Stoichiometry.

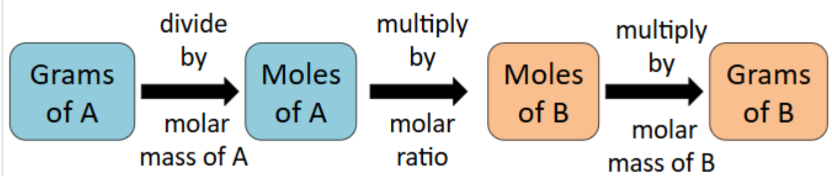
A balanced chemical equation is like a recipe for a chemical reaction. Calculations based on this recipe are known as stoichiometry. Consider the following chemical equation: **$2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O\ (\ell)$**. The numbers in front of the formulas are stoichiometric coefficients. We interpret this equation as "two hydrogen molecules react with one oxygen molecule to make two water molecules." Since we are usually reacting far more than one or two molecules at a time, we can also interpret the equation as "two moles of hydrogen react with one mole of oxygen to form two moles of water". Conversion factors based on the coefficients of a reaction are known as molar ratios and are used to convert moles of one substance in a reaction to moles of another. Some molar ratios based on the equation above are:

$$\frac{2\text{ mol } H_2}{1\text{ mol } O_2} \qquad \frac{2\text{ mol } H_2}{2\text{ mol } H_2O} \qquad \frac{1\text{ mol } O_2}{2\text{ mol } H_2O}$$

Suppose we need to know how many moles of oxygen are needed to react with 2.8 moles of hydrogen. As we did with converting units, we start with our given quantity and use the appropriate conversion factor ensuring that the unit mol H_2 cancels:

$$2.8\ \cancel{\text{mol } H_2} \times \frac{1\text{ mol } O_2}{2\ \cancel{\text{mol } H_2}} = 1.4\text{ mol } O_2$$

Molar ratios can be combined with conversion factors from molar mass to find mass relationships in chemical reactions. Most stoichiometry problems start with the mass of one molecule and ask you to determine the mass of another substance. As with all stoichiometry problems, it is important that you start with a balanced chemical equation. The general strategy for solving these mass-mass problems is the following three steps:



For example, let's determine the number of grams of SO_3 that would be produced from the reaction of 45.3 g of O_2 with excess SO_2:

$$2\ SO_2(g) + O_2(g) \rightarrow 2\ SO_3(g)$$

Start with the given O_2 grams, divide by its molar mass, use a molar ratio to convert to moles SO_3, then multiply by the molar mass of SO_3 to get grams.

$$45.3\ \cancel{\text{g } O_2} \times \frac{1\ \cancel{\text{mol } O_2}}{32.00\ \cancel{\text{g } O_2}} \times \frac{2\ \cancel{\text{mol } SO_3}}{1\ \cancel{\text{mol } O_2}} \times \frac{80.06\text{ g } SO_3}{1\ \cancel{\text{mol } SO_3}} = 227\text{ g } SO_3$$

The theoretical yield is the maximum amount of a product that can be made from the limiting reactant (the reactant that gets used up first). It is calculated with the same three step process as any other stoichiometry problem. The actual yield is the amount actually formed in the lab. It is usually less than the theoretical yield due to loss from transferring or purification. The percent yield is calculated by the equation below. The closer it is to 100%, the more efficient the reaction is.

$$\text{percent yield} = \frac{actual\ yield}{theoretical\ yield}\ x\ 100$$

Laboratory Activity

Materials: $NaHCO_3$(s) | HCl (1.0M) | Na_2CO_3 (s) | beakers (250ml, 50ml, 50 mL) | hot mitts | ¼ antacid chunk | graduated cylinders | hot plates

Procedure

A. Decomposition of Sodium Hydrogen Carbonate

1. Weigh a 250 mL beaker and record the mass. ***Always record ALL digits on the scale.***
2. Tare (zero) the beaker on the scale. Add between 4 and 5 grams of sodium bicarbonate to the beaker. Record the mass.
3. Set the hot plate to 400°C. Set the beaker on the hot plate and heat for 20 minutes.
4. Take the beaker off the hot plate with hot mitts, place on the benchtop and let cool until it reaches room temperature. Record the mass.
5. Dispose of waste in the sink.

B. Reaction of Antacid with Hydrochloric acid

6. Measure 15 mL of 1.0 M HCl with a graduated cylinder and pour it into a 50 mL beaker. Record the mass of the beaker with liquid. HCl will be excess reactant.
7. Tare (zero) a weighboat, then weigh a chunk of antacid tablet. Record the mass of the tablet on your data sheet.
8. Off the scale, add the tablet to the beaker. Swirl gently as the reaction proceeds. *Do not use a stirring rod - liquid clinging to the rod will affect the mass calculations*.Allow to react for at least 5 minutes or until no more bubbles are formed.
9. Tilt the beaker without spilling the liquid to remove gas formed. Weigh the beaker. Repeat the process until you are getting a consistent mass, then record it on your data sheet. Subtract this mass from the sum of the tablet and initial HCl/beaker mass to determine the mass lost.

