Lab #1: Acid/Base Rocket Lab

Background: The year was 1232. The Chinese and Mongols were at war. During the battle Kai-Feng, the Chinese repelled the Mongol invaders by "arrows of flying fire." The simple arrows were solid-propellant rockets. Later, during the latter part of the 17th century, Sir Isaac Newton devised the laws of motion, ultimately trajectory, and Dutch professor Willem Gravensande the steam jet-car. Today, the United States and Russia share experimental programs with astronauts in space. Why? Acid and base reactions.

$$\mathrm{CH_3COOH\ (Acid) + NaHCO_3(Base) \rightarrow CH_3COONa + CO_2 + H_2O} \qquad \textbf{Eqn 1}$$

$$\mathrm{C_6H_8O_7\ (Acid) + NaHCO_3(Base) \rightarrow C_6H_7O_7Na + CO_2 + H_2O} \qquad \textbf{Eqn 2}$$

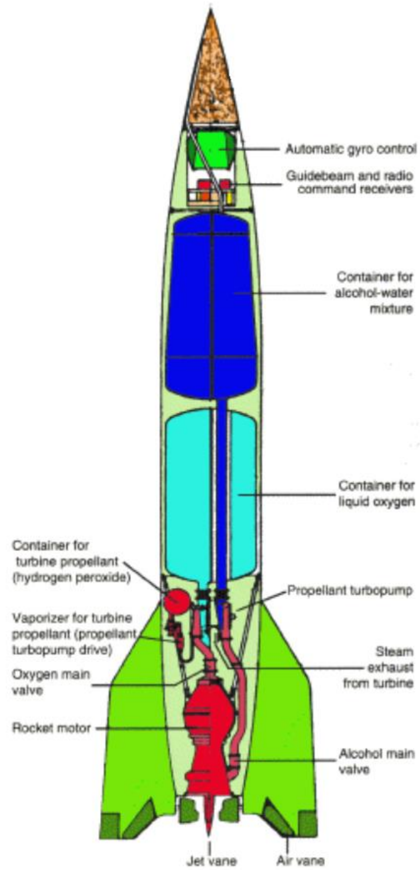
Null Hypothesis: Reaction ratios cannot theoretically approximate the maximal height of launch.

Alternative Hypothesis: Reaction ratios theoretically approximate the maximal height of launch.

Goal: An experiment with estimated reaction masses prior to the initial launch.

Learning Outcomes:

1. A material list accurately prepared for an experimental launch.
2. Precise chemical reaction ratios calculated before experiment.
3. Masses of vinegar (CH_3COOH), sodium bicarbonate ($NaHCO_3$), and citric acid ($C_6H_8O_7$) recorded.
4. A rocket volume from measured dimensions.
5. Final evidence results about mass ratios.



Experimental:

1. In a lab notebook, experimentally record the mass of the solid rocket propellants.
2. With a scale or graduated cylinder, quantitatively record the liquid rocket propellant's volume.
3. A rocket launch.
4. The rocket design, reactants, and model for increased height
5. Steps two through five repeated, three times.

Data:

Evaluation:

Note: Please practice on paper before submission.

1. What were the materials?
2. What was the initial chemical mass: sodium bicarbonate?
3. How much mass (or volume) of acid was in the initial launch?
4. The rocket weighed how much?
5. What height was the initial test?
6. What were the trial numbers?
7. What changed after the first test?
8. Final launch changed how? Masses changed in sodium bicarbonate?
9. How much acid (g or mL) measured in the final launch?
10. What was the final mass in the rocket?
11. What height was the final launch?
12. What confirms the alternative hypothesis?

Lab #2: Gibbs Free Energy, Enthalpy, and Entropy

Background: Surroundings are everything around a system. We define systems with different parameters, such as temperature, pressure, and volume. With parameters, scientists model simple ideas. Macroscopic criteria are rate; time-duration from reactants to products; work; the differences between volume or pressure; and heat; the energy transfer. Chemist characterize a reaction by enthalpy (ΔH), entropy (ΔS), and Gibbs free energy (ΔG). Enthalpy is the heat absorbed or emitted from a reaction under constant pressure. Entropy is the number of microscopic arrangements in the system. While, Gibbs free energy is the relationship between enthalpy (ΔH) and entropy (ΔS) at a specific temperature. Negative Gibb's free energy indicates a spontaneous reaction. Else, a positive Gibbs, and the reaction is non-spontaneous.

Compound	ΔH = Enthalpy (kJ)	ΔS = Entropy (J/K)
Acetic Acid [CH_3COOH]	-874.5	86.6
Ammonium Chloride [NH_4Cl]	-314.4	94.6
Ammonium Ion [NH_4^+]	-132.5	113.4
Carbon Dioxide [CO_2]	-167.2	213.6
Chlorine Ion [Cl^-]	0.0	56.5
Copper [Cu^{2+}]	-142.6	33.2
Copper (I) Nitrate [$CuNO_3$]	-277.7	46.8
Ethanol [CH_3CH_2OH]	-174.1	160.7
Nitric Acid [HNO_3]	33.2	155.6
Nitrogen Dioxide [NO_2]	0.0	240.0
Oxygen [O_2]	0.0	205.0
Sodium Bicarbonate [$NaHCO_3$]	-947.7	102.1
Water (l) [H_2O]	-285.8	69.9
Water (g) [H_2O]	-242.0	188.7
Hydrochloric Acid (g) [HCl]	-167.1	-131.2
Sulfuric Acid (g) [H_2SO_4]	-909.3	20.1
Sodium carbonate [Na_2CO_3]	-1130.7	135.0

Equation #1: Gibbs Free Energy

$$\Delta G = \Delta H - T\Delta S$$

Null Hypothesis: The thermodynamic table never predicts the spontaneity of a reaction.

Alternative Hypothesis: The thermodynamic table predicts the spontaneity of a reaction.

Goal: From experimental measurements, student devise experimental proof and evidence by a thermodynamic table.

Learning Outcomes:

1. Identify exothermic and endothermic processes
2. Predict spontaneity using a thermodynamic data
3. Understand the difference between enthalpy (ΔH), entropy (ΔS), and Gibbs free energy (ΔG).
4. Demonstrate relationships between enthalpy (ΔH), entropy (ΔS), and Gibbs free energy (ΔG).

Experimental:

1. Prepare [1 M] NaOH and dissolve in 100 mL of H_2O
2. Add 25 mL of 1M M NaOH into four test tubes
3. Measure the room's temperature within each vial
4. Add 25 mL of [1 M] HCl to a test tube
5. Measure the maximum reaction temperature
6. Repeat steps #1-6 for HNO_3, H_2SO_4, and Na_2CO_3

Data:

	HCl	**HNO_3**	**H_2SO_4**	**Na_2CO_3**
Initial Temperature	24.0 °C	24.0 °C	24.0 °C	24.0 °C
Final Temperature	28.5 °C	29.0 °C	27.0 °C	24.0 °C

Evaluation:

Note: Please practice on paper before submission.

1. What is positive or negative heat?
2. The **HCl** reaction was exothermic or endothermic?
3. An **HNO_3** reaction was exothermic or endothermic?
4. The **H_2SO_4** reaction was exothermic or endothermic?
5. An **Na_2CO_3** reaction was exothermic or endothermic?
6. What is (ΔG) for all compounds in the table at a temperature, 298 K?
7. Spontaneity and definitions.
8. What was Gibbs Free Energy (ΔG) for **HCl, HNO_3**, **H_2SO_4**, and **Na_2CO_3**?
9. The hypothesis or null hypothesis was correct?

Lab #3: Physical Quantities, Units, and Measurements

Background: Physical quantities, units, and measurements are essential to chemistry. Physical quantities describe a fundamental expression. The base description is a unit, such as mass, length, and time. While, tools or instruments measure the unit for scientists. In-depth terminology from scientist is both intensive and extensive units. Today three pieces of glassware demonstrate error in a unit measurement by density.

