STOICHIOMETRY

EQUATIONAL MATHEMATICS

STOICHIOMETRY

The word is Greek for “measuring elements”

- It is the calculations of quantities in chemical reactions based on a balanced equation.

STOICHIOMETRY

- We can interpret balanced chemical equations several ways, in terms of:
- Particles, Moles, Mass or Volume

IN TERMS OF PARTICLES

- Atom - Element
- Molecule -
  - Molecular compound (non- metals)

    or diatomic (O_2 etc.)

Formula unit -

  - Ionic compounds (Metal and
  - non-metal)

PARTICLES

- $2H_2 + O_2 \rightarrow 2H_2O$
  Two molecules of hydrogen and one molecule of oxygen form two molecules of water.
- $2\ Al_2O_3 \rightarrow 4Al + 3O_2$
- *2 formula units Al_2O_3 form 4 atoms Al and 3 molecules O_2*
- $2Na + 2H_2O \rightarrow 2NaOH + H_2$

In Terms of Moles

- $2 Al_2O_3 \rightarrow 4 Al + 3 O_2$
- *The coefficients tell us how many moles of each kind of compound or element.*

In Terms of MASS

- The law of conservation of mass applies.
- We can check using moles
- $2H_2 + O_2 \rightarrow 2H_2O$
- 2 moles H_2 / 2.02 g H_2 = 4.04 g H_2

  / 1 mole H_2
- 1 mole O_2 /32.00 g O_2 = 32.00 g O_2
- / 1 mole O_2
-
- Total 4.04 + 32.00 = 36.04 g reactants

MOLE TO MOLE CONVERSIONS

- $2\ Al_2O_3 \rightarrow 4Al + 3O_2$
- Every time we use 2 moles of Al_2O_3 we make 3 moles of O_2
- 2 moles Al_2O_3
- 3 mole O_2
- *or*
- 3 moles O_2
- 2 moles Al_2O_3

Mole to Mole Conversions

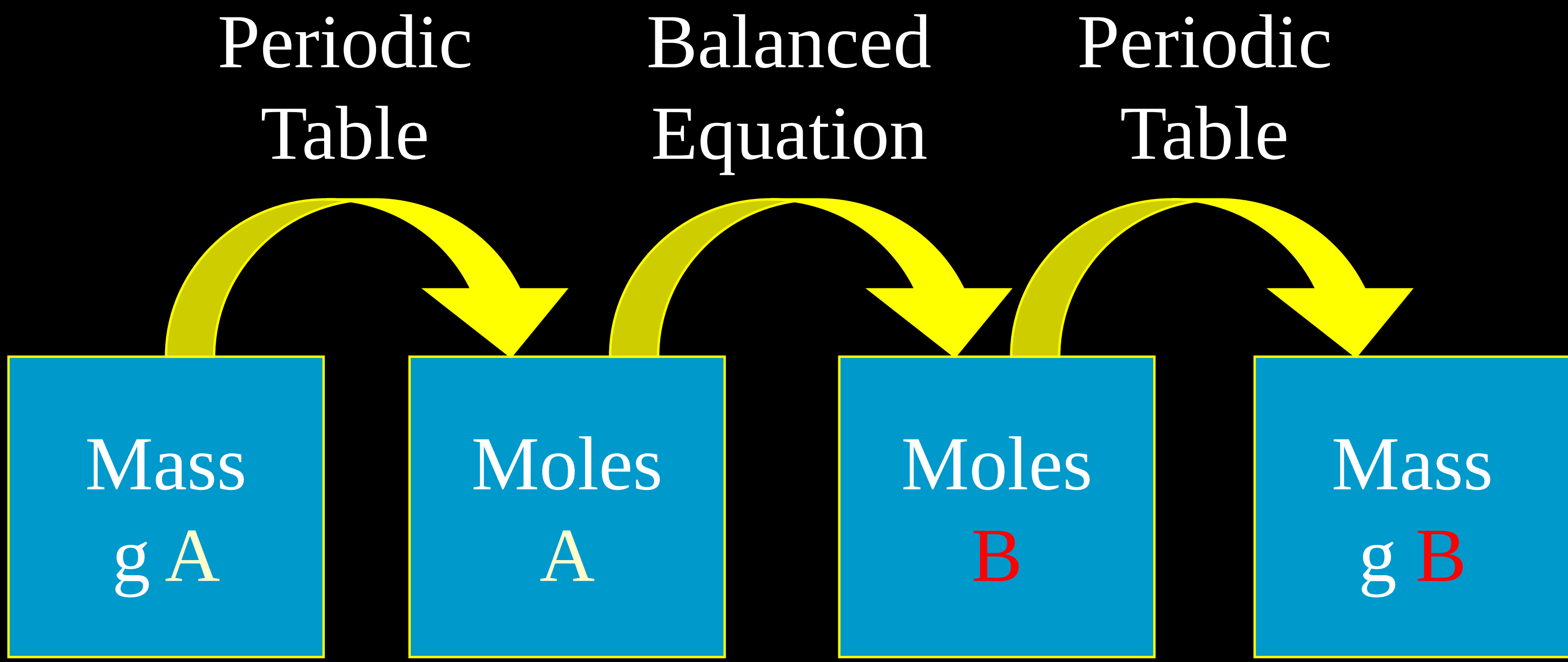
- How many moles of O_2 are produced when 3.34 moles of Al_2O_3 decompose?
- $2\ Al_2O_3 \rightarrow 4Al + 3O_2$
- <u>3.34 moles Al_2O_3 / 3 mole O_2</u>
- / 2 moles Al_2O_3
- = 5.01 moles O_2