C. Reaction of Sodium Carbonate with Hydrochloric acid

1. Measure 10 mL of 1.0 M HCl with a graduated cylinder and pour it into a 50 mL Erlenmeyer flask. Record the mass of the flask with liquid.
2. Tare(zero) a weighboat, then weigh between 0.1 and 0.12g of sodium carbonate. Record the mass on your data sheet.
3. Off the balance, carefully add the sodium carbonate to the flask, bending the weighboat and tapping to add solid. Swirl gently as the reaction proceeds. *Do not use a stirring rod - liquid clinging to the rod will affect the mass calculations*. Allow to react for at least 5 minutes or until no more bubbles are formed.
4. Tilt the flask to remove gas, but not liquid. Weigh the flask, then remove from the scale and tilt again. Repeat until you reach a stable mass and record it on your data sheet. Subtract this mass from the sum of the sodium carbonate and initial HCl/beaker mass to determine the mass lost.
5. Wet the end of a stirring rod in the flask liquid then touch the rod to blue litmus paper. If it turns pink/red, HCl is still present.

Waste Disposal

- Dispose of all reactions down the sink

Safety

- 1.0 M HCl is corrosive and an irritant. Wear gloves and rinse immediately if it gets on your skin.

Name___________________________

Team Name ________________________

CHM101 Lab – Stoichiometry – Grading Rubric

To participate in this lab you must have splash-proof goggles, proper shoes and attire.

Criteria	Points possible	Deductions
Printed lab manual and goggles brought to lab	2	
• Safety and proper waste disposal procedures observed • Followed procedure correctly without depending too much on instructor or lab partner • Work space and glassware was cleaned up	3	
Reaction A - data recorded with correct sig figs and units,	1	
Questions A1 - A4 Work and units shown for calculations	4	
Reaction B - data recorded with correct sig figs and units,	1	
Questions B1 - B4 Work and units shown for calculations	4	
Reaction C - data recorded with correct sig figs and units,	1	
Questions C1 - C4 Work and units shown for calculations	4	
Total	20	

Subject to additional penalties at the discretion of the instructor.

Data and Calculations

A. Decomposition of $NaHCO_3$	*Record all digits on the scale!*
1. Mass of beaker	
2. Initial mass of $NaHCO_3$	
3. Mass of beaker plus products after heating.	
4. Mass of product (actual yield) (#3 - #1)	

A1. Balance the reaction for the decomposition reaction.

___$NaHCO_3(s)$ → ___$Na_2CO_3(s)$ + ___$CO_2(g)$ + ___$H_2O(g)$

A2. a) Mass is conserved in chemical reactions. Why did the mass in the beaker decrease? (Look at the phases of the products)

b) Which is the only product in the beaker at the end of the reaction? ____________

A3. Calculate the theoretical yield of the product in grams. Show your work for the three step stoichiometry problem. Start with the mass of the reactant (#2)

$$\text{g } \mathbf{NaHCO_3} \times \frac{\_\_\_\_\_\_\text{ mol } \mathbf{NaHCO_3}}{\text{g } \mathbf{NaHCO_3}} \times \frac{\_\_\_\_\_\_\text{ mol } Na_2CO_3}{\text{mol } \mathbf{NaHCO_3}} \times \frac{\_\_\_\_\_\_\text{ g } Na_2CO_3}{\text{mol } Na_2CO_3} = \qquad \text{g} Na_2CO_3$$

A4. Calculate the percent yield of the reaction.

B. Reaction of Antacid and HCl	***Record all digits on the scale!***
5. Mass of beaker and HCl (aq)	
6. Mass of antacid	
7. Mass of antacid plus beaker/HCl (#5 + #6)	
8. Mass of beaker and contents after reaction	
9. Mass lost after reaction (#7 - #8)	

B1. Balance the reaction for the antacid (active ingredient $CaCO_3$) and HCl.

___$CaCO_3$(s) ___HCl(aq) → ___$CaCl_2$ (s) + ___CO_2(g) + ___H_2O(l)

B2. The mass in the beaker decreased. Which product caused the decrease in mass?________

B3. Calculate the mass of $CaCO_3$ in the tablet chunk. Show your work for the three step stoichiometry problem. Start with the mass of the product (#9). All numbers in work must have a unit and a formula.

x __________________ x ___________________ x ___________________ = g $CaCO_3$

B4. a) The mass of an entire tablet is 2.233g. Use a proportion to calculate the grams of $CaCO_3$ in a tablet.

$$\frac{g\ CaCO3\ in\ chunk\ (QB3)}{g\ of\ chunk\ (data\ table\ \#6)} = \frac{(x)\ g\ CaCO3\ in\ tablet}{2.233\ g\ of\ entire\ tablet}$$

b) Compare your results to the grams per tablet on the label.

C. Reaction of Sodium Carbonate and HCl	*Record all digits on the scale!*
10. Mass of flask and HCl (aq)	
11. Mass of sodium carbonate Na_2CO_3	
12. Mass of sodium carbonate plus flask/HCl (#10 + #11)	
13. Mass of flask and contents after reaction	
14. Mass lost after reaction (actual yield) (#12 – #13)	

C1. Balance the reaction for the Na_2CO_3 and HCl.

___Na_2CO_3(s) ___HCl (aq) → ___NaCl (aq) + ___CO_2(g) + ___H_2O(l)

C2. The mass in the flask decreased. Which product caused the decrease in mass?________

C3. Based on litmus a) Which reactant was in excess? ________ b) Which was the limiting reactant? ________

C4. Calculate the theoretical yield of CO_2 in grams based on the limiting reactant. Show your work for the three step stoichiometry problem. All numbers in work must have a unit and a formula.

x __________________ x ___________________ x ___________________ = g CO_2

C5. Calculate the percent yield of the reaction.