Null Hypothesis: Analytical glassware has no quantifiable unit and error from a measurement.

Alternative Hypothesis: Analytical glassware has a quantifiable unit and error from a measurement.

Goal: Chemical glassware experiences through liquid water. Also, experimentally review lab glassware by average and standard deviation.

Learning Outcomes:

1. Exposure using a thermometer, digital-scale, beaker, Erlenmeyer flask, and volumetric flask.
2. A correlation between density and temperature inside glassware.
3. An average, percent error, and standard deviation from the equations below.
4. A lab summary about scientific laboratory data.

Equation #1: Density:

$$Density = \frac{mass\ (g)}{volume\ (mL)}$$

Equation #2: Temperature:

$$°C = \frac{9}{5}°\mathrm{F} + 32$$

Equation #3: Average:

$$\bar{x} = \frac{\sum_{i=1}^{N} x_i}{N}$$

Equation #4: Standard Deviation:

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N} |x_i - \bar{x}\,|^2}{N}}$$

Equation #5: Percent Error:

$$Percent\ Error\ (\%) = \frac{|Measured\ value - Actual\ value|}{|Actual\ value|} * 100\%$$

Experimental Steps:

1. The experiment began with a beaker, Erlenmeyer flask, and volumetric flask on a top loading scale. What were the masses on the scale?
2. Incrementally, 20mL of water poured into each glassware.
3. A thermometer recorded temperature in liquid water.
4. Soon after, glassware mass from the scale.
5. Steps #1-3 for five measurements and fill-in the table below.

Tabular Data: **Atmospheric Pressure (atm): _______ Water Temperature (°F): __________**

Beaker (100 mL)	
Measurement	**Mass (g)**
1	
2	
3	
4	
5	
Erlenmeyer Flask (100 mL)	
Measurement	**Mass (g)**
1	
2	
3	
4	
5	
Volumetric Flask (100 mL)	
Measurement	**Mass (g)**
1	
2	
3	
4	
5	

Evaluation:

Note: Please practice answers on paper before submission.

1. What were the average masses?
2. What glassware was most near actual volume?
3. What is density?
4. Why is temperature important to the experiment?
5. Why is pressure important to today's experiment?
6. What is percentage error?
7. Why care about standard deviation?
8. What photographs or drawings describe accuracy and precision?

Lab #4: Soaps and Detergents

Background: Soap has history before the 16th century. Figurative information dates to salve, resin, tallow, suet, and grease. Romans referenced soap to Romance, Germans to 'flattery' of loan, while today's vocabulary of Saponification to the jocular Latin root of sapon. Saponification converts oils, fats, and glycerides into glycerin with "salt." For proof-of-concept, students process raw material in a strong base to produce household soap.

Hypothesis: A strong base reacts with fats or oils into glycerin.

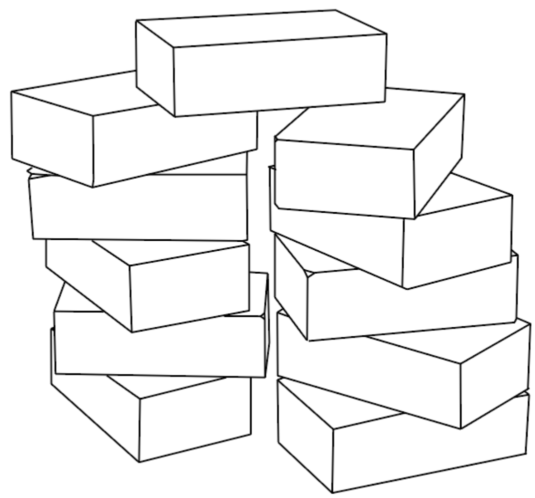
Null Hypothesis: A strong base never reacts with fats or oils into glycerin.

Goal: Trial chemical reactants for practice and the production of soap via saponification.

Learning Outcomes:

1. Understand soap production includes raw ingredients, oils, fats, and glycerides
2. Assess the chemical safety about sodium hydroxide in laboratory setting
3. Create good soaps from crude chemical instruction and procedure

Chemical Safety:



Sodium Hydroxide (Safety Data Sheet):

Health: _________________________

Fire: ___________________________

Reactivity: ______________________

Personal Protection: _____________

Experimental:

1. A graduated cylinder measures 50 mL of deionized water.
2. A scale weighs 10 grams of **NaOH** flakes.
3. Mixtures begin with **NaOH** into deionized water.
4. A hot plate raises the temperature of **NaOH** + $\mathbf{H_2O}$ solution to boiling
5. Thermometers record temperature of hot **NaOH** + $\mathbf{H_2O}$ solution (solution A)
6. Separately, a scale weighs 100 grams of solid-phase fats or oil.
7. A solid-phase fat melts above room temperature.
8. Thermometers record temperature of boiling liquid-phase fat solution (solution B)
9. Solution A mixes with solution B.
10. The mold is for the liquid mixture. The soap hardens within 24 hours.

Data:

Record Temperatures:

Solution A (K): ______________________________

Solution B (K): _______________________________

Evaluation:

Note: Please practice answers on paper before submission.

1. What fat or oil was a reactant in the experiment?
2. The null or alternative hypothesis was correct? Why?
3. The chemical sodium hydroxide (**NaOH**) was innocuous?
4. What temperature melted the fat and/or oil?

Lab #5: Mineral Decomposition Rate

Background: Decay order describes rate in liquid or gas phase. Mineral decomposition occurs from a reaction, additional pressure, radioactive decay, and friction. In the environment, calcium carbonate decomposes by acidic rains. Decay order follows acidic aliquots onto calcium carbonate for masses loss.

Null Hypothesis: Acidic solutions onto a mineral never quantify decay order in aqueous medium.

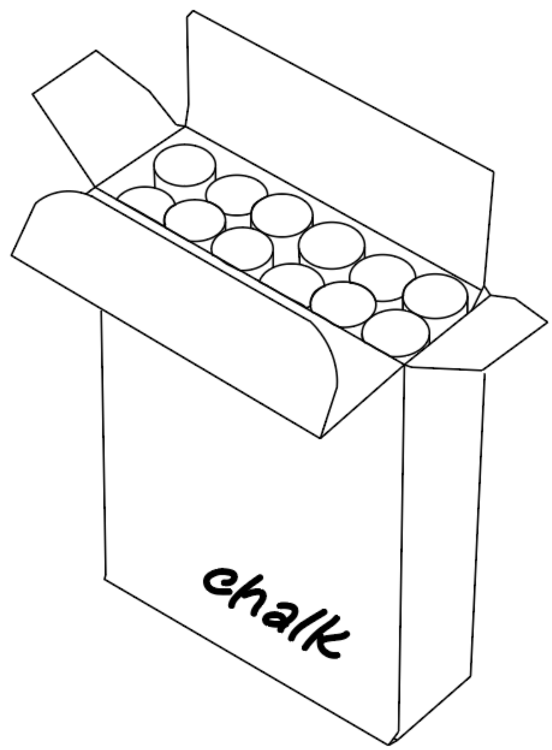
Alternative Hypothesis: Acidic solutions onto a mineral quantify decay order in aqueous medium.

Goal: Reaction order of a controlled experiment between calcium carbonate and sulfuric acid.

Learning Outcomes:

1. The rate of decomposition from, a substitute, calcite mineral known as chalk
2. Arithmetically average aliquots of H_2SO_4 for standard drop-mass
3. Mass vs. time data as incremental amounts of acidic solutions add to chalk

Chemical Safety:



Sulfuric Acid (Safety Data Sheet)

Health: ________________________

Fire: __________________________

Reactivity: _____________________

Personal Protection: _____________

Reaction: $H_2SO_4(aq) + CaCO_3(s) \rightarrow H_2O(l) + Ca^{2+}(aq) + SO_4^{2-}(aq) + CO_2(g)$

Experimental:

1. A watch glass needs a mass before the drop averages.
2. Drop-by-drop aliquot sulfuric acid onto a watch glass on top a scale with record.
3. Chalk mass on a scale needs an initial mass
4. Repeatedly, drops react with the chalk into aqueous components into product, carbon dioxide (CO_2).

