYSIS

Equations

- REACTANTS on the L, PRODUCTS on the R
- $CO + 2H_2 \rightarrow CH_3OH$
  - Stoichiometry- QUANTITATIVE relationship between (or measurement of) substances.
  - In the reaction of CO with H_2 to produce CH_3OH, one MOLECULE of carbon monoxide is *stoichiometrically equivalent* to two MOLECULES of hydrogen and one MOLECULE of methanol...This molecule ratio of 1:2:1 applies to MOLES as well, and allows us to generate conversion factors which are extremely useful.
    - How many g of H2 are required to react with 28g CO?
    - (28g CO) (1 mol CO/28g CO) **(2 mol H_2/1 mol CO)** (2g H_2/mol H_2)

Equations- development/meaning



Equations

- Sometimes, there is additional info present

Elevated temperature

$$NH_4Cl(s) \xrightarrow{\Delta} NH_3(g) + HCl(g)$$

Actual temperature at which reaction is carried out

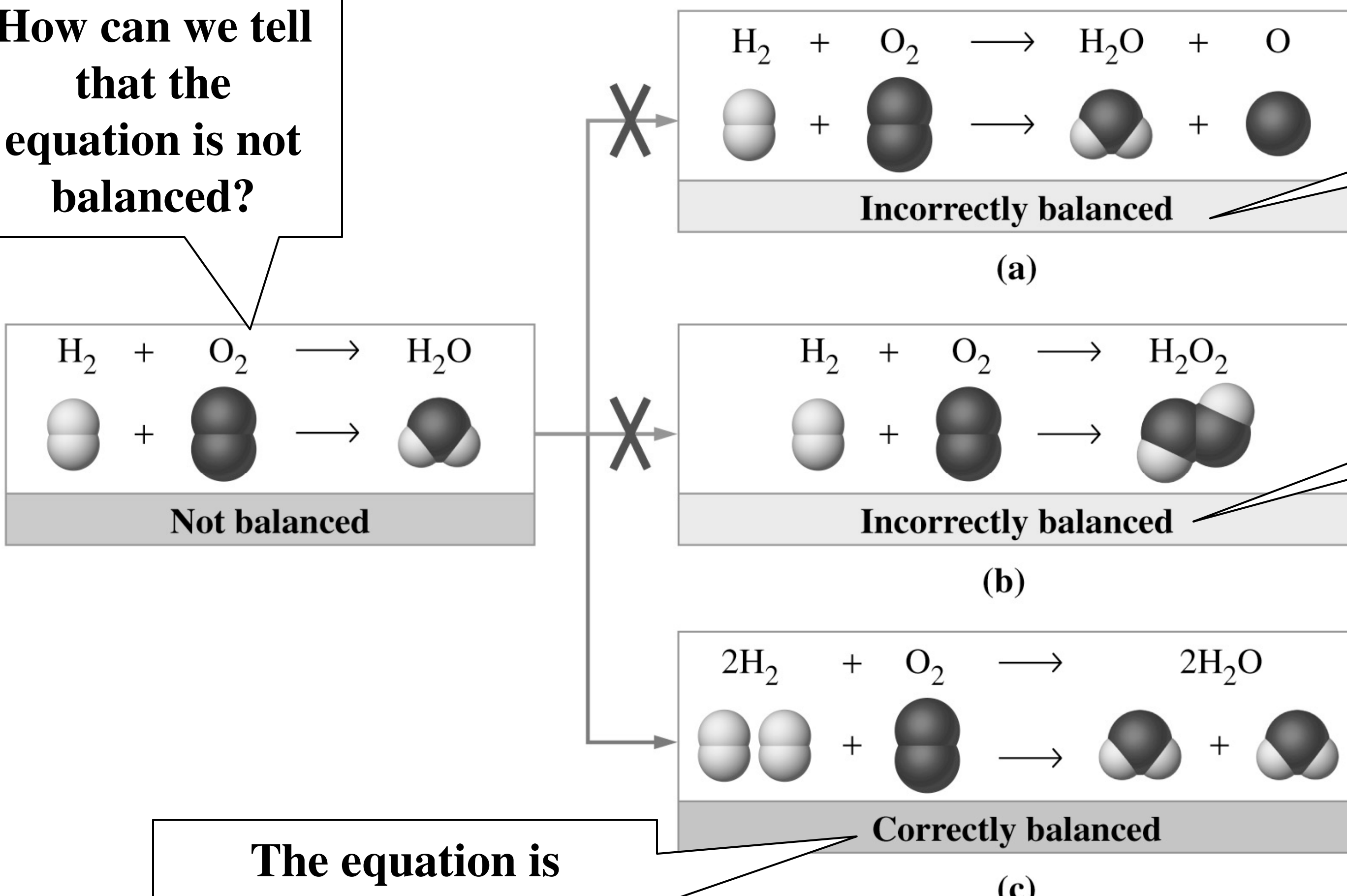
$$HCOOH(g) \xrightarrow{160\ °C} CO_2(g) + H_2(g)$$

Balancing equations illustrated

How can we tell that the equation is not balanced?

… not by changing the *equation* …

… and not by changing the *formulas*.



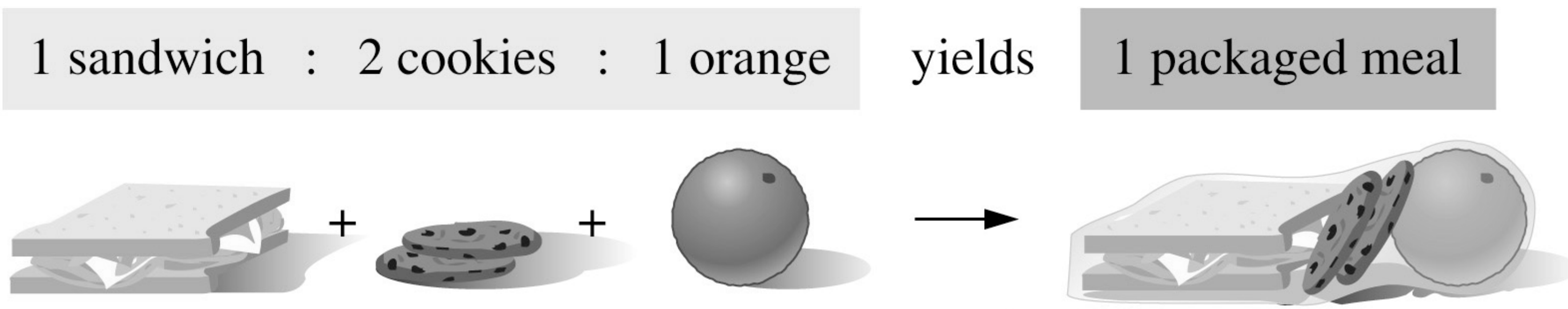
The equation is balanced by changing the *coefficients* …

Guidelines for Balancing Chemical Equations

- If an element is present in just one compound on each side of the equation, try balancing that element first.
- Balance any reactants or products that exist as the free element last.
- In some reactions, certain groupings of atoms (such as polyatomic ions) remain unchanged. In such cases, treat these groupings as a unit.
- At times, an equation can be balanced by first using a fractional coefficient(s). The fraction is then cleared by multiplying each coefficient by a common factor.
- Try starting with the heaviest element…
- Trial and error... Do it until it works!

Yield

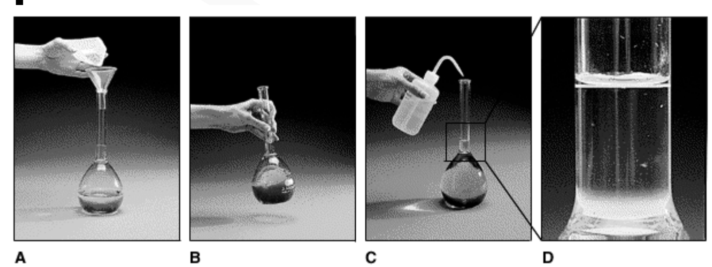
- If one reactant runs out before another, it is the LIMITING REACTANT or LIMITING REAGENT



- May not be the one present in the lowest mass!!!
- Reactions do not always produce 100% of the product potential or THEORETICAL YIELD

Solutions

- A SOLUTE is dissolved in a SOLVENT to form a SOLUTION
- The solvent is usually present in greater amount than the solute
- DILUTE and CONCENTRATED are terms which refer to the relative CONCENTRATION of the solution- how much solute is dissolved per unit of solvent

