LABS & USER MANUAL

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1 TUTORIALS

1.1 Introduction Tutorial (Grades 9 to 10)

This experience describes immersion in a virtual laboratory environment, using virtual reality (RV) or augmented reality (RA) to simulate scientific experiences.

It aims to familiarize participants with virtual laboratory equipment and basic chemistry procedures, emphasizing the use of immersive technologies for education and training.

1.1.1 Educational Goals

- ***Familiarization with the virtual environment:*** learn to navigate and interact with a simulated laboratory environment, using RV or RA commands to manipulate laboratory objects and equipment.
- ***Use of protective equipment:*** Understanding the importance of personal protective equipment (PPE) in a laboratory, even in a virtual environment, highlighting safety practices.
- ***Substances measure:*** exercise to measure the mass of solids and the volume of liquids using virtual laboratory instruments, such as electronic scales and graduated cylinders, to develop skills in manipulation and precise measurement.
- ***Virtual chemical experimentation:*** carrying out basic chemical experiences, such as checking the pH of a solution, to understand the chemical reactions and the properties of substances.
- ***Analysis and communication of results***: Learn to analyze the results of experiences in a virtual interface and to communicate these results, illustrating the importance of documentation and communication in science.
- ***Challenges to overcome:*** Protect yourself: virtually put the necessary PPEs before starting the experiences. Weigh a solid substance in powder: use virtual instruments to precisely measure the mass of a powder.
- ***Measure the volume of a liquid substance:*** apply volume measurement techniques to prepare a solution. Check the pH of a solid sample: Understand how to prepare a solution and test your pH using chemical indicators. Recover and send the results: use the virtual interface to examine and share the results of the experiments.

This immersive experience offers an innovative approach to scientific education, allowing participants to learn and practice laboratory techniques in a secure and controlled environment, without the risks associated with real chemicals.

It highlights the potential of virtual reality technologies and augmented in teaching science, offering an interactive platform for the exploration, and understanding of scientific concepts.

1.1.2 Protocol

In the top right corner of your workspace, there are two cylindrical buttons. You can switch between virtual reality and augmented reality at any time by pressing the left button, or make the interactive whiteboard appear and disappear by pressing the right button.

In the room there is a poster showing the basic controls if you are in virtual reality.

To pick up an object with hand tracking, place your open hand facing the object, when the object turns green (symbol that it can be picked up), completely close your fist to pick up the object.

To release the object with hand tracking, you simply have to reopen the hand.

To pick up an object with the controllers, place your hand opposite the object. When the object turns green (symbolizing that it can be picked up), press and hold the pick-up button.

To release the object with the controllers, simply release the pickup button.

You can return to the Meta menu at any time by pressing the Meta menu access button or, in hand tracking mode, by making the gesture indicated on the basic controls poster.

In case of a problem, you can also reset the experiment by pressing the "Restart" button on the tablet. This can be found in the options menu, which is accessible from the main menu.

Before any experiment, it is important to equip oneself with the appropriate protective equipment.

1. Put on the smock.

2. Put on safety glasses.

3. Put on the nitrile gloves.

Weigh a solid substance in powder form

Some laboratory instruments can be used to collect and transport solid or liquid substances.

Among these instruments, some like the tweezers or the pipette, require an additional action for their operation.

In hand tracking mode, once the interactive object is picked up, join the thumb and index finger to activate the object's interaction.

With the controllers, press the interaction button to operate the object.

Some laboratory instruments may require pressing buttons. To press a button, push it with a finger.

4. Place the weighing basket on the platform of the electronic scale. (Close and then reopen the hand)

5. Press the "Tare" button located on either side of the digital display of the scale to zero it out. (Touch with a finger)

6. Using the weighing basket, weigh approximately 38 g of sodium chloride. To do this, remove the lid from the corresponding brown container. Then, take one of the spatulas available to you and put it in this container. You should see that it is now full of powder. Finally, tilt the spatula over the weighing basket to pour. Repeat the operation with different spatulas until you have reached the desired 38g. Since NaCl has a density of 2.16g/mL, you will need to weigh 17.5mL. The spatulas are calibrated to 5mL, 2.5mL, 1mL, and 0.12mL.

Use the hot plate.

7. Using the graduated cylinder and the cleaning flask, measure 100 mL of distilled water. A washing bottle full of distilled water is located to your right. Be careful to measure accurately using the meniscus!

8. Pour the measured distilled water into a 250mL Erlenmeyer flask.

9. Pour the sodium chloride from the weighing boat into the Erlenmeyer flask. It is normal for a precipitate to form at the bottom (NaCl).

10. Insert a magnetic stick (small blue cylinder to the left of the hot plate) into the Erlenmeyer flask. Simply bring it close to the opening of the Erlenmeyer flask and release it.

11. Close the Erlenmeyer flask with a two-hole rubber stopper with a glass elbow. It is behind the heating plate.

12. Place the Erlenmeyer flask on the hot plate.

13. In the available hole on the cap, insert a thermometer.

14. Start the magnetic stirrer (left button of the hot plate). Then start the digital stopwatch at the bottom of your work plan.

15. Set the hot plate to 105°C using the adjustment buttons on the right side of the device. This involves pressing the "+" button and holding it in place until the chosen target temperature is reached. The precipitate should dissolve in the water as the temperature increases.

16. Check the boiling point of water (100°C) on the thermometer, as well as in the results table. This latter is accessible by returning to the main menu of the tablet. Once in the results section, 2 sub-sections are available to you, the table and the graph. The table is a log of your experiment while the graph provides you with concise information on the main variables of it.

Note that in this experiment, the boiling speed of water is multiplied by 2.

Heat without exceeding the boiling point of water by 5°C and ensure not to burn the solute.

18. When almost all the solvent (water) has been vaporized and a solid residue is visible (NaCl), lower the temperature of the hot plate to the minimum. The vaporization should take a little over a minute.

Determine the acid-base character and the pH of a liquid substance.

19. Dip a universal pH indicator paper into the beaker of 0.1 M hydrochloric acid.

20. Compare the obtained color with those available on the pH chart.

21. One can also measure using a pH meter.

22. Immerse the electrode of the pH meter into the same beaker.

23. Read the measurement on the digital dial.

24. Rinse the electrode with distilled water.

25. Dry the electrode with absorbent paper.

1.1.3 Anticipated Outcomes

- The Erlenmeyer containing HCl 0.1M, will display a pH of approximately 1.
- The red litmus paper will stay red (solution is acidic).
- The blue litmus paper will turn red (the solution is acidic).
- The solubility of NaCl at 25°C is 360g/L and increases with the rise in temperature.

1.1.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic navigation, introduction to PPE, and simple volume measurements.
- **Activities**: Putting on PPE, measuring liquid volumes, and simple solution preparation.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate navigation, detailed use of PPE, and precise measurement skills.
- **Activities**: Putting on PPE, measuring solid masses and liquid volumes, and basic pH testing.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced navigation, comprehensive PPE use, precise and accurate measurements, advanced chemical experiments, and result analysis.
- **Activities**: Putting on PPE, measuring solid masses and liquid volumes, advanced pH testing, and analyzing and communicating results.

1.1.5 Laboratory essentials

Instrument(s):

Beakers (50ml, 250ml & 1000ml).
Bucket plate.
Droppers.
Electronic Scale.
Erlenmeyer (250ml).
Glass Rod.
Graduated Cylinders (25ml & 100ml).
Hot plate.
Magnetic stirrer.
Paper towel.
PH meter.
Pipette.
Spatulas.
Test Tubes.
Thermometers.
Timer.

Product(s):

HCl 0.1M (solution).
Distilled water.

1.2 Balance Tutorial (Grades 6 to 8)

This experience illustrates the basic techniques to measure the mass of different types of solids, both in full -fit and powdered, using a three -plague balance, a classic laboratory instrument.

The objective is to learn to weigh substances precisely and to understand the importance of precision in scientific measures.

This section establishes the fundamental steps to properly use a three-plague balance, including initial calibration, the positioning of the object on the tray, and the adjustment of the cursors to obtain precise reading of the mass.

The addition of the masses indicated by the sliders makes it possible to determine the total mass of the object.

Measure the mass of a whole solid: This process implies the use of a weighing nacelle to measure the mass of whole solids, such as magnesium ribbons.

The procedure details how to adjust the scale, weigh the nacelle alone, then weigh again with the magnesium ribbons, allowing to calculate the mass of the ribbons by subtracting the mass of the empty nacelle from the total mass.

Measure the mass of a solid powder: This part focuses on the measurement of the mass of a solid powder, such as magnesium oxide. The method consists in using a spatula to transfer a specific amount of powder in the nacelle, weigh the whole, and calculate the mass of the powder by performing the appropriate subtraction.

1.2.1 Educational Goals

- ***Learn to use a triple beam balance:*** Understanding the operation and steps necessary to obtain a precise measurement of the mass.
- ***Develop skills with precise measurement:*** exercise to weigh objects of different forms and sizes, as well as powdered substances, which is essential in many scientific procedures.
- ***Understanding the importance of precision:*** recognizing the importance of precisely measuring the mass in scientific experiences to guarantee the reliability and validity of the results.