Data: Watch glass (g): __________________

Drop	Total Mass (g)
1	
2	
3	
4	
5	
6	
7	

Average (g): ______________________________

Standard Error (g): _______________________________

Mass of Chalk (g): _________________

Drop	Remaining Chalk Mass (g)	Time (s)
1		
2		
3		
4		
5		
6		
7		

Reaction Kinetics: Rate = k $[Ca^{2+}]^m[CO_3^{2-}]^n$

Order of Reaction: m = _________ n = __________

Evaluation:

Note: Please practice answers on paper before submission.

1. Why was chalk a substitute to calcium carbonate ($CaCO_3$)?
2. Why an average drop mass?
3. What units describe rate?
4. What were rate constants, m and n?
5. What was the experimental rate?

Lab #6: Biological Catalysis

Background: Danish chemist, Christian Hansen's rennet specimens started a revolution in biochemistry. Enzymes digested lactose inside saline solutions, eventually a foundational concept for researchers and industry. Although, historically practicianors fermented foods centuries before the comprehensive material. Today, biochemists in industry ferment food, digest textiles, bate leather, and wash detergents with enzymes. Enzymatic digestion is the topic today with solid enzymes tablets.

Null Hypothesis: Enzymes decompose cabbage into a dissimilar textures, colors, and smells.

Alternative Hypothesis: Enzymes decompose cabbage into a similar textures, colors, and smells.

Goal: Experiment in enzymatic digestion with an enzyme discovered in 1874 called β-amylase enzyme.

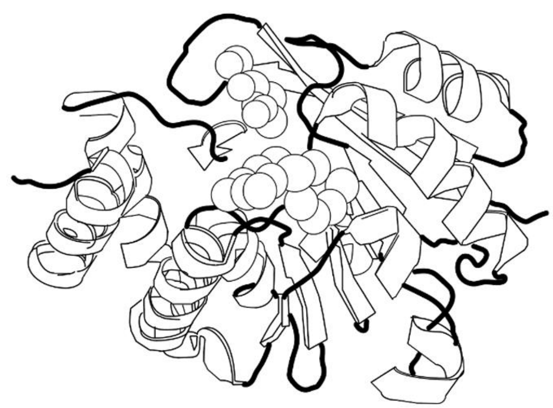
Learning Outcomes:

1. A laboratory procedure containing biological components from a blank sheet.
2. Cabbage fermentation with an enzyme catalyst, such as general β-amylase tablet
3. Qualitative, along with quantitative information for experimental fermenting

Reaction: $Cabbage + Enzyme \xrightarrow{Fermentation} Decomposition$

Materials:

1. A glass jar [Two holes]
2. Painter's tape [A cover for holes]
3. Black marker [Date]
4. Cabbage [Digestant]
5. Enzyme tablet [Enzyme]
6. Scale [Cabbage mass]
7. Water [As appropriate]



Laboratory Procedure:

Note: A personally prepared fermentation lab

1.

2.

3.

4.

5.

6.

Evaluation:

Note: Please practice answers on paper before submission.

1. What is an enzyme?
2. Enzymes derive from what in the environment?
3. How was the personal procudure?
4. Tape had what purpose?
5. Any necessary changes in personal procedure?
6. After two weeks, what was the outcome for the null hypothesis?

Lab #7: Lewis Acid Concentration

Background: The American physicist Gilbert Newton Lewis won a Nobel Prize by a new model for chemical acids and bases. The Lewis acid accepts pairs of electrons. While a Lewis base donates electrons in the acid-base conjugate pair. After electronic bond produces an adduct, the product after the reaction. For metal chemistry examination, student interaction entails colorimetric analysis toward a Lewis acid concentration.

Null Hypothesis: Copper ions (Cu^{2+}) never react with sodium hydroxide (NaOH) as a Lewis acid.

Alternative Hypothesis: Copper ions (Cu^{2+}) never cause a reaction with sodium hydroxide (NaOH) as a Lewis acid.

Goal: The intense blue color indicates copper ion concentration, especially through measurement.

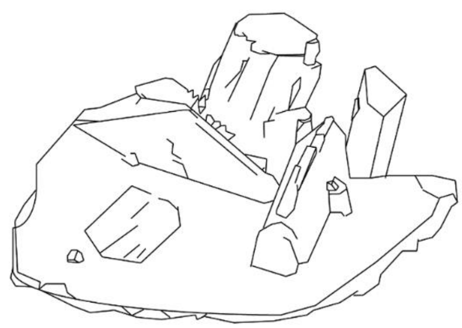
Learning Outcomes:

1. Information about standard solution concentration.
2. A serial dilution with sets of test tubes, graduated cylinders, and mathematical ratios.
3. Aliquots of base in order to decrease the Lewis acid concentration.
4. With colorimetric analysis, an equation describing concentration.

Reaction: $CuSO_4 + 2NaOH \rightarrow Cu(OH)_2 + Na_2SO_4$

Experimental:

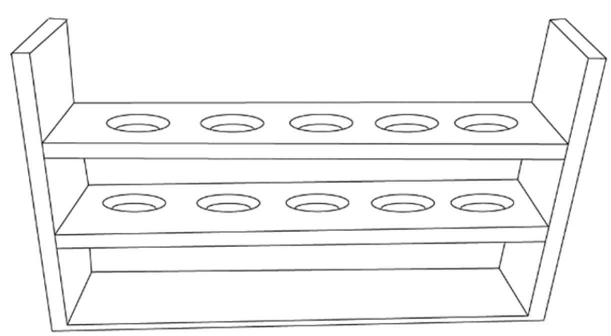
1. Five test tubes each with a label "10 M", "5 M", "1 M", "0.5 M" and "0.1 M" $CuSO_4$ for experimental analysis of linear series
2. NaOH drops decrease the concentration of $CuSO_4$
3. A linear model for the instruction of colorimetric testing conclusions and results
4. Linear Equation:



Evaluation:

Note: Please practice answers on paper before submission.

1. What color is copper sulfate ($CuSO_4$)?
2. What are the independent variables in the linear equation?
3. What are the dependent variables in the linear equation?
4. What is the purpose for a linear equation?
5. What was a necessary alteration in the steps?
6. Concentration is both qualitative and quantitative. A qualitative analysis involves inspection of color. A paragraph length of 4-5 sentences about quantitative concentration analysis.



Lab #8: Molarity measuring

Background: Concentration is ubiquitous. In a tea leaf mixture or simple Sweet Black Tea, concentration is visible by both color and taste. In other words, chemists comprehend concentration (molarity). Specifically, how substance mass relates to volume. The Periodic Table of Elements aids with the determination by elemental mass. This day, students embark on a definition about concentration, molarity.

Null Hypothesis: Additional mass never increases molarity and not possibly visible by eye.

Alternative Hypothesis: Additional mass never increases molarity and not possibly visible by eye.

Goal: The Periodic Table of Elements applied to chemical calculations in molarity.

Learning Outcomes:

1. With an analytical scale, concentration from a Erlenmeyer flask with blue solution.
2. Molarity calculating in a solution at a constant volume in a volumetric flask.
3. The percent error of original molarity measurements by a top loading scale.