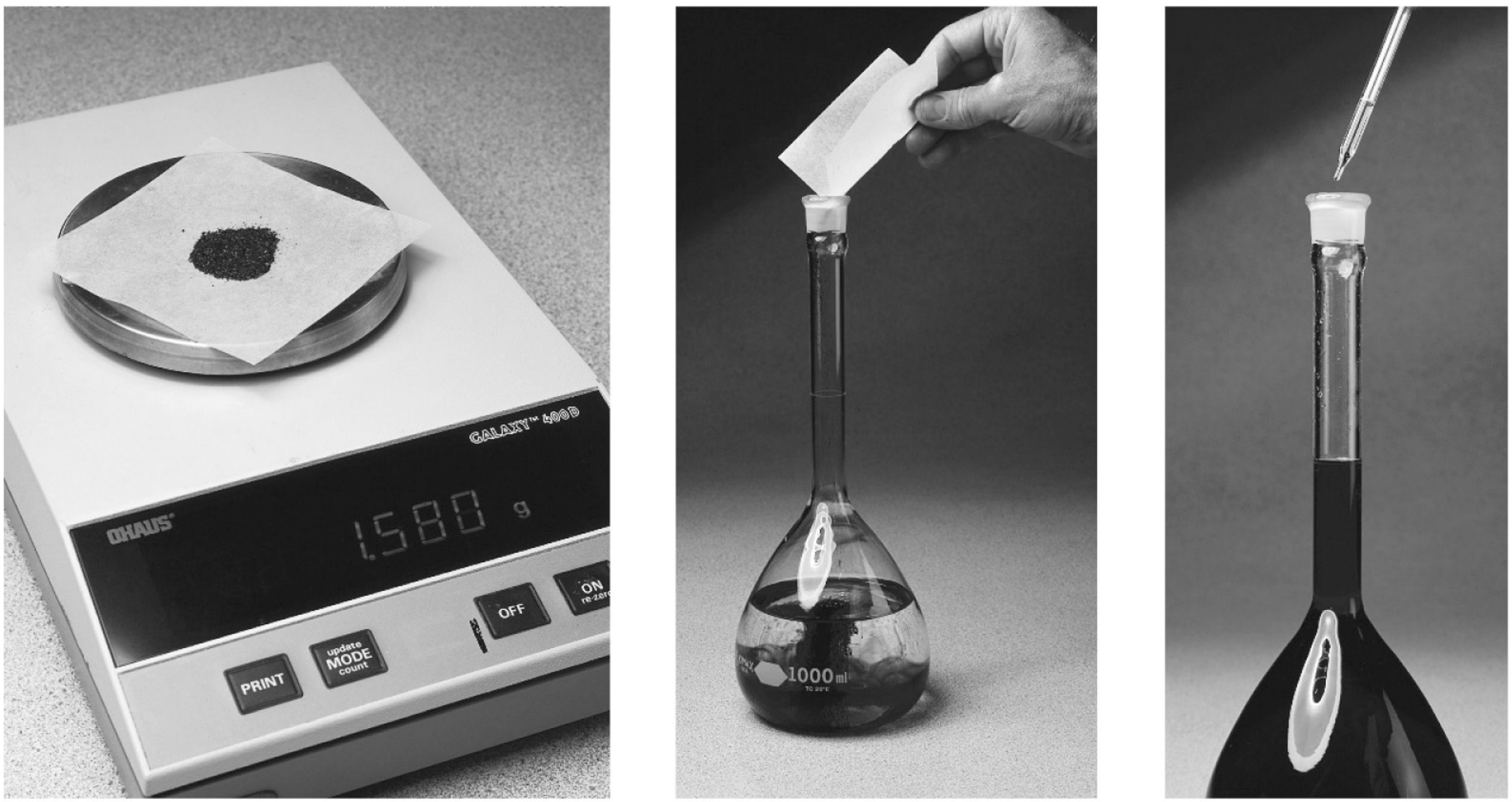


Solutions (cont'd)

- MOLARITY or MOLAR CONCENTRATION is the amount of SOLUTE in moles per LITER of SOLUTION
- We will rarely deal with MOLALITY, moles of solute per KILOGRAM of solvent
- Dilution does not change the amount of solute, but DOES change concentration
- $M_1V_1 = M_2V_2$
- Given the concentration of a reactant in solution, there is simply one more conversion (M to mol) involved in stoichiometric calculations

Solutions in the lab

- TC vs. TD



(a) (b) (c)

Dilution of Solutions

- ***Dilution*** is the process of preparing a more dilute solution by adding solvent to a more concentrated one.
- Addition of solvent does not change the amount of ***solute*** in a solution but does change the solution ***concentration***.
- It is very common to prepare a concentrated *stock solution* of a solute, then dilute it to other concentrations as needed.

Visualizing the Dilution of a Solution

$$\frac{0.0050 \text{ mol } I_2}{0.10 \text{ L solution}} = 0.050 \text{ M } I_2$$

$$\frac{0.0050 \text{ mol } I_2}{0.50 \text{ L solution}} = 0.010 \text{ M } I_2$$

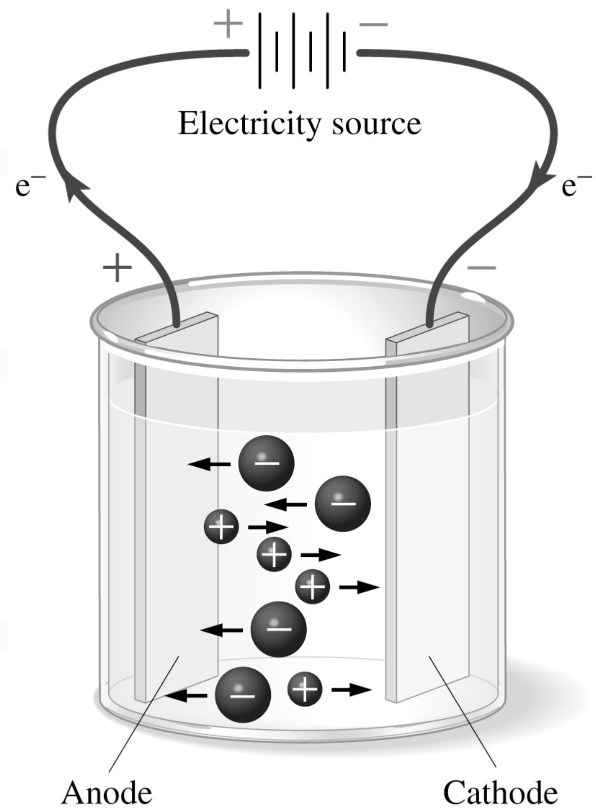
End of section

Chemical reactions

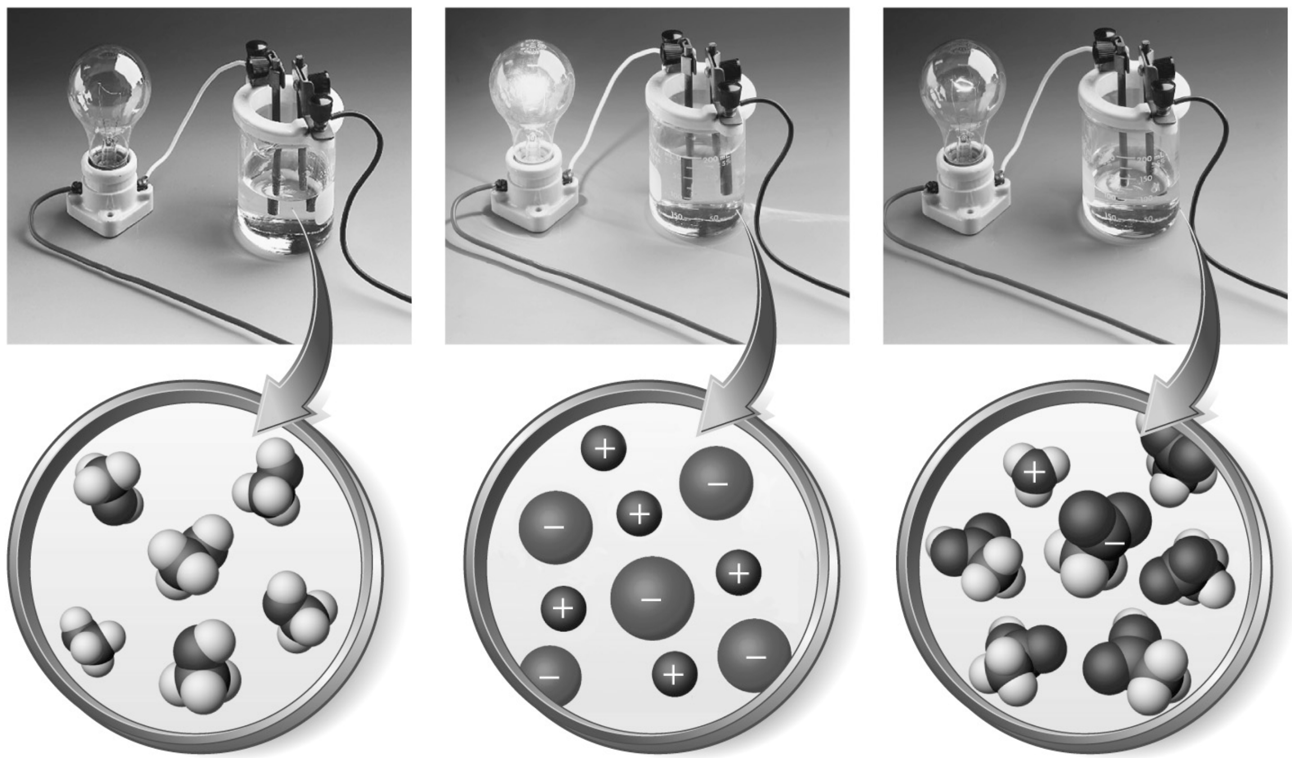
- How do the atoms and molecules come together so that their bonds can be broken and formed (the definition of a chemical reaction)?
- Solids are commonly made into solutions.

