Stoichiometry

Basic Mathematics for Chemistry

THE ARC.

What will we discuss in this workshop?

- **Who** is this workshop for?
- **What** will I learn?
- **How** do I used the concepts?
- **When** will I use the concepts?
- **Why** is it important?

Who is this workshop for?

*1

Who is this workshop for?

- General chemistry students
- People who do math problems for sciences
- Anyone else

What will I learn?

*2

What is Stoichiometry?

- **Stoichiometry** (/ˌstɔɪkiˈɒmɨtri/) is a branch of chemistry that deals with the relative quantities of reactants and products in chemical reactions

What is Stoichiometry used for?

- Converting between different units
- Forming ratios between products and reactants
- Describing ratios between compounds in a reaction
- Calculating quantities of products or reactants (in mass, moles, volume, etc.)

THE ARC.

How will I use the concepts?

*3

How do you convert between units?

- Multiply by clever values of one
- Keep track of your units

What is a clever value of one?

- **Example 1**: Converting between feet and inches
  - We know that 12 inches = 1 foot
  - Therefore $\frac{12 inches}{1 foot}$ is equal to 1, and hence, a clever value of 1
- **Example 2**: Converting between moles and grams
  - 1 mole of Na = 22.99 g Na
  - Therefore $\frac{1 mole Na}{22.99 grams Na}$ is also equal to 1

Why are units so important?

- Units help you keep track of your numbers
- Units help keep equalities true
- For example, we all know that there are <u>12 inches in 1 foot</u>. If we mixed up the units to read <u>12 feet per 1 inch</u>, any conversion we were trying to make would be incorrect.

Table 4a – Metric Prefix				Scientific Notation	
Prefix	Symbol	Multiplier	Exponential	Normalized	E Notation
yotta	Y	1,000,000,000,000,000,000,000,000	10^{24}	1.0×10^{24}	1.0E24
zetta	Z	1,000,000,000,000,000,000,000	10^{21}	1.0×10^{21}	1.0E21
exa	E	1,000,000,000,000,000,000	10^{18}	1.0×10^{18}	1.0E18
peta	P	1,000,000,000,000,000	10^{15}	1.0×10^{15}	1.0E15
tera	T	1,000,000,000,000	10^{12}	1.0×10^{12}	1.0E12
giga	G	1,000,000,000	10^{9}	1.0×10^{9}	1.0E9
mega	M	1,000,000	10^{6}	1.0×10^{6}	1.0E6
kilo	k	1,000	10^{3}	1.0×10^{3}	1.0E3
hecto	h	100	10^{2}	1.0×10^{2}	1.0E2
deca	da	10	10^{1}	1.0×10^{1}	1.0E1
		1	10^{0}	1.0×10^{0}	1.0E0
deci	d	0.1	10^{-1}	1.0×10^{-1}	1.0E-1
centi	c	0.01	10^{-2}	1.0×10^{-2}	1.0E-2
milli	m	0.001	10^{-3}	1.0×10^{-3}	1.0E-3
micro	µ	0.000001	10^{-6}	1.0×10^{-6}	1.0E-6
nano	n	0.000000001	10^{-9}	1.0×10^{-9}	1.0E-9
pico	p	0.000000000001	10^{-12}	1.0×10^{-12}	1.0E-12
femto	f	0.000000000000001	10^{-15}	1.0×10^{-15}	1.0E-15
atto	a	0.000000000000000001	10^{-18}	1.0×10^{-18}	1.0E-18
zepto	z	0.000000000000000000001	10^{-21}	1.0×10^{-21}	1.0E-21
yocto	y	0.000000000000000000000001	10^{-24}	1.0×10^{-24}	1.0E-24

$$\frac{1000 meters}{1 kilometer}$$

$$\frac{100 centimeters}{1 meter}$$

$$1 kilometer = 1 kilometer * \frac{1000 meters}{1 kilometer} * \frac{100 centimeters}{1 meter} = 100,000 centimeters$$

How do you convert between prefixes of the same unit?

- Metric prefixes help you convert between different quantities within the same unit.
- Again, we multiply by a clever value of 1.
- **Example 3**: Converting from

How can we use these concepts in Chemistry?