In summary, this experience teaches fundamental laboratory skills, essential for the realization of precise and reproducible experiences in science, by emphasizing the exact measure of the mass of solids in different states.

1.2.2 Protocol

General procedure

1) Ensure the balance sliders are at zero and the platform is clean.

2) Check that the needle points to zero. If the needle is not aligned with the zero point, calibrate the balance using the adjustment screw.

3) Place the object to be weighed on the balance platform.

4) Move the slider of the larger scale until the needle is lower than the zero point.

5) Move the slider back one notch to the left so that the needle is above the zero point.

6) Repeat steps 4 and 5 with the second slider.

7) Move the slider of the smaller scale until the needle is perfectly aligned with the zero point.

8) Add the mass of the sliders to find the mass of the object.

Measuring the mass of a solid object

1) Adjust the level of the balance using the adjustment screw.

2) Weigh the weighing boat using the balance.

3) Place all the pieces of CaCO3 into the boat on the balance platform using tweezers. (Reminder : To use the tweezer in hand tracking mode, once the interactive object is picked up, join the thumb and index finger to activate the object's interaction.)

4) Weigh the boat and the pieces.

5) Calculate the mass of the substance as follows: mass of the container and substance - mass of the empty container.

6) Remove the pieces of CaCO3 from the boat.

Measuring the mass of a powdered solid

1) Take 5 mL of CaCO3 powder using the large spatula and place it in the boat.

2) Weigh the boat and the CaCO3 powder.

3) Calculate the mass of the substance as follows: mass of the container and substance - mass of the empty container.

4) Remove the boat from the balance platform.

5) Remove the CaCO3 powder from the boat.

6) Reset the balance sliders to zero.

1.2.3 Anticipated Outcomes

This is a practical session to familiarize yourself with the use of the triple beam balance.

1.2.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic operation of a triple beam balance and simple measurement tasks.

- **Activities**: Using balance to measure small objects, discussing the importance of precision in basic terms.

Grades 6-8 (Ages 11-13)

- **Focus**: Detailed understanding of balance operation and more complex measurement tasks.
- **Activities**: Measuring a variety of objects, including powders, discussing the role of precision in scientific results.

Grades 9-12 (Ages 14-18)

- **Focus**: Mastery of balance operation, advanced measurement tasks, and deep understanding of precision in scientific research.
- **Activities**: Precise measurement of complex objects, in-depth discussions on the impact of precision on scientific reliability and validity.

1.2.5 Laboratory essentials

Instrument(s):

Spatula.
Triple beam balance.
Tweezers.

Product(s):

Calcium carbonate (pieces).
Calcium carbonate (powder).

1.3 Volume Tutorial (Grades 6 to 12)

This experience is designed to teach methods for measuring the volume of different material states: liquid, solid, and gas, using specific techniques and equipment for each case. It makes it possible to understand the principles of measurement and the physical properties of matter through practical methods.

Part 1: Measure the volume of a liquid. This part demonstrates how to precisely measure the volume of a liquid using a graduated cylinder. The meniscus technique is essential to obtain a precise reading because it considers the curvature that the liquid forms on the surface due to the surface tension forms.

Part 2: Measure the volume of a solid by movement of water. This method uses the principle of Archimedes, which stipulates that the volume of fluid moved is equal to the volume of the submerged object. By measuring overflowed water when a solid is immersed in a too full vase, you can determine the volume of the solid. It is a particularly useful technique for irregular solids that cannot be measured directly with a rule or a caliber.

Part 3: Measure the volume of a gas. Measuring the volume of a gas uses a gas burette submerged in water, allowing gas to replace water in the burette. This method illustrates how gases can be contained, and their volume measured by moving another fluid. It depends on the atmospheric pressure and the capacity of the gas to occupy all the available space, in accordance with the laws of the gas.

1.3.1 Educational Goals

- ***Practice specific measurement methods:*** students learn to use different measuring instruments and correctly interpret the readings to obtain specific results.
- ***Understanding the properties of matter:*** experience illustrates the fundamental physical properties of the different states of matter, such as the capacity of liquids to form a meniscus, the solidity of the solids which allows them to move water, and the expansibility of gas.
- ***Apply physical principles:*** steps involve the application of physical principles, such as the principle of Archimedes for solids and gas laws to measure the volume of gases.

By combining theory and practice, this experience educates on basic measurement techniques in physics and chemistry, while strengthening understanding of the properties of matter in its different states.

1.3.2 Protocol

Part 1: Measuring the Volume of a Liquid

1. Using the sink, measure 70 mL of liquid in the appropriate graduated cylinder.

2. Check the base of the meniscus in the graduated cylinder to confirm the volume.

Part 2: Measuring the Volume of a Solid Using an Overflow Vessel

To measure the volume of a solid, we can use water displacement.

3. Fill an overflow vessel to its full capacity before overflowing (500 mL).

4. Place a 25 mL graduated cylinder under the overflow spout of the vessel.

5. Drop 5 pieces of iron (III) nitrate into the overflow vessel using tongs.

6. Using the overflow from the vessel and the meniscus in the graduated cylinder, determine the volume of the solid.

Part 3: Measuring the Volume of a Gas

To measure the volume of a gas, we can use a gas burette.

7. Fill a 1 L beaker with 700 mL of tap water.

8. Position this beaker next to the stand.

9. Install a universal clamp above the center of the beaker to support the gas burette.

10. Fill the gas burette with water.

11. Holding the burette upside down, block its opening with your thumb.

12. Place the inverted gas burette in the clamp, ensuring its opening is near the bottom of the beaker.

13. Gently release your thumb to allow the burette to be submerged without losing water.

14. Adjust the setup if necessary to prevent water loss from the burette.

15. Attach a "J" shaped plastic connector under the opening of the gas burette.

16. Connect the blue hose from the gas cylinder to the connector and start the timer.

17. Open the valve of the gas cylinder.

18. Allow the gas burette to fill halfway with gas. This should take about a minute.

19. Close the gas valve and read the volume on the gas burette.

1.3.3 Anticipated Outcomes

This is a practical session to familiarize yourself with the use of the graduated cylinder, the overflow vessel, and the gas burette.

The calculated density of iron (III) nitrate should be approx. 1.68 g/mL, which will result in 5.3 mL.

1.3.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to measurement techniques and understanding matter properties.
- **Activities**: Using graduated cylinders for liquids, simple water displacement for solids.

Grades 6-8 (Ages 11-13)

- **Focus**: Developing measurement skills and applying basic physical principles.
- **Activities**: Precision in using graduated cylinders, applying Archimedes' principle, introduction to gas volume measurement.

Grades 9-12 (Ages 14-18)

- **Focus**: Mastering measurement techniques and understanding advanced physical principles.
- **Activities**: Advanced use of graduated cylinders, detailed application of Archimedes' principle, precise gas volume measurement.

1.3.5 Laboratory essentials

Instrument(s):	*Product(s):*
Beaker (1000 ml).	Iron (III) nitrate (pieces).
Gaz burette.	
Gaz connector.	
Gaz tank.	
Graduated cylinders (10 ml, 25 ml, 70 ml, 250 ml).	
Lab Stand & Clamps.	
Overflow Vessel.	
Spatula.	
Timer.	
Tweezers	

2 CHEMICAL AND PHYSICAL PROPERTIES

2.1 Osmosis (Grades 6 to 8)

This experience aims to demonstrate dialysis through a simulation of the dissemination of different substances through a semi-permeable membrane, represented by the dialysis bag.

Experience illustrates the key concepts of cell biology and chemistry, such as the permeability of membranes, diffusion, and specific chemical reactions to test the presence of certain molecules in a solution. Here is the course and the objectives of the experience:

2.1.1 Educational Goals

- ***Preparation of the solution and heating:*** The beginning of the experience is to prepare an aqueous solution and to heat a test tube containing glucose to simulate the preparation of the "virtual cell" and the surrounding solution. Preparation of reagents for tests: preparation of buckets with specific reagents for glucose, starch, and salt prepares the ground to test the presence of these substances after dialysis.
- ***Preparation of the dialysis bag:*** The experience simulates the cell membrane using a dialysis bag, in which starch, salt, and glucose solutions are placed. The bag is then immersed in distilled water to simulate the extracellular environment. Diffusion and dialysis: The implementation makes it possible to observe the process of diffusion of molecules through the semi-permeable membrane of the dialysis bag, imitating the functioning of a living cell in its environment.
- ***Chemical tests:*** After a period of dialysis, chemical tests are carried out to identify the substances that have disseminated through the bag. These tests include the use of Lugol to detect starch, fehling A and B for glucose, and silver nitrate for salt.
- ***Observation of changes:*** Experience makes it possible to observe the changes in the chemical composition of the surrounding water and inside the dialysis bag, as well as any change in volume in the bag, illustrating the principles of osmosis and diffusion. Objectives of experience:
- ***Understand dialysis:*** demonstrate how substances diffuse through a semi-permeable membrane according to their gradients of concentration.
- ***Illustrate the principles of diffusion and osmosis:*** observe directly how molecules move from a high concentration area to a low concentration area, and how this affects volume in the dialysis bag.
- ***Application of chemical tests:*** use specific chemical reactions to test the presence of glucose, starch, and salt, stressing the importance of chemical indicators in substances detection.