MOLE TO MOLE PROBLEMS

- $2\ C_2H_2 + 5\ O_2 \rightarrow 4\ CO_2 + 2\ H_2O$
- *1.If 3.84 moles of C_2H_2 are burned, how many moles of O_2 are needed?*
- *2. How many moles of C_2H_2 are needed to produce 8.95 mole of H_2O?*
- *3. If 2.47 moles of C_2H_2 are burned, how many moles of CO_2 are formed?*

WE CAN'T MEASURE MOLES!!

- What can we do?
- We can convert grams to moles.
- Use the Periodic Table to determine amu or gfm
- You must have a *Balanced Equation* for the mole ratio step.
- Then turn the moles back to grams.



- Decide where to start based on the units you are given,
- and stop based on what unit you are asked for.

Mass to Moles Problems

- $2C_2H_2 + 5\,O_2 \rightarrow 4CO_2 + 2\,H_2O$
- *1. How many moles of C_2H_2 are needed to produce 8.95 g of H_2O?*
- *2. If 2.47 moles of C_2H_2 are burned, how many grams of CO_2 are formed?*

MASS TO MASS PROBLEMS

- For example…
- *If 10.1 g of Fe are added to a solution of Copper (II) Sulfate, how much solid copper would form?*
- $Fe + CuSO_4 \rightarrow Fe_2(SO_4)_3 + Cu$
- $2Fe + 3CuSO_4 \rightarrow Fe_2(SO_4)_3 + 3Cu$

- 10.1 g Fe/ 1 mol Fe / 3 mol Cu / 63.6 g Cu
- / 56 g Fe / 2 mol Fe / 1 mol Cu
- = 17.2 g Cu

MORE MASS TO MASS PROBLEMS

- To make silicon for computer chips they use this reaction
- $SiCl_4 + 2Mg \rightarrow 2MgCl_2 + Si$
- *1. How many grams of Mg are needed to make 9.30 g of Si?*
- 2. 3.74 mol of Mg would make how many grams of Si?
- *3. How many grams of $MgCl_2$ are produced along with 9.3 g of silicon?*

MORE MASS TO MASS PROBLEMS

- The U. S. Space Shuttle boosters use this reaction
- $3\ Al(s) + 3\ NH_4ClO_4 \rightarrow$
  $Al_2O_3 + AlCl_3 + 3\ NO + 6H_2O$
- *1. How many grams of Al must be used to react with 652 g of* NH_4ClO_4 *?*
- *2. How much water is produced?*
- *3. How much* $AlCl_3$*?*

- How do you get good at this?
- PRACTICE

VOLUME PROBLEMS

- We can also change liters of a gas to moles at STP.
- STP stands for standard temperature and pressure. For gases STP is 0°C and 1 atmosphere pressure
- At STP 22.4 Liters of a gas = 1 mole

MASS TO VOLUME PROBLEM

- *If 6.45 moles of water are decomposed, how many liters of oxygen will be produced at STP?*
- $H_2O \rightarrow H_2 + O_2$
- $2H_2O \rightarrow 2H_2 + O_2$
- 6.45 g H_2O/1 mole H_2O/1 mol O_2 /22.4 L H_2O
- /18 g H_2O /2 mol H_2O / 1 mol O_2
- = 4.01L H_2O

MASS TO VOLUME PROBLEMS

- *1. How many liters of CO_2 at STP will be produced from the complete combustion of 23.2 g C_4H_{10}?*

- 2. What volume of oxygen will be required?