Equation #1: Molar Mass:

$$\boldsymbol{Molar\ Mass = \frac{Mass\ (g)}{Amount\ (mol)}}$$

Equation #2: Molarity:

$$\boldsymbol{Molarity = \frac{Amount\ (mol)}{Volume\ (L)}}$$

Equation #3: Percent Error:

$$\boldsymbol{Percent\ Error = \frac{|Measured - Actual|}{Actual} * 100\%}$$

Tabular Data: **Temperature (°F): ______________________ Density of H_2O (g/cm^3): __________________**

Compound	Chemical Formula	Molarity Label [M]	Substance Mass (g)	Volume (mL)	Solution Mass (g)	Liquid Mass (g)	Actual Molarity [M]
Sodium Iodide	NaI						
Sodium Iodide	NaI						
Sodium Iodide	NaI						
Iron (II) Chloride	$FeCl_2$						
Iron (II) Chloride	$FeCl_2$						
Iron (II) Chloride	$FeCl_2$						
Copper (II) Carbonate	$CuCO_3$						
Copper (II) Carbonate	$CuCO_3$						
Copper (II) Carbonate	$CuCO_3$						

Evaluation:

Note: Please practice answers on paper before submission.

1. Why is concentration apparent from additional mass?
2. What color was sodium iodide (NaI)?
3. What color was iron (III) chloride ($FeCl_3$)?
4. Whas was copper (II) carbonate color ($CuCO_3$) in solution?
5. Temperature and water density were critical?

Lab #9: Molar Mass: Carbon Dioxide

Background: The Periodic Table of Elements contains elemental masses for scientific aid. Across majors, scientists depend on accurate atomic masses for references in experiment. Molar mass, the typical mass unit derives a ratio between compounds, such as water or carbon dioxide. The lab determines masses in a gas, carbon dioxide at room temperature.

Goal: Density using a scale and container about a gaseous phase substance, carbon dioxide.

Null Hypothesis: Carbon dioxide density at 1 mole quantity is not the molecular molar mass.

Alternative Hypothesis: Carbon dioxide density at 1 mole quantity is the molecular molar mass.

Learning Outcomes:

1. Conservation of mass from dry ice [carbon dioxide (g)] subliming on a scale.
2. Substance density involves measurements about mass and volume.
3. A relationship between density and molar mass by mole units.

Equation #1: Density:

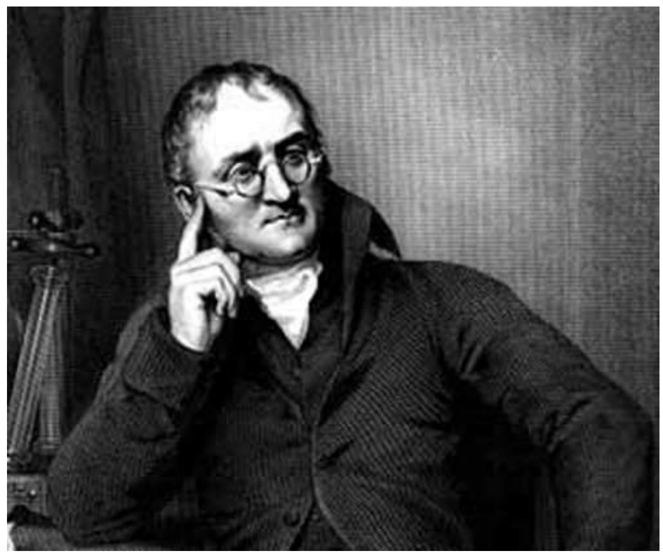
$$Density = \frac{Mass\ (g)}{Volume\ (cm^3)}$$

Equation #2: Avogadro's value:

$$Avogadro's\ Value = \frac{6.022x10^{23}}{1\ mol}$$

Equation #3: Percent Error:

$$Percent\ Error = \frac{|Measured - Actual|}{Actual} * 100\%$$



Tabular Data: **Temperature (°F): __________________ Container mass (g): __________________**

Trial	Mass (g)	Volume (cm^3)	Density (g/cm^3)	Moles (n)	Molar Mass (g/mol)	Percent Error (%)
1				1		
2				1		
3				1		
4				1		
5				1		

Evaluation:

Note: Please practice answers on paper before submission.

1. Temperature was helpful in references to density. Why?
2. Dry ice is solid carbon dioxide (CO_2). Solid and gaseous carbon dioxide had equal mass?
3. What is the mole unit?
4. Percent error helps a scientist. Why?
5. A paragraph about John Dalton (5-7 sentences).

Lab #10: Molar Mass: Water

Background: 'Atomism' was a perspective from John Dalton, and a natural philosophy about fundamental particles. The developments about molecular gases led to the law of multiple proportions, then eventually molar mass. An explanation about elemental ratios; electrolysis examples John Dalton's 'atomism' with hydrogen and oxygen. This lab separates water into components for determination of molar mass.

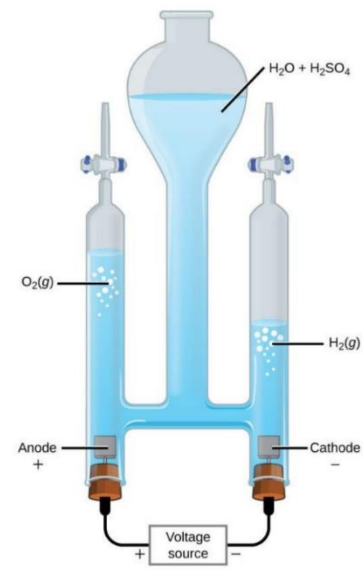
Goal: Pure water's molar mass from molecular ratios and differences inside a volumetric container.

Null Hypothesis: An electrolysis device never separates water into molecular ratios.

Alternative Hypothesis: An electrolysis device separates water into molecular ratios.

Learning Outcomes:

1. Conservation of mass using an electrolysis apparatus with water inside the vessel.
2. Substance density through discernable molecular ratios.
3. A substance's molar mass at standard temperature and pressure, 1 mole equals 22.4 liters.



Equation #1: Density:

$$Density = \frac{Mass\ (g)}{Volume\ (cm^3)}$$

Equation #2: Molar Mass:

$$Molar\ Mass = \frac{Mass\ (grams)}{Amount\ (mol)}$$

Equation #3: Percent Error:

$$Percent\ Error = \frac{|Measured - Actual|}{Actual} * 100\%$$

Tabular Data: **Temperature (°F):** ________________

Trial	Ratio of Oxygen	Ratio of Hydrogen	Volume Oxygen (mL)	Volume Hydrogen (mL)	Moles Oxygen (mols)	Moles Hydrogen (mols)	Molar Mass (g/mol)	Molar Mass Error
1								
2								
3								
4								
5								

Evaluation:

Note: Please practice answers on paper before submission.

1. What were hydrogen and oxygen ratios?
2. What dangerous activity proves different gases in the left and right columns?
3. The true water (H_2O) molar mass is 18 g/mol. How accurate an answer in the experiment?
4. The electrolysis apparatus separated water into molecular gases. What about other liquids? What is the outcome with juice, tea, or coffee?
5. Why was Dalton's conjecture correct?
6. The 1 mole equals 22.4 L was in the experiment. Why?

Lab #11: Temperatures effect on Equilibria

Background: Le Châtlier's principal models chemical shift in reactants and products from current environmental parameters. Ambient temperature shifts an equilibrium away or toward heat production. Pressure and volume also shift an equilibrium. Other conditions change's reaction potential, state-parameters, and reaction outcomes. For classes' lab, students examine thermodynamic effects of equilibria through temperature.

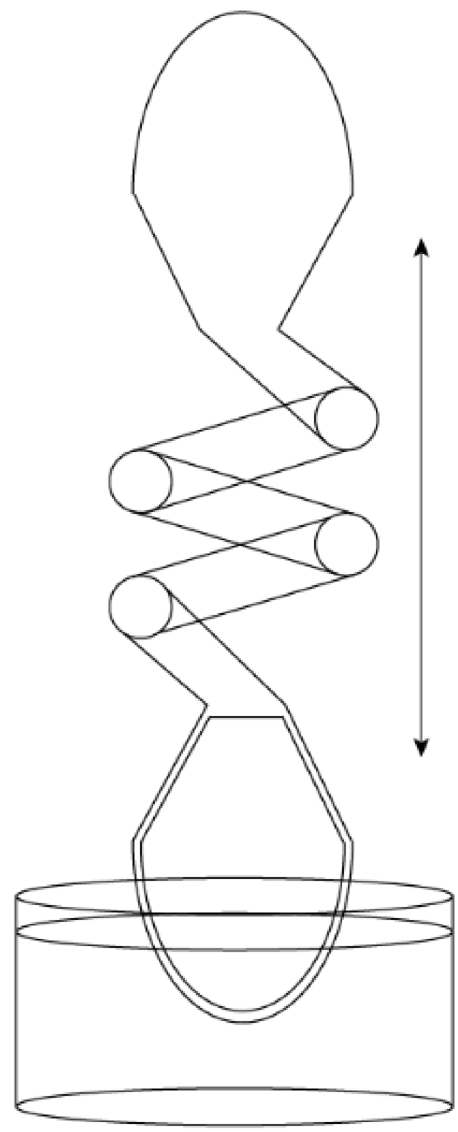
Goal: An observable equilibrium by a simple pressure and temperature vessel.