This experience offers a practical understanding of fundamental biological and chemical processes, using laboratory techniques to explore key concepts in biology and chemistry.

2.1.2 Protocol

Control solutions

Fill 100 mL of tap water into a 250 mL beaker.

2. Place the 250 mL beaker on the heating plate.

3. Add a certain amount of different solutions as follows:

Put ten drops of starch solution in the cup labeled (starch).

Put 10 mL of glucose solution into the test tube labeled (glucose).

Put ten drops of saline solution into the cup labeled (salt).

4. Add a certain amount of the different solutions as follows:

Add 10 mL of Fehling A to the test tube labeled (glucose)

Add 10 mL of Fehling B to the test tube labeled (glucose)

Add ten drops of lugol into the cup labeled (starch).

Add ten drops of silver nitrate into the cup labeled (salt).

5. Mix the labeled cells (starch) and (salt) using a clean glass rod.

6. Place the labeled test tube (glucose) in the 250 mL beaker prepared in step 1 using universal tongs.

Set the hot plate to 75°C and wait for 30 seconds.

Preparation of the osmosis bag

8. Turn off the hot plate.

9. Put 300 mL of warm water into the 600 mL beaker.

10. Soak the dialysis bag in warm water to make it more flexible.

11. Attach the cap at the bottom of the dialysis bag.

In the graduated cylinder, successively pour 3 mL of starch solution, 3 mL of saline solution, and 3 mL of glucose solution.

13. Pour the contents of the graduated cylinder into the dialysis bag.

14. Hold the open end of the dialysis bag tightly and rinse the bag in the 600 mL beaker.

15. Place the empty 250 mL beaker next to the universal stand.

16. Attach the "virtual cell" to the universal support using the universal clamp and place it all vertically in the 250 mL beaker.

Fill the 250 mL beaker with distilled water so that the contents of the bag are immersed in the water. The water should not touch the end where the opening of the bag is located.

18. Take a few drops of water from the beaker and apply as follows:

Put 10 mL of the water solution from the beaker into the labeled test tube (Glucose Test).

Put ten drops of the beaker's water solution into the cup labeled (Starch Test).

Put ten drops of the beaker's water solution into the cup labeled (Salt Test)

Wait 24 hours. (Use the clock button to advance the time)

Use of indicators

20. Take a certain amount of water from the beaker and put it as follows:

Put 10 mL of the water solution from the beaker into the test tube labeled (Glucose Test).

Place ten drops of the beaker's water solution into the cup labeled (Starch Test).

Put ten drops of the solution from the beaker's water into the cup labeled (Salt Test).

Fill 100 mL of tap water into a 250 mL beaker.

22. Place the 250 mL beaker on the hot plate and heat at maximum intensity until boiling.

23. Observe the volume of water contained in the dialysis bag and note if there are any changes.

24. Put 10 mL of Fehling A and 10 mL of Fehling B into the two labeled test tubes (Glucose Test).

25. Put ten drops of lugol in the two labeled cups (Starch Test).

Put ten drops of silver nitrate into the two cups labeled (Salt Test).

Place the labeled test tube (Test Glucose) initially in the 250 mL beaker prepared in step 21 and wait a few moments. (Fehling's reaction).

28. Repeat the previous step with the test tube labeled (Glucose Test) after 24 hours (Fehling's reaction).

2.1.3 Anticipated Outcomes

The iodine (I-) contained in Lugol's solution reacts with starch to form an iodine-starch complex. When iodine is added to starch, it fits inside the helical structure of the starch molecules, resulting in a color change to blue-black. This reaction is often used as a qualitative test to indicate the presence of starch.

The Fehling A solution is essentially a CuSO4 solution with a molarity of 0.05M, with its's characteristic sky-blue color due to Cu2+ ions. The Fehling B solution contains Rochelle salt (potassium sodium tartrate) and NaOH 0.0625M. Fehling's B solution is typically a clear, colorless liquid.

When Fehling's A solution is mixed with Fehling's B solution without heating, the two solutions react to form a deep blue complex. This complex is a result of the copper (II) ions from Fehling's A reacting with the tartrate ions from Fehling's B in an alkaline environment, forming a copper (II)-tartrate complex. The mixture will be a deep blue color. Heat is necessary to drive the reduction of copper (II) to copper(I), resulting in a deeper blue color.

When you introduce reducing sugars to the heated Fehling's solution (a mixture of Fehling's A and B), a chemical reaction occurs where the reducing sugars donate electrons to the copper (II) ions, reducing them to copper(I) ions. The solution's color changes from deep blue to light blue, followed by the appearance of a red precipitate, is indicative of the presence of reducing sugars.

This test is specific for reducing sugars, which are sugars that have free aldehyde or ketone groups capable of acting as reducing agents. Common reducing sugars include glucose, fructose, lactose, and maltose. Non-reducing sugars, like sucrose, do not react in this test unless they are hydrolyzed to their reducing sugar components. Silver nitrate reacts with chloride (Cl^-) to produce a white precipitate of AgCl (s).

Water has moved from outside the cell to the inside. This is observed by the water level in the beaker, which has slightly decreased, and by the bag, which has slightly enlarged. Glucose and starch have moved from inside the bag to the external medium. They are detected in the water surrounding the bag using Lugol's iodine and Fehling's solution tests. The concentration of substances inside and outside the membrane, as well as the size of the particles relative to the size of the membrane's pores.

<u>This could be explained by 3 principles:</u>

- ***Water movement:*** This describes a process like osmosis, where water moves across a semi-permeable membrane from an area of lower solute concentration to an area of higher solute concentration. In this case, the water inside the beaker (outside the cell or bag) moves into the bag (representing the cell), causing the water level in the beaker to decrease and the bag to expand as it fills with water.
- ***Movement of glucose and starch***: This indicates that glucose and starch, initially inside the bag, have moved to the outside environment (the beaker water). This movement could be due to dialysis, a process where smaller molecules and ions can move through a semi-permeable membrane, while larger molecules cannot. The presence of glucose and starch in the external solution is confirmed using specific tests: Lugol's iodine test for starch, which turns blue-black in the presence of starch, and Fehling's solution test for reducing sugars like glucose, which results in a color change when glucose reduces the copper (II) ions in Fehling's solution to copper(I) oxide.
- ***Concentration and particle size***: This statement refers to the factors influencing the movement of substances across a membrane. The concentration gradient (the difference in substance concentration inside and outside the membrane) and the relative size of the particles compared to the membrane's pore size determine which substances can pass through the membrane. Larger particles or molecules that exceed the pore size of the membrane cannot pass through, while smaller ones can.

2.1.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to osmosis and diffusion, simple preparation steps, and basic observations.
- **Activities**: Preparing simple solutions, basic use of a dialysis bag, and introductory chemical tests.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of osmosis and diffusion, detailed preparation steps, and intermediate observations.
- **Activities**: Preparing and heating solutions, using a dialysis bag for diffusion experiments, and applying chemical tests.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced understanding of osmosis and diffusion, detailed preparation and observation, and comprehensive chemical testing.
- **Activities**: Preparing detailed solutions, performing complex diffusion experiments with a dialysis bag, and conducting in-depth chemical tests and analyses.

2.1.5 Laboratory essentials

Instrument(s):

Beaker (250 ml & 600 ml).
Bucket plate.
Droppers.
Graduated cylinder (10 ml & 100 ml).
Hot plate.
Lab stand & Clamps.
Osmosis bag.
Test tubes.

Product(s):

Distilled water.
Fehling A.
Fehling B.
Glucose.
Lugol (2%).
Silver nitrate.
Sodium chloride.
Starch

2.2 Identification of elements using luminous flames (Grades 3 to 8)

The experience is designed to explore the fascinating phenomenon of flame tests, which reveal the presence of specific chemical elements within substances through the distinctive colors they emit when exposed to fire.

This hands-on approach not only sheds light on elemental identification but also serves as an introductory platform for mastering fundamental laboratory practices.

2.2.1 Educational Goals

- ***Introduction to Flame Testing:*** Learn to conduct flame tests, observing the unique colorations emitted by various substances when ignited, which serves as a basis for identifying chemical elements.
- ***Laboratory Techniques Mastery:*** Acquire skills in utilizing a burner, ensuring the safe handling of chemicals, and effectively interpreting experimental outcomes by juxtaposing them against established reference materials.
- ***Chemical Element Identification:*** Utilize the distinctive colorations observed during the flame tests to ascertain the presence of specific elements within the substances under examination.
- ***Safety and Procedure Compliance:*** Emphasize the significance of adhering to safety protocols during the handling and combustion of chemicals, highlighting the importance of proper safety gear and procedures.
- ***Analytical Skills Development:*** Enhance the ability to analyze and interpret the results of flame tests, improving understanding of the chemical composition of substances and the principles of elemental identification.
- ***Reference Utilization:*** Employ a reference chart of colors associated with various chemical compounds to aid in the identification process, fostering a deeper comprehension of the relationship between elements and their flame test colorations.