Electricity

- The flow of charged particles.
- What enables this flow through a liquid?
- The presence of charged particles, or IONS (CATION positive, ANION negative).
  being drawn to the cathode (negative) and anode (positive).
- In a strong ELECTROLYTE, the solute DISSOCIATES completely and is present almost entirely as ions.
- In a NONELECTROLYTE, the solute exists almost entirely as NON-DISSOCIATED molecules.
- A weak electrolyte exists as both ions and molecules in solution. There exists an EQUILIBRIUM between the molecules and ions (next slide).



Electrolytes



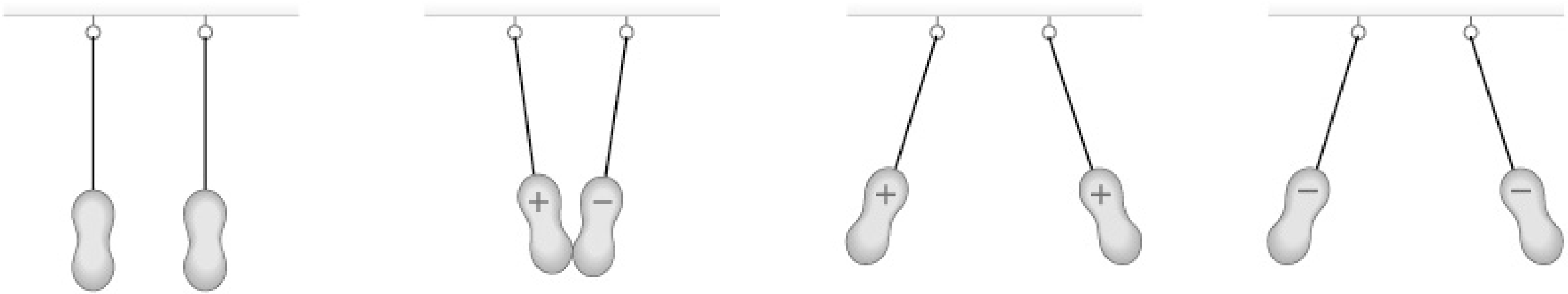
(a)
1 M CH_3OH
Nonelectrolyte
Solute consists
of molecules;
no ions

(b)
1 M NaCl(aq)
Strong electrolyte
Solute consists of ions:
Na^+ Cl^-

(c)
1 M CH_3COOH(aq)
Weak electrolyte Solute consists
mostly of molecules; some ions:
CH_3COO^- H_3O^+

Electrostatic Forces

- Unlike charges (+ and –) attract one another
- Like charges (+ and +, or – and –) repel one another
- Different from "like dissolves like" when discussing solutions



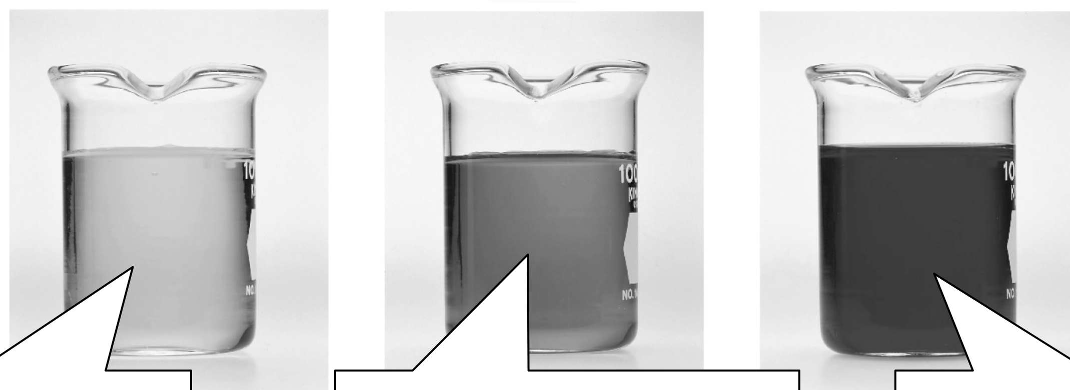
(a) (b) (c) (d)

Ion concentration

- A strong electrolyte like 1 mole of NaCl would generate 1 mole of Na^+ ions and 1 mole of Cl^- ions in solution.
- 1 mole of Na_2SO_4 would generate 2 moles of sodium ions and 1 mole of sulfate ions

Acids and bases

- Remember your definitions
- Strong acids and bases are strong electrolytes
- We measure acid and base strength using a pH meter or an indicator (see below)
- For a POLYPROTIC acid like H_2SO_4 the first ionization is generally stronger than the second (more later)
- Acid plus base makes salt plus water- NEUTRALIZATION



Phenol red is yellow in acidic solution …

… orange in neutral solution …

… and red in basic solution (really!).

Common Strong Acids and Strong Bases

Not HF!

A pragmatic method of determining whether an acid is weak … just learn the strong acids!

Table 4.1 Common Strong Acids and Strong Bases

Acids		Bases	
Binary Hydrogen Compounds	**Oxoacids**	**Group 1A hydroxides**	**Group 2A hydroxides**
HCl	HNO_3	LiOH	$Mg(OH)_2$
HBr	H_2SO_4[a]	NaOH	$Ca(OH)_2$
HI	$HClO_4$	KOH	$Sr(OH)_2$
		RbOH	$Ba(OH)_2$
		CsOH	

[a] H_2SO_4 is a strong acid in its first ionization step but weak in its second ionization step.

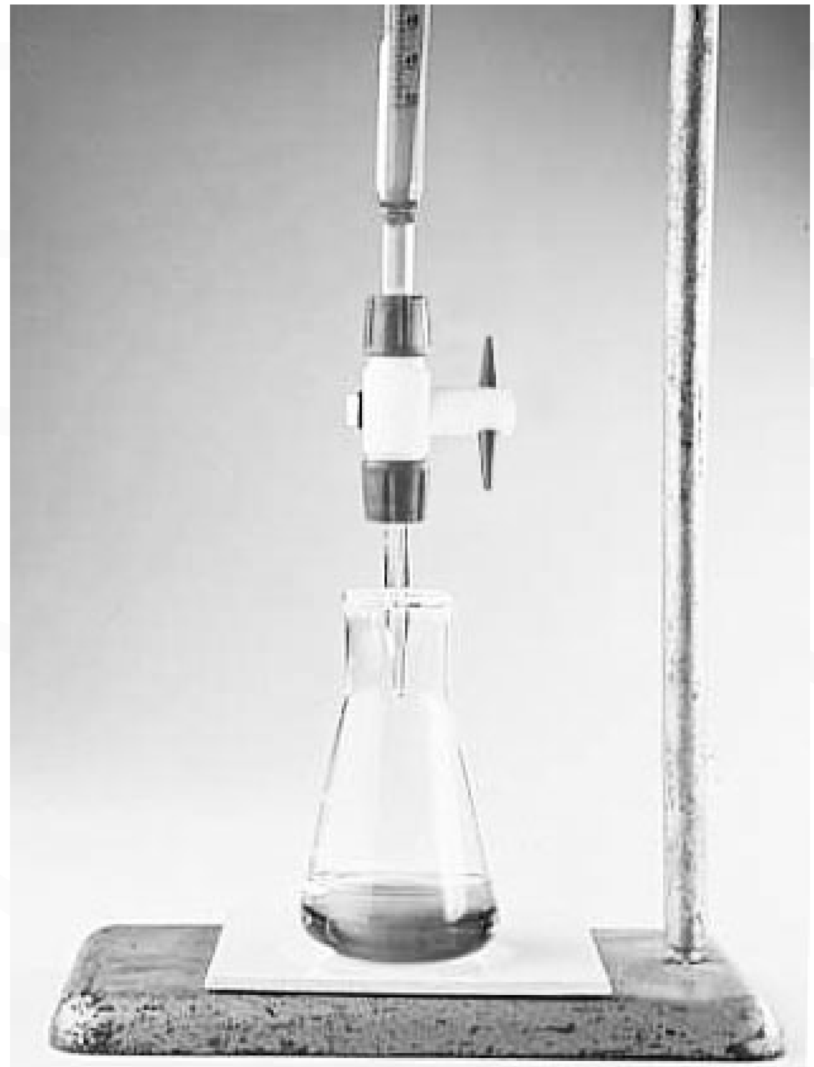
Equations

- A NET IONIC EQUATION shows only the particles undergoing change in the reaction
- Ex- $HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$
  FULL EQUATION (for the neutralization)
- $H^+(aq) + Cl^-(aq) + Na^+(aq) + OH^-(aq) \rightarrow$
  $Na^+(aq) + Cl^-(aq) + H_2O(l)$
  IONIC EQUATION
- $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$
  NET IONIC EQUATION
- Ions left out of the net ionic equation are SPECTATOR IONS