Hypothesis: Temperature never perturbs an equilibrium throughout repeatable experiments.

Null Hypothesis: Temperature perturbs an equilibrium throughout repeatable experiments.

Learning Outcomes:

1. A table about Le Châtlier's principles before laboratory testing
2. The temperature inside a water bath before fluid displacement
3. Temperature's effect on equilibria by evaluating a model system



Le Chatlie'rs Principle:

Equilibrium Reaction: $N_2(g) + 3H_2(g) \leftrightarrow 2NH_3(g)$

	Parameter Increase	Parameter Decrease
Temperature		
Pressure		
Volume		
Concentration		

Procedure:

1. A beaker with 50 mL water for demonstration of Le Châtlier's principles.
2. A thermometer measures the temperature of a lukewarm water bath.
3. The final temperature records below.
4. An equilibrium apparatus goes into a water bath for conditional equilibrium change.
5. Steps #2-#3 repeat for apparatus demonstration.

Temperature (°C):____________________________

Evaluation:

Note: Please practice answers on paper before submission.

1. What are Le Châtlier's principles?
2. What happened in the equilibrium device?
3. What average temperature shifted the apparatus' inner-liquid?
4. Why was the above table important?
5. How many predictions in the table were correct?

Lab #12: Emission Spectra

Background: A flame test is a mechanism to element type. Color in the fire is unique to a large set of elements. The light derives from two processes; one, the metal solid vaporizing into a gaseous elemental state; while the second, the metal solid reacting with oxygen into a gaseous oxide fume. The simple description about a flame test being a phase transition and final light emission. For our experiment vaporization of a salt solid generates emission upon transition.

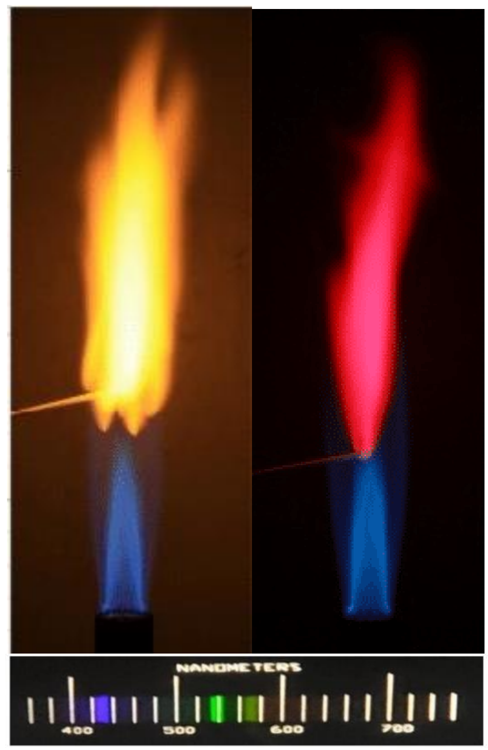
Goal: An elemental type via the emission spectra of a gaseous salt.

Hypothesis: The element has assignable colors when a phase transition occurs from heat.

Null Hypothesis: The element has no assignable colors when a phase transition occurs from heat.

Learning Outcomes:

1. An unknown salt vaporizing from solid to gaseous phase with a Bunsen burner, wand, and flame.
2. A spectrometer to quantitatively measure emission spectra of gaseous salts in darkness.
3. A data table of atomic spectra for determining an unknown metal.
4. Accuracy and precision measuring.



Equation #1: Accuracy (Average):

$$Average = \frac{\sum_{i=1}^{n} x_i}{n}$$

Equation #2: Precision (Standard Deviation):

$$Precision = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \overline{x})^2}{n}}$$

Chemical Process:

$$Unknown\ (s) \rightarrow Unknown\ (g) + Light$$

Data table:

Instrument Model (No): ____________________

Gas	Trial #1: $\lambda_{Low\leftrightarrow High}(nm)$	Trial #2: $\lambda_{Low\leftrightarrow High}(nm)$	Trial #3: $\lambda_{Low\leftrightarrow High}(nm)$	Average (nm)	Salt	Standard Deviation (nm)
Unknown A						
Unknown B						
Unknown C						
Unknown D						

Evaluation:

Note: Please practice answers on paper before submission.

1. Why was the flame test helpful?
2. What was the standard deviation from flame experiments?
3. What was dangerous about the experiment?
4. The elements each had unique colors. Why did each element produce different colors?
5. A sketch exampling the experimental setup.

Lab #13: Second Law of Thermodynamics

Background: Law is congressional agreement. A committee (or chamber of representatives) enact a formal resolution of theory through experimental legislation. If their experiment fails, then new-found resolution is assented (or ordained). The second law of thermodynamics classifies natural law and order. Heat's relationship to temperature, or division, thereof, jointly, typifies measurable outcomes of local motion. By creating a boat from convection, students are account for gaseous molecules temperature-dependence. With a majority resolution, members for both in-house, and constitutional signature.

Goal: A steam-powered boat certifying natural laws of entropy and thermodynamics.

Learning Outcomes:

1. A convection vessel, ship, or barque validating entropic quantities of nature.
2. Motion of gas molecules by the heating of a glass test tube via candle stick
3. Entropy through recording temperature and heat change of an open system

Equation #1: Second Law of Thermodynamics

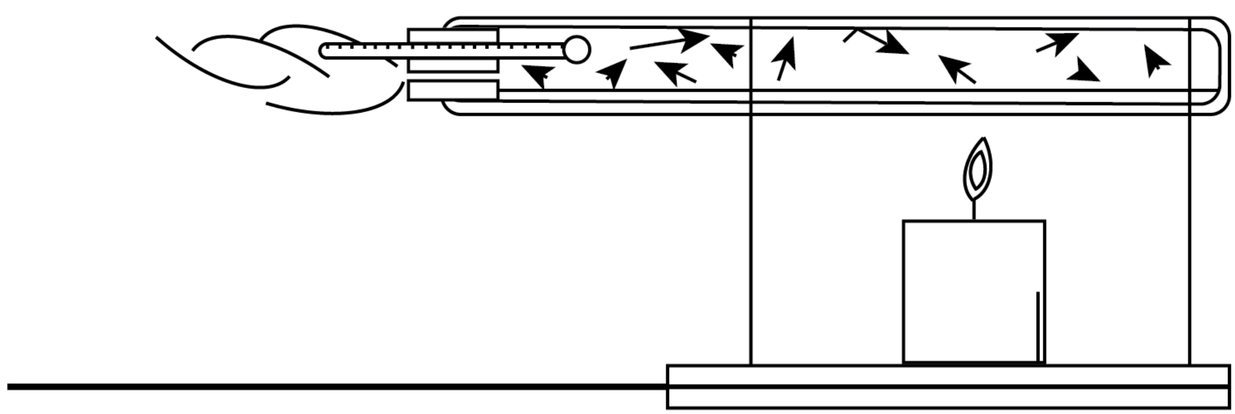
$$Entropy = \frac{\Delta q}{T} = \frac{q_{Final} - q_{Initial}}{T} = \frac{mC\Delta T}{T}$$

Equation #2: Celsius to Kelvin:

$$K = °C + 273$$

Tabular Data:

Determination of Second Law of Thermodynamics - Entropy					
Air Volume (cm^3)	**Air Density (g/cm^3)**	**Specific Heat of AIr (J/g °C)**	**Initial Temperature (°C)**	**Final Temperature (°C)**	**Entropy (J/K)**



Evaluation:

Note: Please practice answers on paper before submission.

