

Stoichiometry

Basic Mathematics for Chemistry

What will we discuss in this workshop?

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

Who is this workshop for?

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Who is this workshop for?

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

What will I learn?

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ARC.

What is Stoichiometry?

- **Stoichiometry** (\angle stɔɪki'ɒmɪtri/) 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.)

How will I use the concepts?

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

$$\frac{1 \text{ mole Na}}{22.99 \text{ grams Na}}$$

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 12 inches in 1 foot. If we mixed up the units to read 12 feet per 1 inch, 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	1.0x10 ²⁴	1.0E24
zetta	Z	1,000,000,000,000,000,000,000	10 ²¹	1.0x10 ²¹	1.0E21
exa	E	1,000,000,000,000,000,000	10 ¹⁸	1.0x10 ¹⁸	1.0E18
peta	P	1,000,000,000,000,000	10 ¹⁵	1.0x10 ¹⁵	1.0E15
tera	T	1,000,000,000,000	10 ¹²	1.0x10 ¹²	1.0E12
giga	G	1,000,000,000	10 ⁹	1.0x10 ⁹	1.0E9
mega	M	1,000,000	10 ⁶	1.0x10 ⁶	1.0E6
kilo	k	1,000	10 ³	1.0x10 ³	1.0E3
hecto	h	100	10 ²	1.0x10 ²	1.0E2
deca	da	10	10 ¹	1.0x10 ¹	1.0E1
		1	10 ⁰	1.0x10 ⁰	1.0E0
deci	d	0.1	10 ⁻¹	1.0x10 ⁻¹	1.0E-1
centi	c	0.01	10 ⁻²	1.0x10 ⁻²	1.0E-2
milli	m	$\frac{1000\text{meters}}{1000}$ 0.001	10 ⁻³	1.0x10 ⁻³	1.0E-3
micro	μ	$\frac{1\text{kilometer}}{1,000,000}$ 0.000001	10 ⁻⁶	1.0x10 ⁻⁶	1.0E-6
nano	n	0.000000001	10 ⁻⁹	1.0x10 ⁻⁹	1.0E-9
pico	p	$\frac{100\text{centimeters}}{100,000,000,000}$ 0.000000000001	10 ⁻¹²	1.0x10 ⁻¹²	1.0E-12
femto	f	$\frac{1\text{meter}}{1,000,000,000,000,000}$ 0.000000000000001	10 ⁻¹⁵	1.0x10 ⁻¹⁵	1.0E-15
atto	a	0.0000000000000000001	10 ⁻¹⁸	1.0x10 ⁻¹⁸	1.0E-18
zepto	z	0.000000000000000000001	10 ⁻²¹	1.0x10 ⁻²¹	1.0E-21
yocto	y	$\frac{1\text{kilometer}}{100,000,000,000,000,000,000,000}$ 0.00000000000000000000001	10 ⁻²⁴	1.0x10 ⁻²⁴	1.0E-24

1kilometer

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

= 100,000centimeters

How do you convert between prefixes of the same unit?

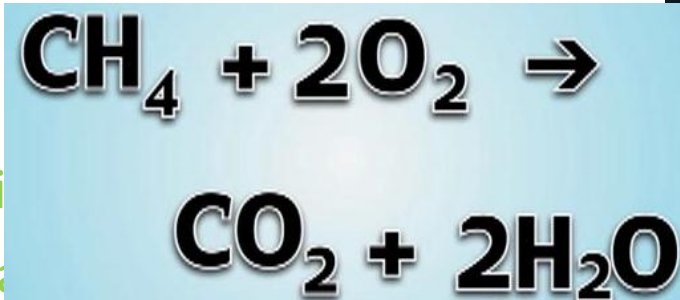
- Metric prefixes help you convert between different quantities within the same unit.
- Again, we multiply by a clever value of 1.

•Example 2: 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:
- Note the coefficients: 1, 2, 1, 2 respectively
- Coefficients give a ratio of necessary starting materials to the ratio of products made

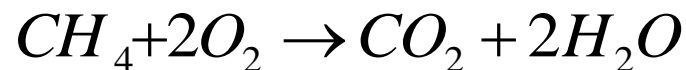


Example 4: Finding the product given a reactant and a chemical equation

- 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:



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

$$\begin{aligned} & 5.29 \text{ liters } CH_4 \\ &= 5.29 \text{ Liters } CH_4 * \frac{1 \text{ mole } CH_4}{22.4 \text{ Liters } CH_4} * \frac{1 \text{ mole } CO_2}{1 \text{ mole } CH_4} * \frac{44 \text{ g } CO_2}{1 \text{ mole } CO_2} \\ &= \frac{5.29 * 44}{22.4} \text{ g } CO_2 \\ &= 10.4 \text{ g } CO_2 \end{aligned}$$

Example 5: A comprehensive problem

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



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.

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: $2\text{Al}_{(s)} + \text{Fe}_2\text{O}_{3(s)} \rightarrow \text{Al}_2\text{O}_{3(s)} + 2\text{Fe}_{(l)}$

Example 5 continued

- Answer continued
- Convert starting materials to moles

- 4.2 moles $2Al_{(s)}$

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

- 1.75 moles $Fe_2O_{3(s)}$

- Fe_2O_3 is the limiting reactant

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

Example 5 continued

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

$$\begin{aligned} & 1.75 \text{ moles } Fe_2O_3 \\ & = 1.75 \text{ moles } Fe_2O_3 * \frac{2 \text{ moles } Fe}{1 \text{ mole } Fe_2O_3} * \frac{55.85 \text{ g } Fe}{1 \text{ mole } Fe} \\ & = 1.75 * 2 * 55.85 \text{ g } Fe \\ & = 195 \text{ g } Fe \end{aligned}$$

When will I use the concepts?

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When will I use these concepts?

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

Why is it important?

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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.)

References

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- Methane combustion reaction image:
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