Titration

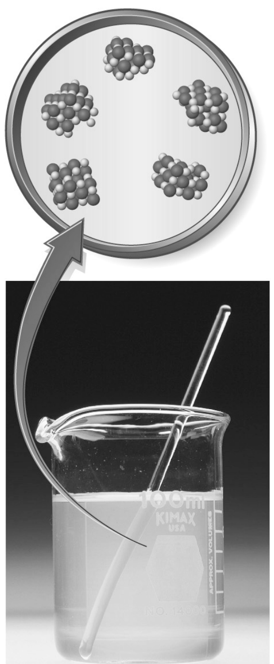
(you will do this extensively in lab)

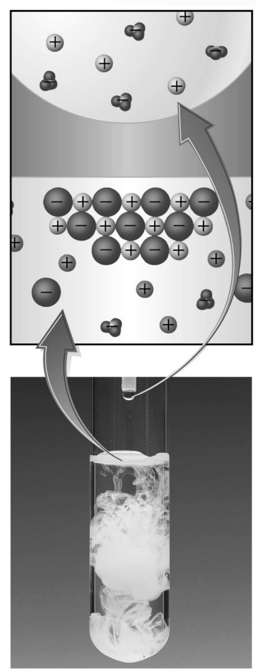
- Experimental technique which allows you to determine concentration of an ANALYTE by employing reaction STOICHIOMETRY
- The TITRANT is added to a flask of sample using a BURET until the EQUIVALENCE POINT or END POINT is reached
- Can be an acid/base titration, a precipitation titration, or a redox titration



Precipitation reactions

- When some cations and anions are combined a product which is insoluble in water (<0.01M) sometimes results. The insoluble product is a PRECIPITATE.
- The real world often believes in moderation, so very often, compounds are neither completely SOLUBLE nor completely INSOLUBLE- they may be SPARINGLY SOLUBLE, existing in a DYNAMIC EQUILIBRIUM





Solubility rules

Table 4.3 General Guidelines for the Water Solubilities of Common Ionic Compounds
Almost all nitrates, acetates, perchlorates, group 1A metal salts, and ammonium salts are *SOLUBLE*.
Most chlorides, bromides, and iodides are *SOLUBLE*. Exceptions: those of Pb^{2+}, Ag^{+}, and $Hg_2{}^{2+}$.
Most sulfates are *SOLUBLE*. Exceptions: those of Sr^{2+}, Ba^{2+}, Pb^{2+}, and $Hg_2{}^{2+}$ ($CaSO_4$ is slightly soluble).
Most carbonates, hydroxides, phosphates, and sulfides are *INSOLUBLE*. Exceptions: ammonium and group 1A metal salts of any of those anions are soluble; hydroxides and sulfides of Ca^{2+}, Sr^{2+}, and Ba^{2+} are slightly to moderately soluble.

Example

Predict whether a precipitation reaction will occur in each of the following cases. If so, write a net ionic equation for the reaction.

(a) $Na_2SO_4(aq) + MgCl_2(aq) \rightarrow$?

(b) $(NH_4)_2S(aq) + Cu(NO_3)_2(aq) \rightarrow$?

(c) $K_2CO_3(aq) + ZnCl_2(aq) \rightarrow$?

Example

A Conceptual Example

The figure shows that the dropwise addition of $NH_3(aq)$ to $FeCl_3(aq)$ produces a precipitate. What is the precipitate?

Precipitation in action

Table 4.4 Some Precipitation Reactions of Practical Importance

Reaction in Aqueous Solution	Application
$Al^{3+}(aq) + 3\,OH^-(aq) \longrightarrow Al(OH)_3(s)$	Water purification. (The gelatinous precipitate carries down suspended matter.)
$Al^{3+}(aq) + PO_4{}^{3-}(aq) \longrightarrow AlPO_4(s)$	Removal of phosphates from wastewater in sewage treatment.
$Mg^{2+}(aq) + 2\,OH^-(aq) \longrightarrow Mg(OH)_2(s)$	Precipitation of magnesium ion from seawater. (First step in the Dow process for extracting magnesium from seawater.)
$Ag^+(aq) + Br^-(aq) \longrightarrow AgBr(s)$	Preparation of AgBr for use in photographic film.
$Zn^{2+}(aq) + SO_4{}^{2-}(aq) + Ba^{2+}(aq) + S^{2-}(aq) \longrightarrow ZnS(s) + BaSO_4(s)$	Production of *lithopone*, a mixture used as a white pigment in both water paints and oil paints.
$H_3PO_4(aq) + Ca(OH)_2(aq) \longrightarrow CaHPO_4 \cdot 2\,H_2O(s)$	Preparation of calcium hydrogen phosphate dihydrate, used as a polishing agent in toothpastes.

Oxidation states

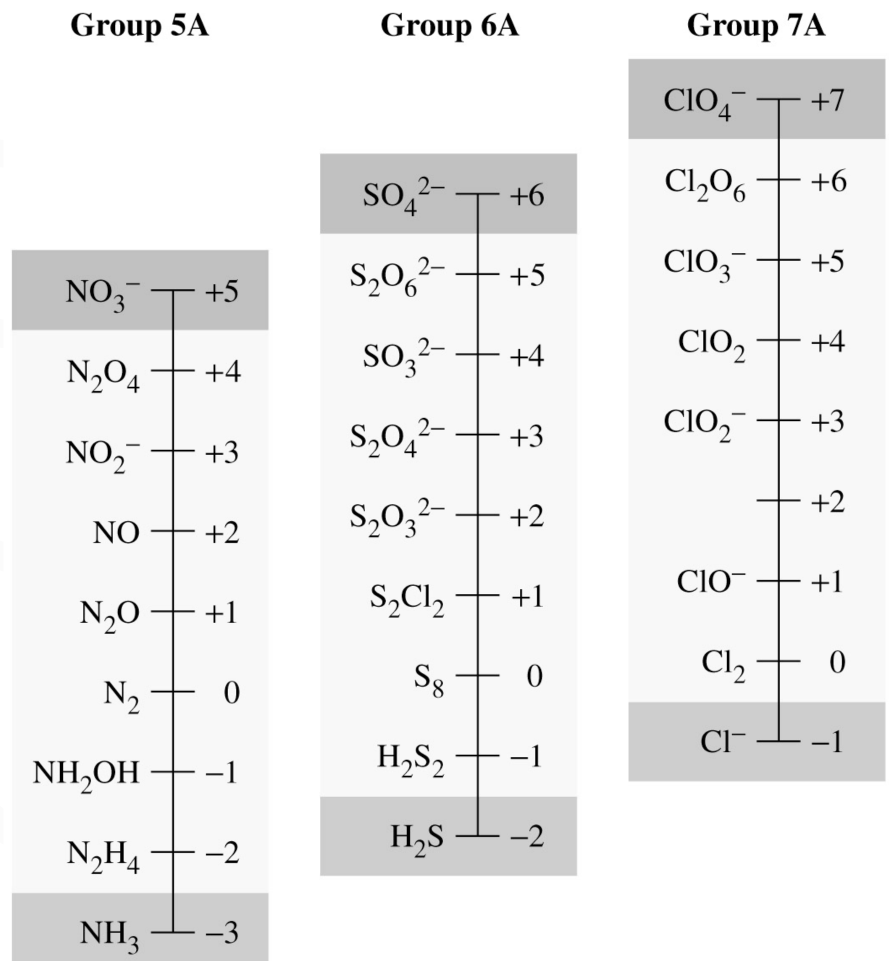
- An OXIDATION NUMBER represents the actual charge on a monoatomic ion or a *hypothetical* charge assigned to an atom in a molecule or polyatomic ion

Rules for determining oxidation states

- For a neutral species, the sum of all the oxidation numbers is zero
- For a reaction, the sum of all the oxidation numbers of reactants must equal the sum of all the oxidation numbers of the products (conservation of charge)
- Group 1A metals have a charge of +1 in their compounds
- Group 2A metals have a charge of +2 in their compounds
- In binary compounds, the ox. no. of Group 7A elements is -1
- In binary compounds, the ox. no. of Group 6A elements is -2
- In binary compounds, the ox. no. of Group 5A elements is -3
- In its compounds, the ox. no. of F is -1
- In its compounds, the ox. no. of H is +1
- In its compounds, the ox. no. of O is -2