- A balanced chemical equation will give you information specific to that reaction
- For example, the reaction for the combustion of methane is:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

- Note the coefficients: 1, 2, 1, 2 respecti
- Coefficients give a ratio of necessary sta the ratio of products made

Example 4: Finding the product given a reactant and a chemical equation

- Question: Find the grams of carbon dioxide gas created when 5.29 liters of methane gas at STP is combusted.

Example 4 continued

- Answer:
  - First, gather all needed information (including clever values of 1)
    - 1 mole of gas = 22.4 liters at STP
    - Molecular mass of:
      - Carbon: 12 g/mol
      - Hydrogen: 1 g/mol
      - Oxygen: 16 g/mol
    - Reaction coefficients:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

THE ARC.

Example 4 continued

- Answer continued:
  - Next, start with what you are given in the question and multiply by 1 until you arrive at your answer, making sure to keep track of your units

$$5.29 liters CH_4$$

$$= 5.29 Liters CH_4 * \frac{1 mole CH_4}{22.4 Liters CH_4} * \frac{1 mole CO_2}{1 mole CH_4} * \frac{44 g CO_2}{1 mole CO_2}$$

$$= \frac{5.29 * 44}{22.4} g CO_2$$

$$= 10.4 g CO_2$$

THE ARC.

Example 5: A comprehensive problem

- Question: The reaction of powdered aluminum and iron(II)oxide,

  $$2Al_{(s)} + Fe_2O_{3(s)} \rightarrow Al_2O_{3(s)} + 2Fe_{(l)}$$

  produces so much heat the iron that forms is molten. Because of this, railroads use the reaction to provide molten steel to weld steel rails together when laying track. Suppose that in one batch of reactants 4.20 mol Al was mixed with 1.75 mol Fe_2O_3.
  - Which reactant, if either, was the limiting reactant?
  - Calculate the mass of iron (in grams) that can be formed from this mixture of reactants.

THE ARC.

Example 5 continued

- Answer
  - Map:
    - Step 1: Find the limiting reactant
    - Step 2: Take the limiting reactant and multiply by clever values of 1, keeping track of units. Arrive at grams of Fe.
  - Gather information:
    - Molecular masses:
      - Aluminum: 26.98 g/mol
      - Iron: 55.85 g/mol
      - Oxygen: 16 g/mol
    - Equation coefficients: $2Al_{(s)} + Fe_2O_{3(s)} \rightarrow Al_2O_{3(s)} + 2Fe_{(l)}$

THE ARC.

Example 5 continued

- Answer continued
  - Convert starting materials to moles
    - 4.2 moles $2Al_{(s)}$

$$4.2 moles Al * \frac{1 rxn}{2 moles Al} = 2.1 eqn$$

    - 1.75 moles $Fe_2O_{3(s)}$
    - Fe_2O_3 is the limiting reactant

$$1.75 moles Fe_2O_3 * \frac{1 rxn}{1 mole Fe_2O_3} = 1.75 rxn$$

THE ARC.

Example 5 continued

- Answer continued
  - Find grams of iron formed from the limiting reactant by multiplying by one

$$1.75 moles Fe_2O_3$$
$$= 1.75 moles Fe_2O_3 * \frac{2 moles Fe}{1 mole Fe_2O_3} * \frac{55.85 g Fe}{1 mole Fe}$$
$$= 1.75 * 2 * 55.85 g Fe$$
$$= 195 g Fe$$

THE ARC.

When will I use the concepts?

*4

When will I use these concepts?

- Convert between units
- Calculations with a balanced chemical equation
  - Moles
  - Volume
  - Density
  - Mass

Why is it important?

*5

Why is it important?

- In school:
  - Units and ratios must be correct to get the right solution
  - Get good grades
- In the real world:
  - bad ratios can have catastrophic and unintended consequences (explosions, toxins, waste of starting materials, waste of money, etc.)

THE ARC.

References

- Wikipedia: http://en.wikipedia.org/wiki/Stoichiometry
- Chemistry, The Molecular Nature of Matter and Change, Silberberg 4th Edition, Chapter 3
- Matter and its Changes, Brady, Russell, and Holum's Chemistry, 3rd Edition, Chapter 3
- Prefix image: http://biolojoy.files.wordpress.com/2011/06/techtips_table_table4a-metric-scinot.jpg
- Methane combustion reaction image: http://video.ecb.org/badger/download/vlc/images/VLC082_Balanced_chemical_equation.jpg

THE ARC.