1. What are laws of thermodynamics?
2. What is a photo about the barque or vessel?
3. What is entropy??
4. The second law of thermodynamics was specific to the experiment. Why?
5. A sketch exampling the experimental setup.

Lab #14: Freezing-point Depression

Background: Colligative properties are physical changes in solution from the addition of a solute to solvent, also an industrial mechanism. From purifying seawater to separating enzymes, colligative properties are proportional to linear concentrations of solutes. The physical properties chemists speak, 'freezing temperature, boiling temperature, vapor pressure, and osmotic pressure.' Our solvent, water's freezing point depresses with the addition of sodium salt.

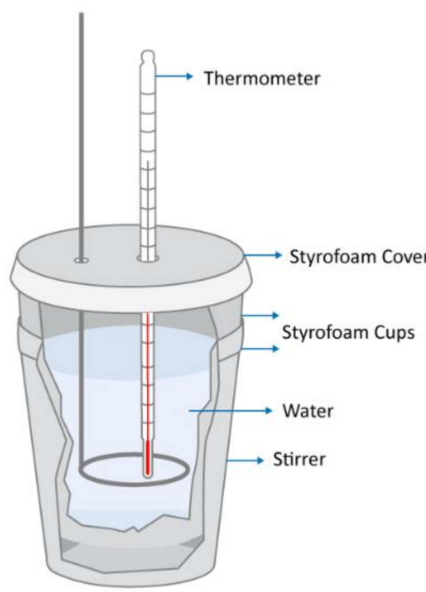
Goal: The freezing point depression of solution while determining the freezing constant (K).

Null Hypothesis: Water's freezing point never changes from additional solutes.

Alternative Hypothesis: Water's freezing point changes from additional solutes.

Learning Outcomes:

1. An accurate temperature change of a frozen solution, such as water vs saltwater.
2. A freezing point constant (K) from sodium chloride (NaCl) adding to water.
3. The experimental error from standard deviating.
4. A freezing point constant compared to literature values.



Equation #1: Accuracy (Average):

$$Average = \frac{\sum_{i=1}^{n} x_i}{n}$$

Equation #2: Precision (Standard Deviation):

$$Precision = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \overline{x})^2}{n}}$$

Equation #3: Freezing Point Depression

$$\Delta T = imK_f$$

Tabular Data: NaCl Molar Mass (g/mol): ____________ Mass of Water (g): _____________

	Initial Solution Temperature (°F):	Mass of Salt (g)	Final Solution Temperature (°F):	Mols of Salt (mol)	Solution Molality (mol/kg)	Van't Hoff Factor (i)	Molal Freezing Point Constant (°F/m)
Trial #1							
Trial #2							
Trial #3							
Trial #4							

Evaluation:

Note: Please practice answers on paper before submission.

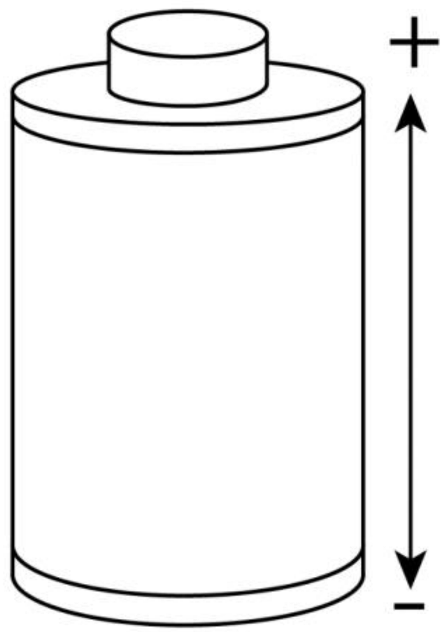
1. How much difference was water's freezing point?
2. What was the standard deviation in water's freezing point?
3. The amount of salt is relevant to freezing point. What was the experimental amount of salt?
4. What happens with a different salt type?
5. Why is Styrofoam helpful to the experiment? Even though, styrofoam is not necessary.

Lab #15: Battery Voltage

Background: Electricity developed as both a technological and social process. The United States of America statuettes electricity as broad resource with policy throughout clean-energy standards, sequestration technologies, and renewable source developments. Initially in the 1870's, electricity was in popular entertainment, playscripts, playbills, and motion pictures. While Early Motion Pictures promoted inventors, such as the Thomas Alva Edison - "Wizard of Menlo Park." In the lab, student's measure voltage.

Goal: With a voltmeter, quantitatively and accurately measure battery voltage across samples.

Null Hypothesis: The standard on a battery label never states appropriate voltage.



Alternative Hypothesis: The engineer's standard on the battery label correctly states appropriate voltage.

Learning Outcomes:

1. A theory for potential energy within different batteries
2. Voltage measurements of battery cells.
3. The standard error from engineers by applying a voltmeter

Equation #1: Voltage:

$$Voltage = \frac{Joules}{Coulombs}$$

Data Table:

Battery Voltage	Experiment				
	Trial #1	Trial #2	Trial #3	Average	Standard Error
1.5 V					
6.0 V					
9.0 V					
12.0 V					

Evaluation:

Note: Please practice answers on paper before submission.

1. What batteries had the most error?
2. Why is an average voltage important?
3. What is the relationship between battery voltage and error? What relationship exist at all between voltage and error?
4. For energy storage, batteries transfer energy. What other objects store energy?
5. Why was a voltmeter useful?

Lab #17: Filtering and Osmosis

Background: A filter separates fluids from solids. Equipment filters by mechanical, gravity, and osmosis methods. A mechanical filter uses a pump (or vacuum). While the gravity filter contains a semi-permeable membrane for fluid separation. Osmosis, also, diffusive filtration translates low concentration water to high concentration solutes. This lab provides three filter apparatus as observation and expository examples.

Goal: A deep examination about three types of filtration equipment categorized by mechanism.

Null Hypothesis: A filter cannot separate liquids from solids by mechanical, gravitational, and osmosis.

Alternative Hypothesis: A filter separates liquids from solids by mechanical, gravitational, and osmosis.

Learning Outcomes:

1. Two expository paragraphs about previously displayed filtration apparatus
2. An expository paragraph explaining a mechanically driven filter
3. A gravity-fed filtration systems for analyzing.
4. A compare-and-contrast about an osmosis separating technique

A Mechanical Filter sketch:

Notes about a Mechanical Filter:

1.
2.
3.
4.
5.

A Gravity-Fed Filter sketch:

Notes about a Gravity-Fed Filter:

1.
2.
3.
4.
5.

An Osmosis Filter sketch:

Notes about an Osmosis Filter:

1.
2.
3.
4.
5.

Evaluation:

Note: Please practice answers on paper before submission.

1. What is filtering?
2. What is osmosis?
3. What is a mechanical filter?
4. What is a gravity-fed filter?
5. What is an osmosis filter?

Lab #19: Ideal Gases

Background: The ideal gas constant derived from experiments by Boyle, Avogadro, Charles, and Gay-Lussac. In reversible systems, the ideal gas constant (R) approximates a relationship between Standard Temperature and Pressure (STP). An ideal gas constant formulates from carbon dioxide reactions. Students weigh carbon dioxide solid, then quantify a reaction by a balloon's volume at room temperature and pressure.

Goal: A gaseous apparatus measuring ideal gas constant.

Null Hypothesis: A gas constant is not possible from an experimental setup about volume.

Alternative Hypothesis: A gas constant is possible from an experimental setup about volume.