This immersive experience underscores the integration of practical laboratory skills with theoretical knowledge, offering participants a comprehensive understanding of flame test procedures and the principles behind the identification of chemical elements. Through this engaging method, the adventure into the realm of chemistry becomes not only educational but also a visually captivating experience.

2.2.2 Protocol

Method for testing a substance's reaction to flame

Turn on the burner.

Take a sample of powder from a substance to be tested with the spatula (substances 1 to 4).

3) Expose the substance to the burner flame.

4) Take a strip of magnesium using the tweezers (substance 5).

Expose the magnesium ribbon to the burner flame.

6) Turn off the burner.

7) The color of the flame is found in the table, in the results section.

8) Compare the color of the flame with reference colors, like those presented below.

The color emitted during the combustion of certain substances

White = Magnesium

Violet = Potassium iodide

Green = Copper sulfate

Yellow = Iron nitrate

Bright red = Lithium chloride

2.2.3 Anticipated Outcomes

When conducting a flame test, the expected outcomes are pivotal for understanding the composition of various substances based on the color they emit when exposed to flame. This simple yet effective method leverages the principle that when elements are heated, their electrons become excited and jump to higher energy levels. As the electrons return to their ground state, they emit light of specific wavelengths, which we perceive as different colors. This phenomenon is fundamental to the flame test, providing a visual fingerprint for each element.

In this protocol, different substances are introduced to a flame, and the color emitted is observed. For instance, when magnesium, substance 5, is exposed to flame, a bright white light is expected, which is characteristic of magnesium's emission spectrum. This result is crucial for confirming the presence of magnesium in a sample.

Similarly, when testing substances 1 to 4, various colors are anticipated based on the compounds. Potassium iodide should emit a purple hue, indicative of potassium's presence. Copper sulfate is expected to produce a green flame, a signature color for copper ions. Iron nitrate should yield a yellow flame, aligning with the emission spectrum for iron.

Lastly, lithium chloride is known to emit a bright red flame, distinctively pointing to lithium.

The significance of these outcomes extends beyond simple identification. In educational settings, the flame test demonstrates fundamental concepts of electron transitions and light emission. In practical applications, it provides a quick and cost-effective method for identifying metallic ions in compounds. By comparing the observed colors to known standards, researchers can infer the composition of unknown samples, aiding in everything from quality control in manufacturing processes to environmental monitoring and forensic analysis.

Understanding the specific color emissions of various elements allows scientists to deduce the presence of these elements in unknown samples. This method, while not as precise as spectroscopic techniques, offers a visually engaging and straightforward approach to chemical analysis, underscoring the interplay between energy, electron movement, and light in the realm of atomic and molecular behavior.

2.2.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to flame testing and simple observations.
- **Activities**: Observing flame colors, basic safety instructions, identifying a few common elements.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding and practical application of flame testing.
- **Activities**: Conducting flame tests, using a reference chart, following detailed safety protocols, and beginning to analyze results.

2.2.5 Laboratory essentials

Instrument(s):

Bunsen Burner
Spatula.
Tweezers.

Product(s):

Copper sulfate (powder).
Iron nitrate (crystals).
Lithium chloride (powder).
Magnesium (pieces).
Potassium iodide (powder).

2.3 Gas Identification (Grades 6 to 8)

This laboratory experience is meticulously crafted to unravel the mysteries of different unknown gases by closely observing their reactions to incandescent wood and their interactions with lime water. The primary focus is to explore the gases' abilities to sustain or extinguish the combustion of a wooden splint and to detect chemical reactions indicative of specific gases, particularly the identification of carbon dioxide through the formation of a white calcium carbonate precipitate. This hands-on approach not only bridges the gap between theoretical concepts and real-world application but also enriches the understanding of the chemical and physical properties of gases.

2.3.1 Educational Goals

- ***Understanding Gas Properties:*** Gain a comprehensive understanding of the chemical and physical properties of gases, focusing on their behavior in the presence of flame and chemical reactivity.
- ***Experimental Observation:*** Learn to conduct experiments to observe the reaction of different gases when exposed to an incandescent wooden splint, distinguishing between flammable gases, those that support combustion, and those that extinguish flames.
- ***Chemical Reaction Analysis:*** Develop skills in conducting chemical tests, such as the addition of lime water to gas samples, to observe and analyze chemical reactions indicative of specific gases, particularly the detection of carbon dioxide.
- ***Theoretical Application:*** Apply theoretical knowledge of gases to practical experiments, enhancing the ability to identify gases based on their properties and reactions.
- ***Safety and Procedure:*** Emphasize the importance of safety and adherence to procedural protocols while handling gases and conducting experiments.
- ***Analytical Skills:*** Enhance analytical skills through the observation of experimental outcomes, fostering a deeper understanding of gas properties and the interpretation of results.

This laboratory endeavor is designed to empower students with the knowledge and skills to experimentally identify the properties of different unknown gases through observation and chemical analysis. By engaging in this practical exploration, students are provided with a unique opportunity to directly apply their theoretical understanding to real-world scenarios, thereby enhancing their comprehension and appreciation of the fascinating world of gases.

2.3.2 Protocol

1. Light the wooden splint.

2. Remove the stopper from one of the test tubes containing unknown gas #1 (test tubes 1 to 3) and quickly introduce the lit splint.

3. Repeat steps 1 and 2 with one of the test tubes containing unknown gas #2 (test tubes 4 to 6) and one of the test tubes containing unknown gas #3 (test tubes 7 to 9).

4. Light another wooden splint.

5. Shake the splint to extinguish it while keeping it glowing.

6. Remove the stopper from a second test tube containing unknown gas #1 and quickly introduce the glowing splint.

7. Repeat steps 4 to 6 with the other two gases.

8. Open the third test tube containing unknown gas #1 and quickly pour in about 15 mL of lime water.

9. Immediately replace the stopper on the test tube and shake.

10. Repeat steps 8 and 9 with the test tubes containing unknown gas #2 (test tubes 4 to 6), then with those containing unknown gas #3 (test tubes 7 to 9).

2.3.3 Anticipated Outcomes

- The unknown gas #1 is CO2 (g).
- The unknown gas #2 is O2 (g)
- The unknown gas #3 is H2 (g).

Review of the 3 steps of the experience:

Introduction of a burning splint into the test tubes containing unknown gases: This step is critical in identifying the presence of oxygen (O2). When a glowing splint is introduced into a tube containing oxygen, the splint will reignite, demonstrating oxygen's role in supporting combustion.

Introduction of an extinguished but still glowing splint into the test tubes: This step helps identify the presence of hydrogen gas (H2). Hydrogen gas is known to reignite a glowing splint with a characteristic 'pop' sound, which is a result of the rapid combustion of hydrogen in the presence of oxygen.

Shaking lime water with the gas in the test tube: This step is designed to detect carbon dioxide (CO2). When CO2 is introduced into lime water (a solution of calcium hydroxide), it reacts to form calcium carbonate, which is insoluble and turns the lime water milky. This is a qualitative test for the presence of carbon dioxide.

The significance of these tests lies in their ability to demonstrate fundamental chemical properties and reactions, such as oxygen's role in combustion, the flammability of hydrogen, and the reaction of carbon dioxide with lime water. These experiments are not only foundational in understanding chemical reactivity and gas identification but also have practical implications in various scientific fields, including environmental science, safety protocols, and industrial processes. Through these simple yet effective tests, students or researchers can gain insights into the reactive behaviors of different gases and apply this knowledge in practical or experimental contexts.

2.3.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to gas identification and simple observations.
- **Activities**: Observing gas reactions with a wooden splint and lime water, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding and application of gas identification techniques.
- **Activities**: Conducting experiments, recording observations, understanding chemical reactions, and following detailed safety protocols.

2.3.5 Laboratory essentials

Instrument(s):

Lighter.
Test tubes.
Wooden Hatches.

Product(s):

Unknown gases (#1 to #9).

2.4 Separation of Solid and Liquid Products (Grades 3 to 8)

This tutorial is designed to teach students two fundamental techniques of separation and purification in chemistry: decantation and filtration. Through hands-on experience, students will learn to separate a solid from a liquid in a heterogeneous mixture, gaining practical skills and understanding the underlying principles of solubility and physical properties.

2.4.1 Educational Goals

The purpose of this experience is to put into practice two fundamental techniques of separation and purification in chemistry: decantation and filtration.

Part 1: Decantation

The decantation aims to separate the phases from a heterogeneous mixture composed of an unparalleled solid (in this case, cobalt hydroxide (II)) and a liquid (water), by exploiting their difference in density. The objective is to obtain a clearer liquid by gently pouring the upper aqueous phase into another container, leaving behind the solid deposited at the bottom of the first beaker. This step allows a coarse separation of the solid and liquid, in preparation for a finer purification.

Part 2: filtration

The filtration is used to complete the separation started by the decantation, by removing the residual solid particles which were transferred with the liquid in the second Becher.

This process uses a filter placed in a funnel to separate the solid (residue) and liquid (filtrate) phases from the mixture.

The filtrate, which is the liquid having crossed the filter, should be purer than the initial mixture, while the residue, made up of solid particles, remains on the filter.