VOLUME TO VOLUME PROBLEM

- *How many liters of CH_4 at STP are required to completely react with 17.5 L of O_2 ?*
- $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
- $\underline{17.5 \text{ L } O_2 / 1 \text{ mol } O_2 / 1 \text{ mol } CH_4 / 22.4 \text{ L } CH_4}$
- $/ 22.4 \text{ L } O_2 / 2 \text{ mol } O_2 / 1 \text{ mol } CH_4$
-
- $= 8.75 \text{ L } CH_4$

MOLES TO PARTICLES

- Equal volumes of gas, at the same temperature and pressure contain the same number of particles.
- Moles are numbers of particles.
- You can treat reactions as if they happen by liters at a time, as long as you keep the temperature and pressure the same.

MOLES TO PARTICLES

- We can also change between particles and moles.
  - 6.02×10^{23} is Avogadro's number of
  - Molecules, Formula Units or Atoms in a mole
  -

Particles

- $2NaHCO_3 + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O + 2CO_2$
- *1. How many grams of sodium sulfate is produced from 2.40 x 10 ^{23} formula units of $NaHCO_3$?*
- *2. How many cm^3 of CO_2 would be produced from 2.40 x 10 ^{23} f u of $NaHCO_3$?*
- *3. How many formula units of H_2SO_4 would be used when 250.0 liters of CO_2 is produced?*

MASS-VOLUME-PARTICLE PROBLEMS

- $12CO_2 + 11H_2O \rightarrow C_{12}H_{22}O_{11} + 12 O_2$
- 1. How many grams of sucrose ($C_{12}H_{22}O_{11}$) is produced from 224 cubic decimeters of carbon dioxide?
- 2. How many dm^3 of CO_2 is needed to produce 5.00 pounds of sugar? (1kg=2.20 lbs)
- 3. What mass of water would be needed to combine with 200.0 cm^3 of CO_2?

LIMITING REAGENT

- If you are given one dozen loaves of bread, a gallon of mustard and three pieces of salami, how many salami sandwiches can you make?
- The limiting reagent is the reactant you run out of first.
- The excess reagent is the one you have left over.
- The limiting reagent determines how much product you can make

LIMITING REAGENT

- How do you find out how much can be produced?
- Do two stoichiometry problems.
- The reactant that makes the least amount of product is the limiting reagent.
- For example:
- Copper reacts with sulfur to form copper (I) sulfide. If 10.6 g of copper reacts with 3.83 g S how much product will be formed?

EXCESS REAGENT

- How much excess reagent is left?
- Use the limiting reagent to find out how much excess reagent you used
- Subtract that from the amount of excess you started with

LIMITING REACTANT AND EXCESS REAGENT

- $Mg_{(s)} + 2\ HCl_{(g)} \rightarrow MgCl_{2(s)} + H_{2(g)}$
- If 10.1 mol of magnesium and 4.87 mol of HCl gas are reacted, how many moles of gas will be produced?
- How much excess reagent remains in liters?

Limiting Reactant and Excess Reagent

- If 10.3 g of aluminum are reacted with 51.7 g of $CuSO_4$ how much copper will be produced?
- How much excess reagent will remain?

PERCENT YIELD

- % yield is the amount of product that is actually made in a chemical reaction.
- Some product is always lost.
- Actual yield- what you *actually* produce in the lab when the chemicals are mixed
- Theoretical yield- what the balanced equation tells you the full amount you should be able make.
- **Percent yield** = $\frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100\ \%$

PERCENT YIELD PROBLEMS

- *6.78 g of copper are produced when 3.92 g of*
- *aluminum are reacted with excess copper (II) sulfate*.
- $2Al + 3\ CuSO_4 \rightarrow Al_2(SO_4)_3 + 3Cu$
- What is the actual yield?
- What is the theoretical yield?
- What is the percent yield?
- *If you had started with 9.73 g of aluminum, how much copper would you expect and what would the percent yield be if 30.0 g of copper are produced?*

Details

- Percent yield tells us how “efficient” a reaction is.
- Percent yield can not be larger than 100 %.

How would you get good at this?

- PRACTICE