Learning Outcomes:

1. The volume using geometry.
2. With stoichiometry, total moles of carbon dioxide produced from a reaction.
3. Room temperature and pressure by a thermometer, along with barometer.
4. An internal pressure calculation from previously recorded results during the experiment.

Equation #1: Gas Constant:

R = 8.135 J/(mol·K)

= 0.08206 L·atm/(mol·K)

Equation #2: Ideal Gas Law:

$$P \propto m\ (slope) * \frac{nT}{V}$$

Equation #3: Reaction of sodium bicarbonate ($NaHCO_3$) and acetic acid (CH_3COOH):

$$\mathrm{NaHCO_3}(s) + \mathrm{CH_3COOH}(aq) \rightarrow \mathrm{Na^+}(aq) + CH_3COO^-(aq) + CO_2(g) + H_2O(l)$$

Tabular Data: Temperature (°C): ____________ Pressure (atm): ______________

Experiment	Balloon Mass (g)	$NaHCO_3$ Mass (g)	$NaHCO_3$ Mass (g)	Radius (cm)	Volume (L)	$NaHCO_3$ (mols)	CH_3COOH (mols)	CO_2 (mols)	Internal Pressure (atm)	Gas Constant (L·atm/mol·K)
Trial #1										
Trial #2										
Trial #3										

Evaluation:

Note: Please practice answers on paper before submission.

1. What is the math toward an average gas constant (R)?
2. What happened in the reaction between sodium bicarbonate ($NaHCO_3$) and acetic acid (CH_3COOH)?
3. How accurate was Equation #1 to results from the experiment?
4. How precise was Equation #1 to results from the experiment?
5. Volume required math. What is the volume in a sphere?

Lab #20: Methane and Hydrogen production

Background: Industry generates vast gas. Research continues in coal gasification, hydrocarbons, steam reform, distillation, pyrolysis, and other alternatives. In 1899, Mathews et. al prepared pure methane from sodium hydroxide and acetate. His methodology heated homes by the 20th century. Also gases, such as, hydrogen propelled rockets into the atmosphere, and beyond. In lab, we prepare both gaseous methane and hydrogen by classical methods.

Goal: The percent uncertainty of reaction when producing methane and hydrogen gas.

Null Hypothesis: Hydrogen and methane are not flammable gases.

Alternative Hypothesis: Hydrogen and methane are flammable gases.

Learning Outcomes:

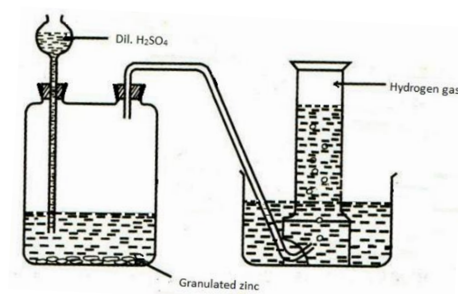
1. An inorganic experiment with special glassware for measuring the yield from a reaction.
2. Aqueous sulfuric acid with solid zinc rendering molecular hydrogen gas.
3. Inside of a chemical hood, Mathews et. al 1899 production of methane.
4. The percent uncertainty from a reaction through measuring both input and output.

Reaction #1 – Sulfuric Acid and Zinc:

$$H_2SO_4(aq) + Zn(s) \rightarrow ZnSO_4(aq) + H_2(g)$$

Laboratory Data:

Test Tube Mass (g): ______________________________
Sulfuric Acid (H_2SO_4) Molarity [M]: ____________________
Sulfuric Acid (H_2SO_4) Volume [mL]: ____________________
Zinc (Zn) Mass [g]: _______________________________
Final Test Tube Mass [g]: ___________________________
Predicted Hydrogen (H_2) Mass [g]: ______________________
Actual Hydrogen (H_2) Mass [g]: _________________________
Percent Uncertainty (%): ___________________________

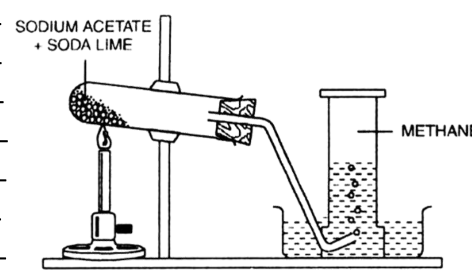


Reaction #2 – Sodium Acetate and Soda Lime:

$$NaCH_3COO(aq) + NaOH(s) \xrightarrow{\Delta,\ CaO} CH_4(g) + Na_2CO_3(s)$$

Laboratory Data:

Test Tube Mass (g): ______________________________
Sodium Acetate ($NaCH_3COO$) Molarity [M]: _______________
Sodium Acetate ($NaCH_3COO$) Volume [mL]: _______________
Soda Lime Mass [g]: _______________________________
Final Test Tube Mass [g]: ___________________________
Predicted Hydrogen (CH_4) Mass [g]: _____________________
Actual Hydrogen (CH_4) Mass [g]: ________________________
Percent Uncertainty (%): ___________________________



Evaluation:

Note: Please practice answers on paper before submission.

1. What is methane gas?
2. What is gaseous hydrogen?
3. The gases were or were not flammable? How many trials certify the hypothesis?
4. What reaction was more dangerous?
5. Which reaction generated more gas? Why?

Lab #21: Distillation of Mint

Background: Essential oils are volatile compounds. The oils embody plants and soaps, flavors, perfumes, incenses, and cosmetics. Popular oils are eucalyptus, peppermint, tea tree oil, citrus, and lavender. A simple separation for oil is vaporization and consecutive condensation. Individual groups boil mint leaves near a temperature toward the spearmint, and peppermint constituents. Analytical analysis confirms yield and purity, thereof.

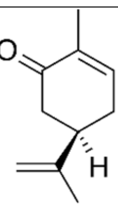
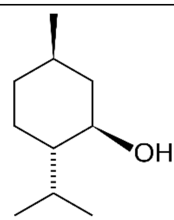
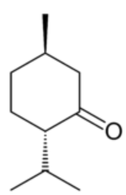
Goal: A co-mixture of high-purity essential oils distilled from native mint leaves.

Null Hypothesis: Oils never resided inside mint leaves with specific properties and smell.

Alternative Hypothesis: Oils reside inside mint leaves with specific properties and smell.

Learning Outcomes:

1. An exposure to liquid-gas phase separation techniques; process chemistry.
2. A simple organic glassware preparation for vaporization and condensation.
3. The percent yield of plant through measuring experimental input and output.
4. Purity of an essential oil co-mixture extracted from mint leaf (genus: mentha).

Chemical	Molecular Structure	Boiling Temperature
Carvone (Spearmint)		231 °C / 448 °F
Menthol (Peppermint)		214.6 °C / 418.3 °F
Menthone (Peppermint)		207 °C / 405 °F

Tabular Setup:

Mint [g]: ____

Essential Oil [g]:____

Evaluation:

Note: Please practice answers on paper before submission.

1. What is mint?
2. What is vaporization?
3. Why was condensation a necessary step in essential oil extraction?
4. What other plants possibly have essential oils?
5. What is a reasonable percent yield of extraction? The percent yield has a standard threshold or not?

Lab #22: Copper (I) Oxide Melting

Background: From Greeks to Romans, astringents, or mordant dyes; copper is foundational to history. From metallurgy, copper was a feasible product before many civilizations. The primary role was mirrors, blades, coins, and statues. During the Industrial Revolution, copper became a majory industry in Great Britain. Later, conductive properties in metals led consumers toward silver, gold, and copper. As a pure reddish-brown metal, and malleable, Copper (^{29}Al) remains an important element. For experimental analysis, contiguous metal melting into a singular piece.

Goal: A solid or liquid copper metal from a reaction with Copper (II) oxide and carbon.

Null Hypothesis: The reaction between Copper (II) oxide and carbon never produces copper.

Alternative Hypothesis: The reaction between Copper (II) oxide and carbon produces copper.