By combining decantation and filtration, this experience aims to teach how to perform an effective separation of the components of a heterogeneous mixture, to understand the principle of solubility and the physical properties which allow the separation of phases, as well as to familiarize the participants with the 'Use of standard laboratory equipment for the separation of mixtures.

2.4.2 Protocol

The purpose of this laboratory is to separate the constituents of a mixture of cobalt (II) hydroxide and water.

Part 1: Decantation

This method allows for a preliminary separation, as cobalt (II) hydroxide is not soluble in water.

1. An aqueous solution with a deposit of cobalt (II) hydroxide has been resting for at least 5 minutes.

2. Gently pour the liquid part (water) of the mixture into a second beaker.

a) At this stage, solid particles may end up in the second beaker.

3. Let the first beaker rest on the counter for the remainder of the laboratory. The residual water will be able to evaporate.

Part 2: Filtration

This method allows for the removal of solid particles that ended up in the mixture after decantation.

1. Attach a medium clamp to the universal stand on the right.

2. Insert the filter into a funnel.

3. Attach the funnel to the clamp on the universal stand.

4. Place an Erlenmeyer flask under the funnel's opening.

5. Slowly pour the mixture over the thick part of the filter.

6. Allow the mixture to pass through the filter.

a) The liquid obtained is called the filtrate.

b) The solid part remaining in the filter is the residue.

2.4.3 Anticipated Outcomes

The objective of this laboratory exercise is to separate the constituents of a mixture of cobalt (II) hydroxide and water. The process involves two main separation techniques: decantation and filtration, which are fundamental in separating solid and liquid phases in a mixture.

Part 1: Decantation

Decantation leverages the insolubility of cobalt (II) hydroxide in water. After allowing the mixture to settle, the water, which is the supernatant liquid, is gently poured off into another beaker, leaving the solid cobalt (II) hydroxide behind. This step is crucial as it relies on the difference in density between the solid and liquid to achieve separation. Some solid particles might transfer into the second beaker, which necessitates the next step, filtration.

<u>Part 2: Filtration</u>

Filtration is employed to remove any remaining solid particles that were inadvertently transferred with the water during decantation. The mixture is poured through a filter, which captures the solid particles, allowing only the liquid to pass through. The liquid collected at this stage is called the filtrate, and the solid retained on the filter is the residue.

During the decantation, the primary outcome is the partial separation of cobalt (II) hydroxide from the water. This step is significant because it demonstrates the principle of using physical properties (solubility and density) for separation.

During the filtration, the expected outcome is the complete separation of the solid cobalt (II) hydroxide from the water. This step is essential to ensure that any solid particles that escaped during decantation are captured, illustrating the efficacy of filtration in separating solids from liquids based on particle size.

The significance of these procedures lies in their wide applicability in various scientific fields, including chemistry, environmental science, and engineering. Understanding these fundamental separation techniques is crucial for students as they are integral to many laboratory and industrial processes, from purifying chemicals to treating wastewater. This lab not only helps in understanding the specific properties of cobalt (II) hydroxide and water but also reinforces the concept of phase separation and the practical applications of decantation and filtration in real-world scenarios.

2.4.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to separation techniques and simple observations.
- **Activities**: Observing decantation and simple filtration, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding and application of separation techniques.
- **Activities**: Performing decantation and filtration, understanding chemical purity, detailed safety protocols.

2.4.5 Laboratory essentials

Instrument(s):

Beaker (50ml & 1000ml).
Erlenmeyer (250 ml).
Funnel.
Funnel filter.
Glass Rod.
Graduated Cylinders (70ml).
Hot plate.
Lab Stand & Clamps.
Magnetic stirrer.
Plastic connector.
Test tubes &
Thermometers & Timer.

Product(s):

Cobalt hydroxide (II).

2.5 Product separation using boiling point 1 (Grades 6 to 8)

This laboratory experience is centered on the distillation process, a fundamental technique for separating or purifying liquids by leveraging the differences in their boiling points. The core objective is to isolate the solvent (water) from the solute (copper sulfate) through heating to evaporate the solvent, which is then condensed back into a liquid (distillate) within a test tube cooled by ice water. This method is highly valued for its ability to purify a liquid or to extract components from a liquid mixture, offering a hands-on approach to understanding the principles of distillation.

2.5.1 Educational Goals

- ***Understanding Distillation:*** Acquire a deep understanding of the distillation process, emphasizing the role of boiling points in the separation of liquid mixtures.
- ***Laboratory Technique Mastery:*** Develop the skills necessary for the proficient use of crucial laboratory equipment, such as Erlenmeyer flasks, magnetic stirrers, heating plates, and thermometers, which are essential for conducting distillation.
- ***Temperature and Pressure Insights:*** Gain insights into the impact of temperature and pressure on the boiling points of liquids and learn how to adjust these parameters to achieve effective distillation.
- ***Practical Application of Theoretical Concepts:*** Apply theoretical concepts related to solubility, boiling points, and phase changes in a practical laboratory setting, enhancing learning through direct experience.
- ***Safety and Precision in Laboratory Work:*** Highlight the importance of adhering to safety protocols and maintaining precise control over temperature to prevent the thermal decomposition of solutes and ensure the success of the separation process.

Through engaging in this distillation experiment, participants are not only introduced to the practical application of distillation for the separation and purification of substances but also to the fundamental scientific concepts underlying the process.

The experiment serves as a bridge between theoretical knowledge and practical application, fostering a comprehensive understanding of the distillation process, the importance of boiling points, and the use of laboratory equipment, all while underscoring the significance of safety and precision in scientific research.

2.5.2 Protocol

1. Pour 60 mL of 1M copper sulfate solution into a 250 mL Erlenmeyer flask.

2. Insert a magnetic stir bar into the Erlenmeyer flask.

3. Close the Erlenmeyer flask with a rubber stopper with a hole and a glass elbow.

4. Place the Erlenmeyer flask on the hot plate.

5. Insert a thermometer into the hole.

6. Fill a 500mL beaker halfway with cold water and ice.

7. Using the universal stand on the left and a large clamp, insert an empty test tube into the ice water beaker.

8. Using the same universal stand and another large clamp, insert a plastic tube into the test tube so as to make a connection with the Erlenmeyer flask.

9. Start the magnetic stirrer, as well as the stopwatch.

10. Set the hot plate to 105°C.

11. Check for the boiling point of water (100°C) on the thermometer, as well as in the results table.

** Note that in this experiment, the boiling rate of water is doubled **

12. Heat without exceeding the boiling point of water by more than 5 °C and ensure not to burn the solute.

13. When almost all the solvent has evaporated and a solid residue is visible, turn off the hot plate.

a. The contents of the test tube are the solvent and are now called the distillate.

b. The contents of the Erlenmeyer flask are the solute.

2.5.3 Anticipated Outcomes

Evaporation of Water: By heating the copper sulfate solution to around 105°C, the water component is expected to evaporate. Since the boiling point of water is 100°C, heating it just above this temperature ensures its transition from liquid to vapor without significantly increasing the temperature of the copper sulfate, which could lead to its decomposition.

Condensation of Water Vapor: The evaporated water is then expected to condense when it meets the cooler surfaces of the setup, particularly within the tubing that connects to the ice-filled beaker. This process demonstrates the physical change of water from gas back to liquid, which is then collected as distillate in the test tube.

Separation of Copper Sulfate: As the water evaporates, the copper sulfate will remain in the Erlenmeyer flask as a solid residue. This demonstrates the principle of using boiling points to separate components in a mixture based on their different physical properties.

The significance of this experiment lies in its demonstration of simple distillation, a fundamental technique in chemistry used to purify or separate liquid mixtures. This process is widely applicable in various scientific and industrial fields, such as pharmaceuticals, food processing, and chemical manufacturing. The experiment provides a hands-on understanding of how differences in boiling points can be leveraged to separate substances, illustrating key concepts in physical chemistry and chemical engineering. Furthermore, the experiment highlights the importance of careful temperature control and the physical processes of evaporation and condensation in separation techniques.

2.5.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to distillation and simple observations.
- **Activities**: Observing phase changes, simple demonstration of distillation, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding and application of distillation techniques.
- **Activities**: Performing basic distillation, using lab equipment, observing temperature effects, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced mastery of distillation and in-depth analysis.
- **Activities**: Conducting detailed distillation, using advanced lab equipment, adjusting experimental parameters, performing detailed analyses, adhering to advanced safety protocols.

2.5.5 Laboratory essentials

Instrument(s):

Beaker (50ml & 1000ml).
Erlenmeyer (250 ml).
Funnel.
Funnel filter.
Glass Rod.
Graduated Cylinders (70ml).
Hot plate.
Lab Stand & Clamps.
Magnetic stirrer.
Plastic connector.
Test tubes.
Thermometers & Timer.

Product(s):

Copper sulfate 1.0M(solution).

2.6 Product separation using boiling point 2 (Grades 9 to 12)

This experience focuses on the process of fractional distillation, a sophisticated method designed to separate or purify components from complex liquid mixtures, such as fog rinse, by leveraging the differences in boiling points of its constituents. The objective is to isolate and analyze the diverse volatile components present in the fog rinse, observing temperature variations to pinpoint the boiling of various elements at specific temperatures.