Rules for determining oxidation states (con't)

- WHY??? There exists a HYPERSTABILITY of an ion when it has as many electrons as its nearest noble gas element
- For non-binary compounds, start with what you know and go from there. For example, in NO_3^-, since each oxygen is -2, the nitrogen must be +5



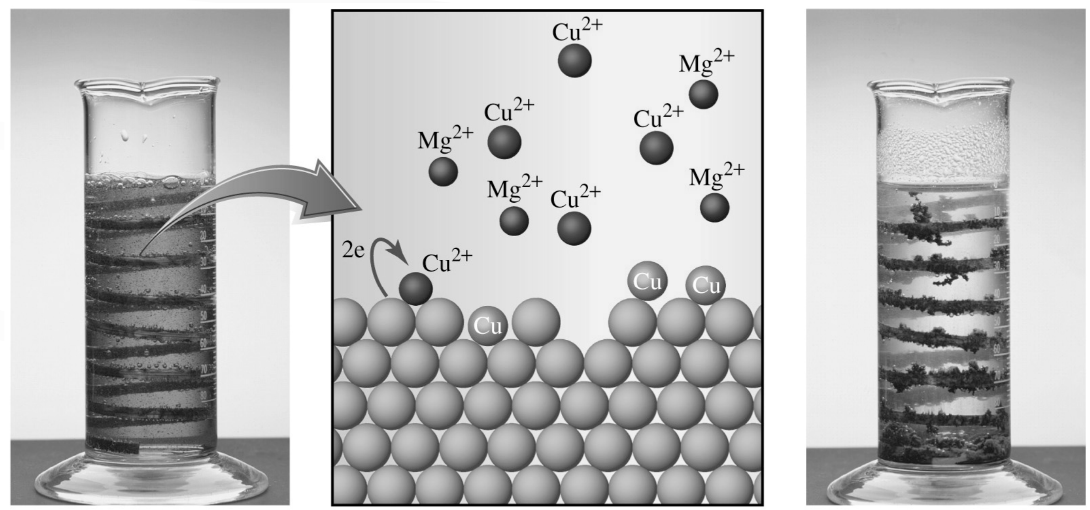
RED-OX REACTIONS

- Oxidation states change
- An element whose oxidation number increases (LOSES e^-) (or becomes less negative) upon going from reactant to product is being OXIDIZED
- An element whose oxidation number decreases (GAINS e^-) (or becomes more negative) upon going from reactant to product is being REDUCED
  - The compound DOING the reducing is the REDUCING AGENT.
    - Note that in DOING the reducing, the REDUCING AGENT gets OXIDIZED. (see Fig 4.15)
  - The compound DOING the oxidizing is the OXIDIZING AGENT.
    - Note that in DOING the oxidizing, the OXIDIZING AGENT gets REDUCED.

Redox reactions (cont'd)

$$\overset{0}{\mathrm{Mg(s)}} + \overset{+2}{\mathrm{Cu^{2+}(aq)}} \longrightarrow \overset{+2}{\mathrm{Mg^{2+}(aq)}} + \overset{0}{\mathrm{Cu(s)}}$$

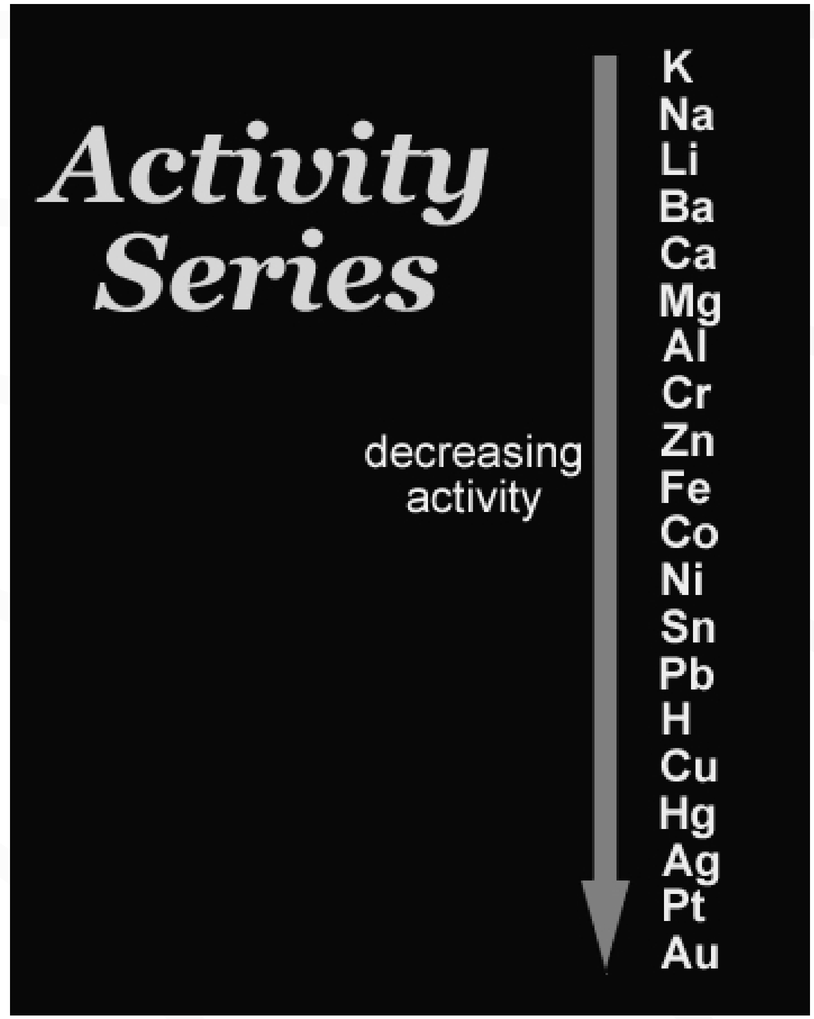
- The compound DOING the reducing is the REDUCING AGENT.
  - The REDUCING AGENT gets OXIDIZED (loses e^-).
- The compound DOING the oxidizing is the OXIDIZING AGENT.
  - The OXIDIZING AGENT gets REDUCED (gains e^-) .



(a) (b) (c)

Activity series

- We will discuss this in more depth when we talk about electrochemistry, but for now, a metal will displace from solution any ion that lies below it on the activity series (strength as a reducing agent)



Redox reactions (cont'd)

- In a redox reaction, BOTH the ATOMS and CHARGES must be balanced
- A reactant that undergoes BOTH oxidation and reduction in the same reaction is involved in a DISPROPORTIONATION

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

More practical examples

- Burning = combustion = rusting = “oxidation”

- What is happening when octane burns?
- What is happening when a nail rusts?

End of section

Forces between atoms/molecules

- BONDS are the INTRAMOLECULAR FORCES holding the atoms in molecules together...
- What holds the molecules of a solid or liquid together?...
- INTERMOLECULAR FORCES.
  - (more later)
- In an IDEAL GAS, these forces between molecules are nonexistent

Kinetic-molecular theory

- Gases are particles in random straight-line motion
- Gas particles are point masses
  - (no volume)
- Collisions are perfectly elastic
  - (no attraction)

Pressure

- The atoms or molecules making up a gas are colliding with each other and their surroundings.
- Gas pressure is expressed in PASCALS which still express FORCE per unit AREA (N/m^2 or kg/ms^2)
- 1 atm =
  760 mm Hg =
  29.921 in Hg =
  760 Torr =
  101.325 kPa =
  1.01325 bar
- Gas pressure is measured with an open- or closed-ended MANOMETER (*not* nanometer)

Example

- A Canadian weather report gives the atmospheric pressure as 100.2 kPa. What is the pressure in Torr? Atm?

- 100.2 kPa (760 Torr/101.325 kPa) = 751.6 Torr
- 751.6 Torr (1 atm/760 Torr) = 0.9889 atm

More on pressure

- P = Force/Area (units = N/m^2)
  = gravity•mass/A
  = g•density•volume/A
  = g•d•height•Area/A
  = g•d•h

Gas Laws

The key equation you must remember is PV=nRT

- Boyle $V \propto \frac{1}{P} \cdots\cdots PV = a \cdots\cdots P_1V_1 = P_3V_2 = a$

- Charles $V \propto T \cdots\cdots V = bT \cdots\cdots \frac{V_1}{T_1} = \frac{V_2}{T_2} = b$

- Avogadro $V \propto n \cdots\cdots V = cn$

- Combined $\frac{PV}{nT} = const$

We can cancel any term (*P*, *V*, *n*, *T*) that is the same on both sides.