Learning Outcomes:

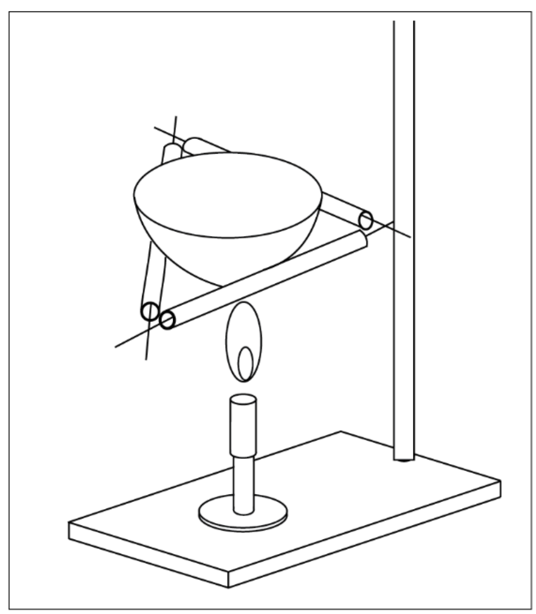
1. A crucible containing metals and carbon above a flame from a Bunsen burner.
2. Copper (II) oxide reaction with carbon as a second reactant.
3. A description of the active developments toward copper metal.
4. Reactant calculations from measuring the mass of solid.

Reaction #1 – Copper (II) Oxide:

$$2CuO(s) + C(s) \xrightarrow{\Delta} 2Cu(s) + CO_2(g)$$

Stoichiometry:

Have: Want:



Mass of Copper (I) Oxide [g]: _______________

Mass of Pure Carbon [g]: __________________

Process Description:

Mass of Copper Metal [g]: _________________

Evaluation:

Note: Please practice answers on paper before submission.

1. What was the color of copper metal?
2. A sketch with labels about tools characterizes the reaction for another scientist.
3. Why is mass important to percent yield?
4. Carbon was necessary? Why?
5. What was the percent yield?

Lab #23: Plastics and Polymers

Background: Plastics and polymers are both synthetic, and non-synthetic. Originally a disposable product, plastics are viable and available for the consumer. Alone, plastics account for a large dollar industry in packages, automotive, and electronics. Plastics, e.g. polymers derive from hydrocarbons. The polymer describes multiple materials; wool, silk, proteins, deoxyribose nucleic acid (DNA), cellulose, and chitin. Modern techniques produce nylon, acrylic, neoprene, polyethene, polyvinyl chloride, and "Teflon." With purpose, material properties are a requirement before commercial production. For laboratory practice, students prepare nylon and measure wet vs. dry tensile strength.

Goal: The tensile strength of wet and dry nylon threads having a diameter of one millimeter.

Null Hypothesis: Tensile strength is never larger in dry nylon than wet nylon averages.

Alternative Hypothesis: Tensile strength is larger in dry nylon than wet nylon averages.

Learning Outcomes:

1. A polymer of nylon from adipoyl chloride in cyclohexane solution.
2. A mixture of 1,6-hexanediamine into an organic solution of reactants.
3. Dry portions of nylon of given diameters for tensile strength.

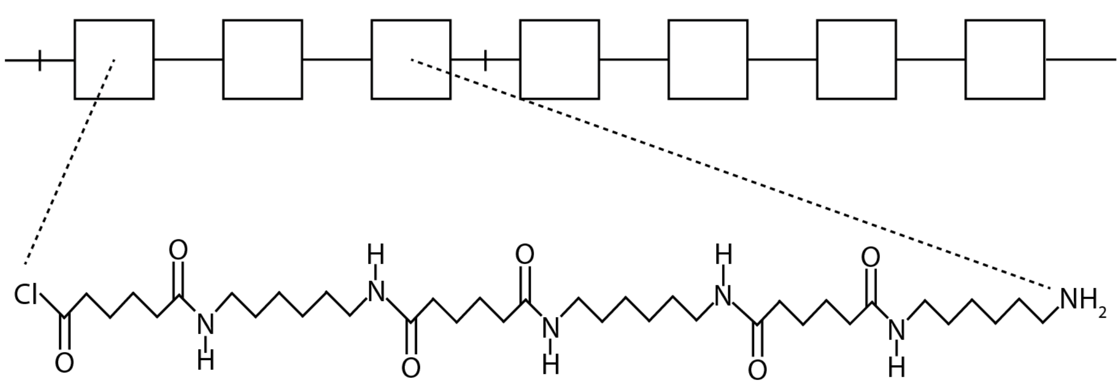
Equation #1 – Nylon Reaction:

$$nC_6O_2Cl_2 + nC_6N_2H_4 \xrightarrow{-HCl} H[C_{12}O_2N_2H_2]_nCl$$

Data Collection:

Dry Trial	Trial #1	Trial #2	Trial #3	Average	Standard Deviation
Nylon Diameter (mm)					
Tensile Strength (mN)					

Wet Trial	Trial #1	Trial #2	Trial #3	Average	Standard Deviation
Nylon Diameter (mm)					
Tensile Strength (mN)					



Evaluation:

Note: Please practice answers on paper before submission.

1. What was the color of wet and dry nylon?
2. Dry nylon had a larger or smaller stress-testing average than wet?
3. The hypothesis was correct or incorrect?
4. What are example polymers?
5. What is the purpose of the photograph on the laboratory page?

Lab #24: Cloud Chamber

Background: Particle physicists’ study atomic structure evolution. Primary methodology derives from nuclear phenomena, including, fission, fusion, ionization, and decay. In 1903, Marie Curie received a Nobel prize for radioactivity. Then, a 20th-century physicist, Enrico Fermi discovered fermions, an entire class of subatomic particles. With a multitude of others, Wolfgang Pauli, Paul Dirac, and later, in 1935 Hideki Yukawa. The carrier particles from radiation were the soon the foundation in both strong and weak forces. The nuclear forces bound Murray Gell-Mann to hadron collider experiments, and the quark model. For this afternoon’s lab, a classroom produces a cloud chamber, radiation, and microscopic photography thereof.

Goal: A cloud chamber for measurements of radioactive decay emission angles.

Null Hypothesis: Radioactive decay never scatters at specific angles from incident source.

Alternative Hypothesis: Radioactive decay scatters at specific angles from incident source.

Learning Outcomes:

1. From a microscopic camera, radioactive particle images in gaseous condensate.
2. A trigonometric function applied to high-resolution snapshots of particle decay.
3. Radiation values through the counting of particles during emissions.

Image Collection:

Tabular Data:

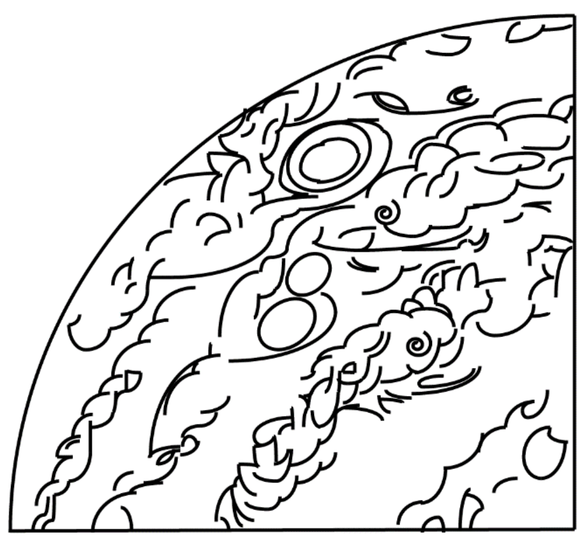
Particle Number	Emission Angle (°)
1	
2	
3	
4	
5	

Emission Flux:

Particle Count (n): ________________________

Duration of Count (s): _____________________

Emission Density (n/s): ____________________



Evaluation:

Note: Please practice answers on paper before submission.

1. What was fun about the experiment?
2. What angles appeared from the experiment?
3. What is a particle? Nuclear particle?
4. Why is angle important?
5. How often is radiation?