2.6.1 Educational Goals

- ***Deep Dive into Fractional Distillation:*** Gain a comprehensive understanding of fractional distillation's principles and its application in separating complex liquid mixtures based on boiling point disparities.
- ***Precision in Temperature Control:*** Emphasize the significance of precise temperature control for the selective vaporization of mixture components, highlighting the crucial role of temperature in the distillation process.
- ***Proficiency with Laboratory Equipment:*** Acquire skills in using essential laboratory apparatus, such as Erlenmeyer flasks, heating plates, and condensation setups, crucial for executing fractional distillation.
- ***Insights into Chemical Properties:*** Enhance knowledge about the physical properties of mixture components, particularly boiling points, and understand how these properties can be utilized for effective separation.
- ***Application of Theoretical Concepts:*** Foster the ability to apply theoretical knowledge in a practical setting, enriching understanding of chemical separation and purification techniques.

This laboratory experience in fractional distillation serves as a practical exploration into the separation and purification of complex mixtures. By focusing on the distillation of fog rinse, participants learn not only about the operational aspects of fractional distillation but also about the importance of precise temperature control and the correct use of laboratory equipment.

The activity aims to provide a hands-on understanding of how different boiling points can be exploited to separate a mixture into its constituent parts, thereby offering a real-world application of theoretical chemical concepts. Through this process, participants gain valuable insights into the physical properties of substances and the practical methodologies for their separation, enhancing their skills and knowledge in chemical analysis.

2.6.2 Protocol

1. Pour approximately 70 mL of 25% v/v ethanol into the 250 mL Erlenmeyer flask.

2. Insert the magnetic stir bar into the Erlenmeyer flask.

3. Close the Erlenmeyer flask with the two-hole stopper with a glass elbow.

4. Insert the thermometer into one of the holes in the stopper with a glass elbow. The thermometer should be immersed in the mouthwash but must not touch the bottom of the Erlenmeyer flask.

Caution! The glass elbow may break if not inserted straight into the hole.

5. Place the Erlenmeyer flask on the hot plate.

6. Fill the 500 mL beaker of ice with cold water.

7. Using a large clamp and the universal stand on the left, place test tube #1 in the beaker.

8. Using another large clamp and the same stand, connect the plastic tube to the glass elbow and insert the other end into the test tube.

9. Start the magnetic stirrer.

10. Start the stopwatch and monitor the results table.

11. Adjust the temperature of the hot plate to 85°C.

12. Monitor condensation of a liquid in test tube #1.

** Note that in this experiment, the boiling rate of water is doubled **

13. When the liquid no longer condenses in the test tube and the solution in the Erlenmeyer changes color:

- remove the rubber tubing from the test tube;
- take the test tube out of the beaker and place it on the test tube rack;
- place test tube 2 in the beaker and insert the end of the tubing into it.

14. Adjust the temperature of the hot plate to 105°C.

15. Monitor for the appearance of another temperature plateau in the results table.

16. When the solution has completely evaporated, turn off the hot plate and wait for the setup to cool down.

2.6.3 Anticipated Outcomes

This laboratory exercise demonstrates the process of distilling a 25% v/v ethanol solution, focusing on the separation of ethanol from water based on their different boiling points. The procedure involves heating the solution, vaporizing the ethanol, and then condensing it back into a liquid form in a separate container.

The expected outcomes are:

- ***Heating the ethanol solution:*** By adjusting the heating plate to 85°C, the ethanol, with a boiling point lower than water, begins to evaporate. This step is crucial for separating ethanol from the solution.

- ***Ethanol evaporation and condensation:*** As ethanol vaporizes, it travels through the setup and condenses upon cooling, collecting in a separate test tube as a distillate. This demonstrates the principle of distillation, where a substance is separated based on its boiling point.
- ***Temperature plateau:*** The temperature plateau observed indicates the phase where ethanol is being evaporated. Since ethanol has a lower boiling point than water (78.37°C at standard atmospheric pressure), it evaporates first. The subsequent rise in temperature indicates the beginning of water evaporation.
- ***Separation and collection of ethanol:*** The ethanol, now separated from the mixture, is collected in a test tube. This process showcases how distillation can be used to separate and collect components of a mixture based on their physical properties, specifically boiling points.
- ***Complete evaporation:*** Increasing the temperature to 105°C ensures the removal of water, demonstrating the complete evaporation of the solution's components at different temperatures.

The significance of this experiment lies in illustrating the practical application of distillation, a fundamental technique in chemistry for separating and purifying liquids. It provides insight into how different substances in a mixture can be separated based on their boiling points. This technique is widely used in various industries, including pharmaceuticals, beverage production, and chemical manufacturing. Understanding this process is crucial for students and professionals in the field, as it highlights the importance of boiling points, phase changes, and the principles of distillation in both laboratory and industrial settings.

2.6.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to distillation and simple observations.
- **Activities**: Observing phase changes, simple demonstration of distillation, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding and application of distillation techniques.
- **Activities**: Performing basic distillation, using lab equipment, observing temperature effects, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced mastery of distillation and in-depth analysis.
- **Activities**: Conducting detailed distillation, using advanced lab equipment, adjusting experimental parameters, performing detailed analyses, adhering to advanced safety protocols.

2.6.5 Laboratory essentials

Instrument(s):

Beaker (50ml & 1000ml).
Erlenmeyer (250 ml).
Funnel & Funnel filter.
Glass Rod.
Graduated Cylinders (70ml).
Hot plate.
Lab Stand & Clamps.
Magnetic stirrer.
Plastic connector.
Test tubes.
Thermometers & Timer.

Product(s):

25% v/v ethanol (solution).

2.7 Melting point and density (Grades 6 to 8)

This educational experience is meticulously structured into two segments, each designed to unravel the fundamental physical properties of paraffin—its density and melting point. These properties are crucial for understanding how paraffin behaves under various conditions and serve as practical illustrations of core principles in chemistry and physics.

2.7.1 Educational Goals

- ***Comprehension of Density:*** Through the water displacement method, participants will learn how to calculate the density of paraffin, gaining insight into this intrinsic property that is vital for the identification and characterization of materials.
- ***Understanding of Melting Point:*** The experiment aims to determine the melting point of paraffin, enhancing understanding of the temperature at which a substance transitions from solid to liquid state. This property is essential for substance identification and purity verification.
- ***Application of Theoretical Concepts:*** Engage in practical applications of theoretical concepts such as Archimedes' principle for volume measurement and the concept of density and melting points, bridging the gap between theory and practice.
- ***Development of Technical Skills:*** Cultivate technical prowess in precise manipulation of measuring instruments and analytical evaluation of experimental data, essential skills for any scientific inquiry.

Part A: Density Determination

The objective is to calculate paraffin's density by first measuring its mass and then determining its volume via water displacement. This process not only illustrates the concept of density but also demonstrates Archimedes' principle in action.

Part B: Melting Point Measurement

This segment focuses on identifying the melting point of paraffin by preparing a sample, heating it until it transitions to a liquid state, and monitoring the temperature at which this change occurs. This exercise provides a hands-on understanding of how a substance's melting point is determined and its significance.

This two-part experience offers a comprehensive exploration of the physical properties of paraffin, providing a practical understanding of density and melting point. Through these experiments, participants not only grasp theoretical concepts in a tangible way but also hone their technical skills, from precise measurement to the critical analysis of results. This approach fosters a deeper appreciation for the nuances of material properties and their implications in scientific research and application.

2.7.2 Protocol

Part 1: The density

Place the weighing basket on the scale tray.

2. Press tare to zero the scale.

3. Weigh 5 or 6 pieces of paraffin.

4. Measure the volume of the paraffin sample by water displacement.

a) Measure 20 mL of water with the graduated cylinder.

b) Let the pieces of paraffin slide into the graduated cylinder. Observe the increase in volume.

The final volume, minus the initial volume (20 ml), equals the volume of the paraffin pieces.

5. Verify that the mass and volume of paraffin are correctly recorded in the results table on the tablet.

6. The mass of paraffin divided by its volume is equal to the density of the paraffin (in g/ml).

Part 2: The melting point

7. Fill a 500 mL beaker with cold water (around 6 °C).

8. Place the beaker of cold water on the hot plate.

9. Knowing the density of paraffin, weigh a mass corresponding to a volume of 18 mL to 22 mL. Use the results table on the tablet for assistance.

10. Pour the weighed paraffin into an empty test tube.

11. Using a universal clamp and a universal stand, place the test tube in the beaker of cold water, on the hot plate.

12. Using another universal clamp, place the thermometer in the test tube. The thermometer should not touch the bottom of the test tube, but should be in contact with the paraffin.

13. Start the stopwatch (red button).

14. Set the temperature of the hot plate to 85 °C, wait for all the paraffin to melt and its temperature to start rising again. Follow the progress of the experiment on the chart in the "results" section of the tablet.