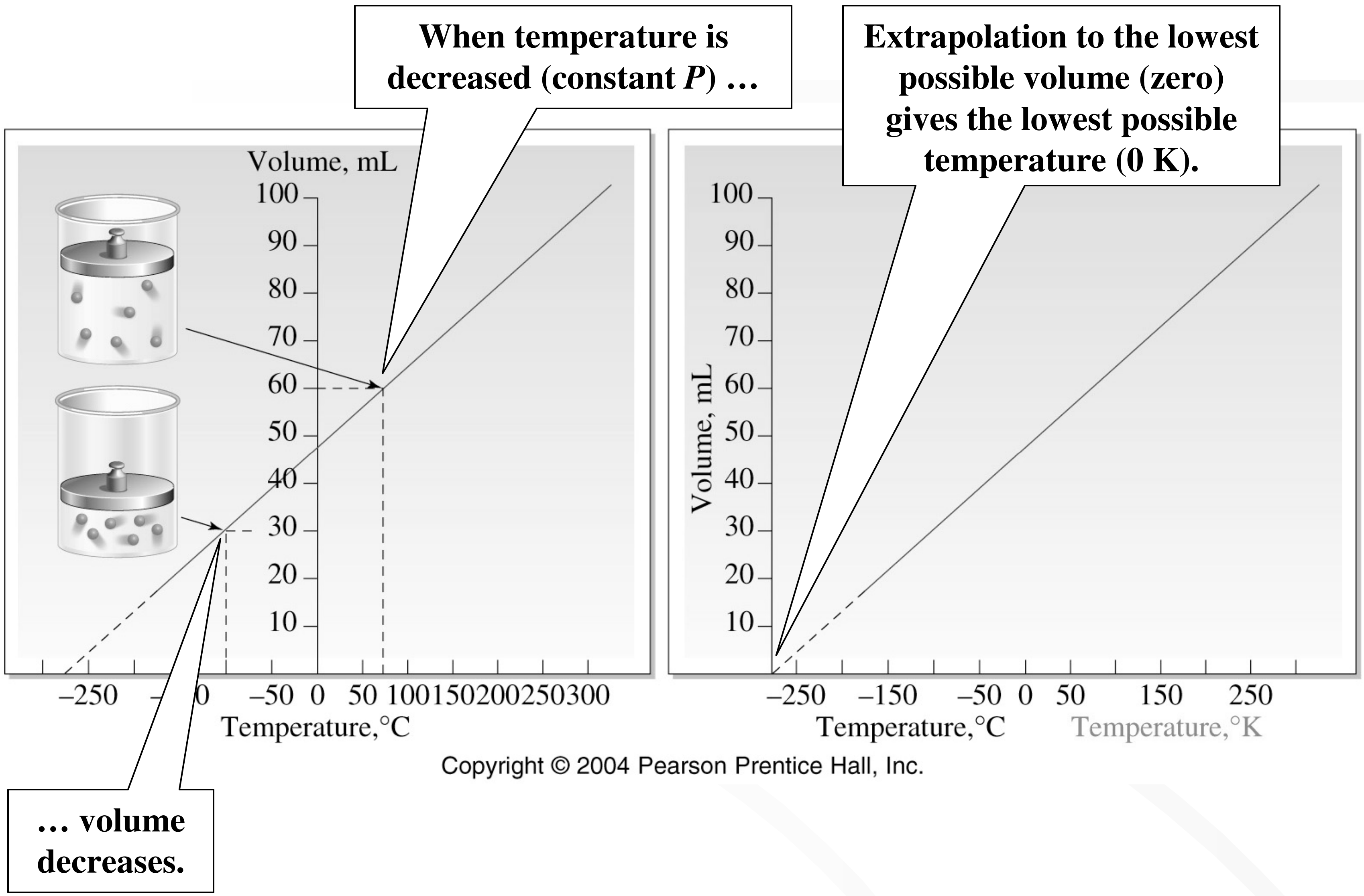
$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$$

STP

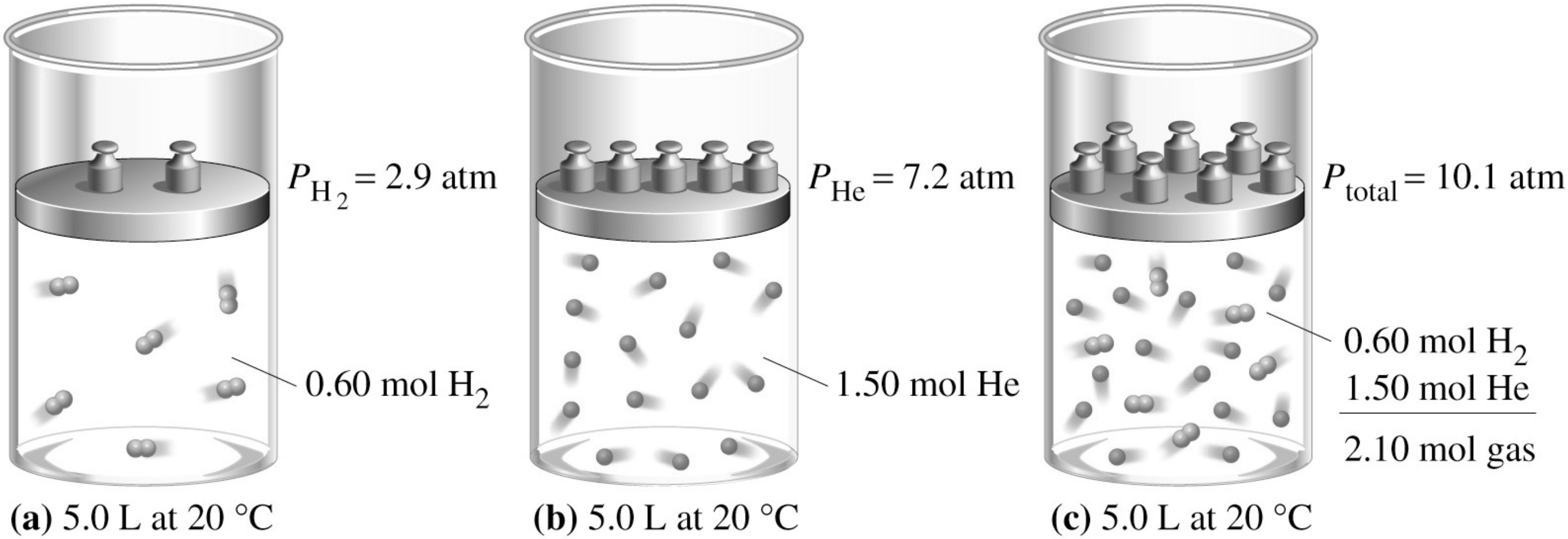
- Standard Temperature and Pressure
- 1 atm
- $0^{o}C$ (273.15K)

- R is the ideal gas constant
  8.314472 J/mol•K
  0.0820574 L•atm/mol•K

Graphical Representation of Charles's Law



Graphical Representation of Avogadro's Law



Dalton's Law of Partial Pressures

- The total pressure exerted by a mixture of gases is equal to the sum of the ***partial pressures*** exerted by the separate gases:

$$P_{total} = P_1 + P_2 + P_3 + \cdots$$

- **Partial pressure**: the pressure a gas would exert if it were alone in the container.

$$P_1 = \frac{n_1RT}{V} \qquad P_2 = \frac{n_2RT}{V} \qquad P_3 = \frac{n_3RT}{V} \cdots$$

Assumptions in the ideal law

- Particles do not interact
- Particles are “point masses”
  - they have no size
  - they occupy no space