15. Turn off the hot plate.

2.7.3 Anticipated Outcomes

The density of paraffin is 0.85 g/mL. 5 or 6 pieces should weigh between 21 and 26 g. The occupied volume should be between 24.7 and 30.6 mL. The melting point of paraffin is around 57 °C. The paraffin will melt and solidify at its melting point, and a plateau of temperature should be observed for a few seconds due to its latent heat of fusion.

The experiment emphasizes the importance of precise measurements, particularly in determining the density and melting point of substances. The careful weighing of paraffin and meticulous volume measurement via water displacement underscore the need for accuracy in scientific experiments.

- ***Observation and Record-Keeping:*** Students learn the value of keen observation (e.g., watching paraffin pieces displace water) and diligent record-keeping, essential skills in any scientific endeavor. Recording the mass and volume accurately on the tablet ensures data integrity.
- ***Understanding Equipment Use:*** Familiarity with lab equipment, such as balance scales, graduated cylinders, and hot plates, is crucial. This exercise provides hands-on experience, reinforcing the correct usage and importance of each tool in conducting experiments.
- ***Density Calculation:*** By dividing the mass of paraffin by its volume, students determine its density, an essential physical property that aids in understanding substance characteristics.
- ***Melting Point Determination***: The experiment allows students to ascertain the melting point of paraffin, a key property that helps categorize and identify substances based on their thermal behavior.
- ***Conceptual Understanding:*** Through practical engagement, students gain a deeper understanding of concepts like density and phase changes, solidifying theoretical knowledge through application.

The experiment demonstrates density as a ratio of mass to volume. In this context, paraffin's density is calculated to understand how compactly its molecules are arranged.

The phase change from solid to liquid is observed as paraffin reaches its melting point. The energy supplied by the hot plate (heat) increases the kinetic energy of paraffin molecules, weakening the forces holding them in a solid structure until they transition to a liquid state.

This method illustrates Archimedes' principle, where the volume of the displaced water equals the volume of the solid submerged, allowing for the volume measurement of irregularly shaped objects like paraffin pieces.

In summary, the experiment is not just a demonstration of measuring physical properties but also an integrated lesson in the practical application of chemistry principles, safety in the lab, and the scientific method.

2.7.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to density and melting point, simple observations.
- **Activities**: Observing water displacement, watching paraffin melt, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding and application of density and melting point concepts.
- **Activities**: Measuring density, determining melting point, applying basic theoretical concepts, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced mastery of density and melting point measurements, in-depth analysis.
- **Activities**: Performing detailed measurements, precise determination of melting points, applying advanced theoretical concepts, adhering to advanced safety protocols.

2.7.5 Laboratory essentials

Instrument(s):

Beakers (50ml, 100ml, 500ml & 1000ml).
Electronic Scale.
Graduated Cylinders (70ml & 100ml).
Hot plate.
Lab Stand & Clamps.
Magnetic stirrer.
Spatulas.
Test Tubes.
Thermometers, Timer & Tweezers.

Product(s):

Paraffin (pieces).

2.8 The Density (Grades 9 to 12)

This experiment is crafted to explore the principles of physics and chemistry by determining the mass and calculating the density of an unknown gas, using propane as the subject. The process involves a series of steps including the preparation of a syringe, creating a vacuum, weighing, gas introduction, and final calculations to derive the mass and density of the gas. This methodical approach not only applies theoretical knowledge but also hones practical skills in handling and analyzing gases.

2.8.1 Educational Goals

- ***Understanding Gas Properties and Handling:*** Learn the techniques for manipulating gases, focusing on the measurement of volume and mass to explore physical properties.
- ***Application of Theoretical Principles:*** Directly apply principles from physics and chemistry to determine the mass and density of a gas, highlighting the practical relevance of these subjects.
- ***Precision in Measurement:*** Emphasize the importance of precision in scientific measurements, encouraging meticulousness in experimental procedures.
- ***Skills in Gas Identification:*** Through determining the density, gain insights into methods for identifying gases, showcasing how physical properties can be leveraged for this purpose.

This experience aims to provide a comprehensive understanding of how to determine the physical properties of an unknown gas, specifically propane, through practical application. By engaging in this experiment, participants will navigate through the process of preparing the syringe, measuring vacuum, weighing, and calculating density, which illustrates the critical relationship between mass, volume, and density.

This hands-on approach not only solidifies theoretical concepts in a tangible manner but also cultivates a deeper appreciation for the intricacies of scientific exploration. Through mastering the techniques of gas manipulation and analysis, participants enhance their knowledge and skills in the realms of chemistry and physics, equipped with the understanding necessary for advanced scientific inquiry.

2.8.2 Protocol

1. Push the syringe plunger to expel all the air from it.

2. Attach the plastic fitting (unknown gas canister) to the end of the syringe and close it with the clamp as close to the end as possible.

3. Pull on the plunger to create a vacuum in the syringe until reaching a volume of 95 to 100ml.

4. Lock the plunger with the nail.

5. Read the volume measurement.

6. Weigh the entire syringe-piston-fitting-nail-clamp assembly.

7. Remove the nail, clamp, and plastic fitting.

8. Push the syringe plunger to return to zero volume.

9. Attach the plastic fitting (unknown gas canister) to the end of the syringe.

10. Open the valve of the unknown gas canister.

11. Draw a volume of unknown gas equivalent to the one measured in step 4 and close the fitting with the clamp as close to the end of the syringe as possible.

12. Insert the nail into the piston hole.

13. Weigh the entire syringe, piston, fitting, clamp, and nail assembly.

2.8.3 Anticipated Outcomes

- The 100mL syringe weighs 45g.
- The nail weighs 0.5g.
- The clamp weighs 0.45g.
- The connector weighs 0.5g.
- At step 6, the total weight is 45g + 0.5g + 0.45g + 0.5g = 46.45g.
- The unknown gas is propane. Its density is 0.000493 g/mL.

A volume of 100mL of propane, at atmospheric pressure and room temperature, weighs approximately 0.0493g. This weight can thus be added to the total weight of the syringe assembly.

Significance of the experiment:

Precision in measurement: This experiment emphasizes the importance of precision in measurements, as even small weights like that of a nail or connector are considered in the total mass calculation.

Understanding gas properties: By calculating the mass of a known volume of propane, the experiment highlights how gas properties like density are crucial for identifying and understanding gases in various contexts.

Application of concepts: The experiment applies basic principles of physics and chemistry, such as mass, volume, and density, demonstrating their interplay in practical scenarios.

This exercise is significant for students or practitioners in fields like chemistry, physics, and engineering, where such calculations and understanding of material properties are fundamental. It also illustrates the methodical approach needed in scientific experiments, where accuracy and attention to detail are paramount.

2.8.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to gas properties and simple observations.
- **Activities**: Observing gas behavior, simple demonstrations of measurements, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding and application of gas properties and handling techniques.
- **Activities**: Measuring gas volume and mass, creating a vacuum, calculating density, recording observations, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced mastery of gas properties and precise measurements.
- **Activities**: Detailed measurement of gas volume and mass, creating a vacuum, advanced calculations of density, detailed recording and analysis, adhering to advanced safety protocols.

2.8.5 Laboratory essentials

Instrument(s):

Electronic scale.
Nail.
Syringe.
Wood clamp.

Product(s):

Gas tank with propane gas.

2.9 Physical properties and product identification (Grades 6 to 12)

This experiment is structured to identify unknown substances by measuring key physical properties: boiling points for liquids and density for solids. It's split into two parts for a comprehensive approach.

Part A: targets the identification of unknown liquids. It involves precise volume measurements, controlled heating to 105°C, and monitoring boiling behavior to ascertain each liquid's boiling point. This step is critical for identifying the liquids or comparing them to known substances.

Part B: focuses on the identification of unknown solids through density measurements. This includes weighing the solids, using water displacement to measure volume—a technique inspired by Archimedes' principle—and calculating density by dividing mass by volume. This process is pivotal for distinguishing or identifying the solid substances.

2.9.1 Educational Goals:

- ***Mastering Measurement Techniques:*** Enhance skills in accurately measuring volume and mass, foundational for scientific analysis.
- ***Understanding Physical Properties:*** Deepen knowledge of how boiling points and density serve as identifiers for substances.
- ***Applying Theoretical Principles:*** Apply principles of physics and chemistry, like Archimedes' principle, to real-world scenarios.
- ***Developing Analytical Skills:*** Cultivate the ability to analyze and identify substances based on their physical properties, utilizing comparisons to known materials for verification or identification.
- ***Integrating Disciplinary Knowledge:*** Demonstrate the integration of chemistry and physics through practical applications, underscoring the interdisciplinary nature of scientific inquiry.

By engaging in this experiment, participants will not only apply essential laboratory techniques but also learn to distinguish and characterize chemicals through their physical properties.

This hands-on experience with **H2O**, ethanol, **CaCO3**, and **Fe(OH)3** as test substances underscores the practical use of boiling point and density in substance identification, offering a profound understanding of the principles guiding the identification of unknown substances in scientific exploration.

2.9.2 Protocol

Identification of unknown liquids

1. Accurately measure 50 mL of unknown liquid #1 using the 50 mL graduated cylinder.

2. Pour the liquid into a 100 mL beaker labeled A".

3. Rinse the graduated cylinder.

4. Repeat steps 1 to 3 with unknown liquid #2, using beaker B.

5. Place both beakers on 2 heating plates.

6. Place a magnetic stir bar inside each beaker.

7. Insert a thermometer into each beaker in such a way that the tip does not touch the bottom, using a universal stand and clamps.