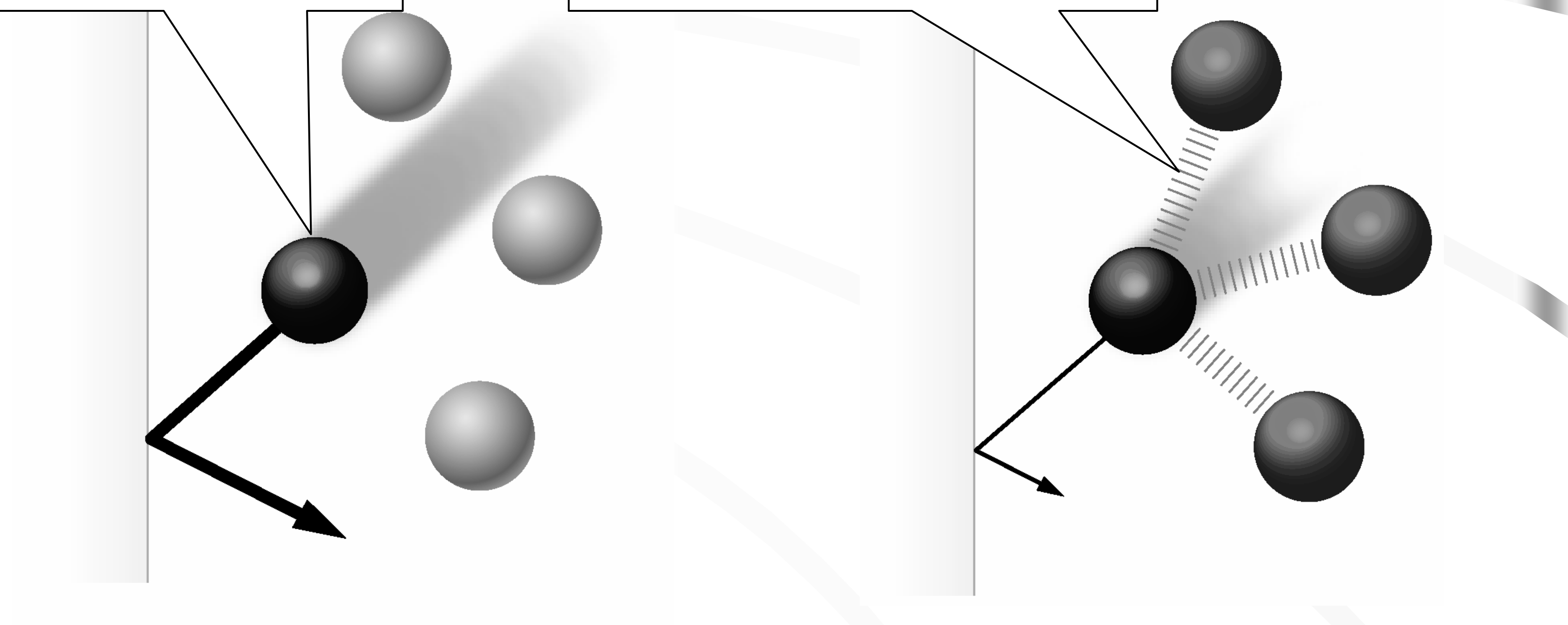
REAL gas deviations

- Particles do have some attraction for each other
  - pressure measured is LESS than ideal
- Particles do occupy space
  - the volume measured is MORE than actual

Intermolecular Forces of Attraction

Occupying no space and having no attraction for its neighbors, the blue molecule simply moves by the neighboring molecules, and strikes the wall of the container with considerable force.

Forces of attraction exist between the blue molecule and neighboring molecules in a real gas; the blue molecule strikes the wall with less force— measured pressure is lower.



Real Gases

- van der Waals equation (real gases):

  $$[P + \{(n^2 a) / V^2\}](V - nb) = nRT$$

- *a* is related to intermolecular force strength.
- *b* is related to volume of the gas molecules (in liters per mole).
- Both *a* and *b* are *empirical* constants, determined by experiment.

Table 5.5 van der Waals Constants for Selected Gases

Substance	a (L^2 atm mol^{-2})	b (L mol^{-1})
He	0.0341	0.02370
Ar	1.34	0.0322
H_2	0.244	0.0266
O_2	1.36	0.0318
CO_2	3.59	0.0427
CCl_4	20.4	0.1383

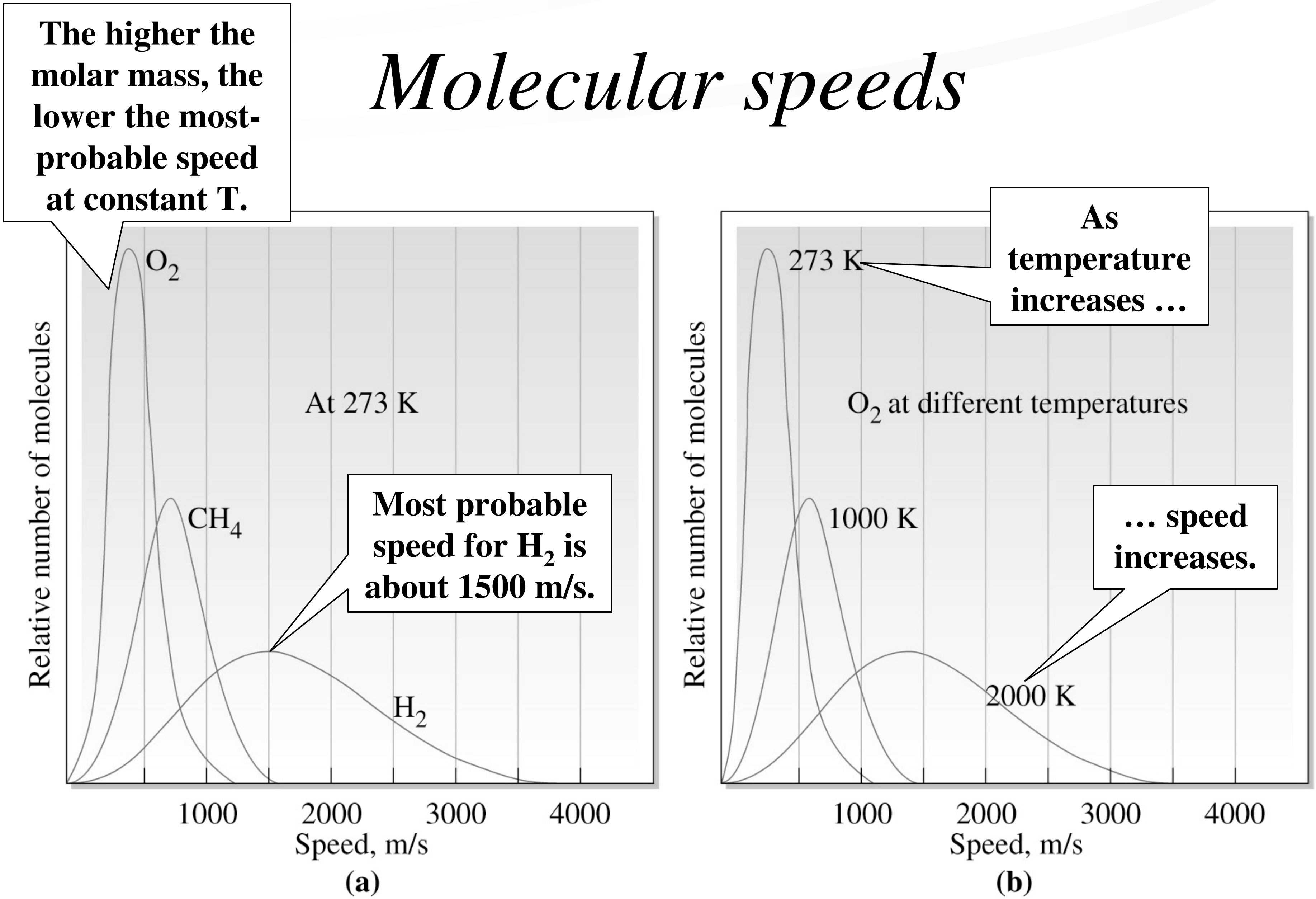
Gas Kinetics

- Gas molecules do not all move at the same speed, they have a wide distribution of speeds.
- The root-mean-square speed, u_{rms}, is the square root of the average of the squares of the molecular speeds.

$$u_{rms} = \sqrt{\overline{u^2}} = \sqrt{\frac{3RT}{M}}$$

- Typical speeds are quite high- on the order of 1000 m/s.
- At a fixed temperature, molecules of higher mass (M) move *more slowly* than molecules of lower mass.
- LIGHTER IS FASTER

Molecular speeds



Diffusion and effusion

- ***Diffusion*** is the process by which one substance mixes with one or more other substances as a result of the translational motion of molecules.
  - Diffusion of gases is much slower than would be predicted by molecular speeds due to the frequent collisions of molecules.
  - The average distance a molecule travels between collisions is called its *mean free path*.
- ***Effusion*** is the process in which a gas escapes from its container through a tiny hole, or orifice, into a vacuum.
  - Effusion is (mathematically) simpler than diffusion since effusion does not involve molecular collisions.
  - At a fixed T, the rates of effusion of gas molecules are *inversely* proportional to the square roots of their molar masses:

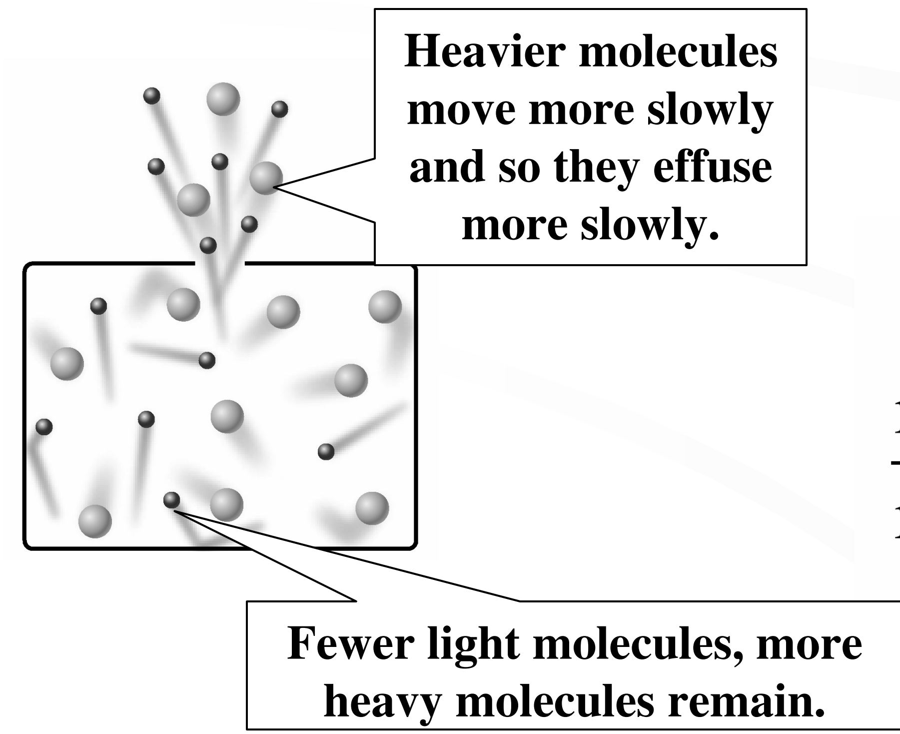
Diffusion of Gases

Why is the "smoke" closer to the HCl bottle than the NH_3 bottle?

Lighter ammonia molecules move faster, and diffuse faster, than heavier HCl molecules.

Effusion

- ***Effusion*** is the process in which a gas escapes from its container through a tiny hole, or orifice, into a vacuum.



- Effusion is (mathematically) simpler than diffusion since effusion does not involve molecular collisions.
- At a fixed T, the rates of effusion of gas molecules are inversely proportional to the square roots of their molar masses:

$$\frac{\text{rate}_1}{\text{rate}_2} = \frac{\sqrt{\dfrac{\cancel{3RT}}{M_1}}}{\sqrt{\dfrac{\cancel{3RT}}{M_2}}} = \sqrt{\frac{M_2}{M_1}}$$

QUIZ

- Express the product of 5.97 and 6.918 using the appropriate number of significant figures.
- A) 41.3
- B) 41.30
- C) 41.300460
- D) 41
- E) 12.9
- Answer: A

QUIZ

- Convert 7.62 quarts to liters. (3.785 L = 1 gal; 4 qts = 1 gal)
- A) 115
- B) 8.05
- C) 28.8
- D) 7.21
- E) 30.5
- Answer: 7.21

QUIZ

- A solid block of material has the dimensions 1.2 cm x 3.5 cm x 4.2 cm. If the mass of the block is 50 g, what is the density of the material?
- A) 880
- B) 0.35
- C) 2.8
- D) 28
- E) 0.28
- Answer: 2.8

QUIZ

- What is the length in meters of a 40-inch rod? (1 m = 39.37in)
- A) 2.3
- B) 1600
- C) 120
- D) 1.0
- E) 1.3
- Answer: 1.0

QUIZ

- How many neutrons are there in the nucleus of a ^{232}Th atom?
- A) 232
- B) 90
- C) 81
- D) 151
- E) 142
- Answer: 142

QUIZ

- An $^{56}Fe^{2+}$ particle contains
- A) 28 protons, 28 neutrons and 26 electrons.
- B) 26 protons, 30 neutrons and 24 electrons.
- C) 26 protons, 26 neutrons and 26 electrons.
- D) 58 protons, 58 neutrons and 56 electrons.
- E) 54 protons, 56 neutrons and 52 electrons.
- Answer: B

QUIZ

- Which formula could not be that of an alkane?
- A) CH_4
- B) C_3H_8
- C) C_6H_{10}
- D) C_8H_{18}
- E) $C_{10}H_{22}$
- Answer: C

QUIZ

- Which formula could NOT be that of a cycloalkane?
- A) C_3H_6
- B) C_5H_{10}
- C) C_7H_{14}
- D) C_8H_{16}
- E) $C_{10}H_{22}$
- Answer: E

QUIZ

- Name the straight chain hydrocarbons shown below in the order given:
- C_4H_{10}, C_5H_{12}, C_3H_8
- A) propane, pentane, butane
- B) propane, hexane, ethane
- C) butane, pentane, propane
- D) propane, butane, ethane
- E) butane, pentane, ethane
- Answer: C

QUIZ

- Calculate to five significant figures, the formula mass of the compound $(NH_4)_2SO_4$
- A) 132.14
- B) 114.10
- C) 132.00
- D) 114.11
- E) 66.138
- Answer: A

QUIZ

- Calculate the number of moles of $Ba(OH)_2$ present in a 100.0 g sample.
- A) 0.137
- B) 0.171
- C) 0.584
- D) 0.648
- E) 100.
- Answer: C

QUIZ

- How many F– ions are present in 2.50 moles of BF_2?
- A) 5.00
- B) 3.01×10^{24}
- C) 1.51×10^{24}
- D) 2.50
- E) 6.02×10^{24}
- Answer: B

QUIZ

- In the compound Na_2HPO_4 which element is present in the largest percent by mass?
- A) Na
- B) H
- C) P
- D) O
- E) H and P
- Answer: D

QUIZ

- Which of the following cannot be an empirical formula?
- A) C_2H_2
- B) CH_2
- C) CH_3
- D) C_2H
- E) C_2H_3
- Answer: A

QUIZ

- When the following equation is balanced with lowest ratio whole number coefficients, the coefficient of CO_2 is

  C_4H_{10} (g) + O_2 (g) → CO_2 (g) + H_2O (l)
- A) 4
- B) 5
- C) 6
- D) 7
- E) 8
- Answer: E

QUIZ

- Benzene and bromine react to form bromobenzene, as represented by the equation below. The densities of benzene and bromobenzene are 0.879 g/mL and 1.50 g/mL, respectively. How many mL of bromobenzene can be prepared from 12.5 mL benzene?

$$C_6H_6\ (l) + Br_2\ (l) \rightarrow C_6H_5Br\ (l) + HBr$$

- A) 21.3
- B) 37.7
- C) 3.64
- D) 25.1
- E) 14.7
- Answer: E

QUIZ

- What would be the molarity of a solution obtained by diluting 125 mL of 6.00 M HCl to 500. mL?
- A) 1.25
- B) 1.50
- C) 0.667
- D) 24.0
- E) 10.4
- Answer: B

QUIZ

- A beaker containing 250 mL of a 0.500 M solution of acetic acid (CH_3COOH) is added to 125 mL of a 0.850 M solution of sodium carbonate. The reaction that ensues produces carbon dioxide, sodium acetate (CH_3COONa), and water. How many grams of carbon dioxide are produced?
- A) 0.00241
- B) 2.75
- C) 15.4
- D) 4.67
- E) 5.50
- Answer: B

QUIZ

- Consider 0.1 M solutions of the following substances. Which would have the greatest electrical conductivity?
- A) CH_3NH_2
- B) CH_3COOH
- C) HCl
- D) $Ca(OH)_2$
- E) NH_4Br
- Answer: D

QUIZ

- Which of the following species is not a base in water?
- A) NaOH
- B) CH_3NH_2
- C) CH_3OH
- D) NH_3
- E) All of the above are bases in water.
- Answer: C

QUIZ

- Calculate the volume, in milliliters, of 0.600 M HCl required to titrate 25.0 mL 0.350 M KOH.
- A) 0.938
- B) 5.25
- C) 15.6
- D) 14.6
- E) 42.9
- Answer: D

QUIZ

- What is the oxidation number of chromium in $Cr_2O_7^{2-}$?
- A) +2
- B) +3
- C) +4
- D) +6
- E) –3
- Answer: D

QUIZ

- An oxidizing agent
- A) loses electrons.
- B) must contain oxygen.
- C) increases its oxidation number.
- D) becomes oxidized.
- E) none of these
- Answer: E

QUIZ

- Regarding the following reaction, what statement is incorrect?

  $Mg + Cu^{2+} (aq) \rightarrow Mg^{2+} (aq) + Cu$

- A) Mg is oxidized.
- B) Cu^{2+} is the oxidizing agent.
- C) Mg^{2+} could be an oxidizing agent.
- D) Mg is the reducing agent.
- E) Cu^{2+} is oxidized.
- Answer: E

QUIZ

- In the reaction
  Cl_2 (aq) + 2 I^- (aq) → 2 Cl^- (aq) + I_2 (aq)
  the oxidizing agent is
- A) Cl_2
- B) I^-
- C) Cl^-
- D) I_2
- E) H_2O
- Answer: A

QUIZ

- Which of the following is a strong electrolyte?
- A) HCl
- B) H_2O
- C) HCOOH
- D) CH_3COOH
- E) C_6H_6
- Answer: A