8. Start the stopwatch.

9. Turn on the magnetic stirrers.

10. Adjust the temperature of the heating plates to 105°C.

11. Check the temperature changes in the results table.

12. Based on the boiling point, what could the unknown liquids be?

Identification of unknown solids

1. Weigh 5 pieces of unknown solid #1 on the scale.

2. Fill the overflow jar with water and let the water drain into the sink.

3. Place a 25 mL graduated cylinder under the spout of the overflow jar.

4. Gently immerse solid #1 into the overflow jar. Be careful! Do not let your fingers touch the water to avoid affecting the results.

5. Collect the overflow water in the 25 mL graduated cylinder.

6. Wait for the water flow to stop completely.

7. Record the weight of the pieces, as well as the volume occupied. This will allow you to calculate the density.

8. Remove solid #1 from the overflow jar.

9. Fill the overflow jar with water and let the water drain into the sink.

10. Place a 25 mL graduated cylinder under the spout of the overflow jar.

11. Weigh a piece of unknown solid #2 on the scale.

12. Gently immerse solid #2 into the overflow jar. Be careful! Do not let your fingers touch the water to avoid affecting the results.

13. Collect the overflow water in the 25 mL graduated cylinder.

14. Record the weight of the pieces, as well as the volume occupied. This will allow you to calculate the density.

15. Thus, you will be able to identify the 2 unknown solids using their density.

2.9.3 Anticipated Outcomes:

- Unknown Liquid #1 is water
- Unknown Liquid #2 is ethanol. Since the boiling point of ethanol is 78°C, it will boil faster than water, which has a boiling point of 100°C.
- Unknown Solid #1 is calcium carbonate (CaCO3), where one piece weighs 2.9 grams and five pieces weigh 14.5 grams. With a density of 2.71 g/mL, these five pieces will occupy a volume of 5.4 mL.
- Unknown Solid #2 is iron (III) hydroxide (Fe(OH)3), with one piece weighing 12.75 grams and five pieces weighing 63.75 grams. Given its density of 4.25 g/mL, the total volume occupied by these pieces will be 15 mL.

Liquid Identification: By heating two unknown liquids to 105°C and observing their boiling points, students deduce that Liquid #1 (water) boils at 100°C and Liquid #2 (ethanol) at 78°C. This experiment not only demonstrates the concept of boiling points but also introduces a method to identify substances based on their physical properties.

Solid Identification: Through displacement method, participants determine the density of two unknown solids. They discover Solid #1 (calcium carbonate, CaCO3) has a density of 2.71 g/mL and occupies a volume of 5.4 mL, and Solid #2 (iron(III) hydroxide, Fe(OH)3) has a density of 4.25 g/mL, occupying a volume of 15 mL. This part of the lab reinforces the concept of density and its role in identifying substances.

<u>Lessons Learned:</u>

Safety and Precision: The importance of safety in the lab is highlighted through the use of protective gear and proper handling of materials. Precision in measurement is crucial for accurate scientific results.

Understanding Physical Properties: Students learn that physical properties like boiling point and density are key to identifying substances. This hands-on experience reinforces theoretical knowledge.

Scientific Method: The protocol exemplifies the scientific method—making observations, forming hypotheses, conducting experiments, and drawing conclusions.

Problem-solving: Students apply critical thinking and problem-solving skills to deduce the identity of unknown substances, an essential skill in scientific inquiry.

2.9.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to boiling points and density, simple measurements.
- **Activities**: Observing boiling points, measuring volume and mass, basic calculations, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding and application of measurement techniques and physical properties.
- **Activities**: Measuring volume and mass, observing boiling points, applying Archimedes' principle, recording observations, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced mastery of measurement techniques and analytical skills.
- **Activities**: Detailed measurement of physical properties, precise control of experimental conditions, advanced calculations, applying theoretical principles, detailed recording and analysis, adhering to advanced safety protocols.

2.9.5 Laboratory essentials

Instrument(s):

Beakers (100ml & 1000ml).
Droppers.
Electronic Scale.
Graduated Cylinders (25ml & 50ml).
Hot plate.
Lab Stand & Clamps.
Magnetic stirrer.
Overflow Vessel.
Spatulas.
Thermometers & Timer.
Tweezers.

Product(s):

Unknown liquids (#1 & #2).
Unknown solids (#1 & #2).

3 BIOLOGY

3.1 Blood and blood groups (Grades 9 to 12)

This experiment is designed to elucidate blood typing through the agglutination reaction, a critical laboratory method for determining blood groups and the Rh factor in blood samples. By observing how antigens on red blood cells interact with specific antibodies (agglutinins), this process identifies blood compatibility with added antibodies, showcasing reactions that confirm the presence of specific blood antigens.

Key Steps and Objectives

Preparation of Samples: Blood drops of group O- are placed in separate cells for reaction tests with anti-A, anti-B, and anti-Rh antibodies, setting the stage for antigen-specific reactions.

Adding Agglutinins: Corresponding agglutinins are introduced to each cell to test for antigens A, B, and Rh on the red blood cells, aiming to identify the antigenic properties of each blood sample.

Observation of Reactions: By mixing and immediately observing the reactions post-agglutinin addition, the antigenic characteristics of the blood samples are identified.

Repetition with Various Blood Samples: Repeating the procedure with diverse blood samples (O+, A+, A-, B+, B-, AB+, AB-) demonstrates how agglutination reactions vary across different blood groups and Rh factors.

3.1.1 Educational Goals

- ***Determine Blood Groups:*** Through the observation of agglutination reactions or their absence, identify blood groups A, B, AB, and O by adding anti-A and anti-B agglutinins.
- ***Identify the Rh Factor:*** Utilize anti-Rh agglutinin to ascertain whether blood samples are Rh positive (agglutination) or Rh negative (no agglutination).
- ***Understand Blood Compatibility Importance:*** Highlight the critical role of knowing blood groups and Rh factors for applications such as transfusions, pregnancy, and other medical scenarios.
- ***Enhance Laboratory Skills:*** Foster proficiency in precise liquid handling, reagent mixing, and the observation of biochemical reactions.

This hands-on experience not only provides a practical understanding of the immunological underpinnings of blood typing but also underscores its significance in the medical field. Through meticulous and careful laboratory techniques, participants gain valuable insights into manipulating and analyzing biological samples, enhancing their knowledge and skills in a crucial aspect of medical science.

3.1.2 Protocol

1. Place 10 drops of O+ blood sample into each of the 3 wells identified as follows:

- The O+ well (anti_A)

- The O+ well (anti_B)

- The O+ well (anti_Rh)

2. Place 2 drops of anti-A agglutinin into the well identified (anti-A).

3. Mix immediately using a clean glass rod.

4. Place 2 drops of anti-B agglutinin into the well identified (anti-B).

5. Mix immediately using a clean glass rod.

6. Place 2 drops of anti-Rh agglutinin into the well identified (anti-Rh).

7. Mix immediately using a clean glass rod.

8. Rinse the glass rods with distilled water.

9. Dry the glass rods using absorbent paper.

10. Repeat the steps for the O-, A+, A-, B+, B-, AB+, and AB- samples.

3.1.3 Anticipated Outcomes

Blood group identification: This experiment is essential for understanding how blood types are determined, showcasing the specificity of antigen-antibody interactions.

Agglutination as an indicator: The presence or absence of agglutination in each well provides critical information about the blood sample's antigens, crucial for transfusions, forensic analysis, and medical diagnostics.

Practical skills: You'll gain hands-on experience with blood typing procedures, enhancing your skills in handling biological samples, and understanding immunological reactions.

Safety and precision: The protocol emphasizes the importance of laboratory safety and precision in handling and analyzing biological samples, fundamental skills in any biological laboratory setting.

This activity is not just a procedure but an insightful journey into the immunological aspects of blood, providing a foundational understanding of blood group systems and their significance in medicine and biology.

3.1.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to blood types and simple observations.
- **Activities**: Observing simulated blood typing reactions, understanding blood compatibility, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding and basic hands-on experience with blood typing.
- **Activities**: Preparing simulated samples, adding agglutinins, observing and recording reactions, understanding blood compatibility, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced understanding and detailed hands-on experience with blood typing.
- **Activities**: Preparing various blood samples, accurately adding agglutinins, detailed observation and analysis of reactions, understanding medical relevance, adhering to advanced safety protocols.

3.1.5 Laboratory essentials

Instrument(s):

Bucket plate.
Droppers.
Glass rod.
Paper towel.
Test tubes.

Product(s):

Distilled water
Samples of blood
Serums (anti-A, anti-B & anti-Rh)

3.2 Observation of animal cells (Grades 6 to 12)

This laboratory session is designed to introduce participants to the principles of microscopy through the examination of oral epithelium cells. The activity involves observing these cells in two conditions: their natural state with the addition of water and a stained state using Lugol's solution to highlight the cell nuclei. This direct comparison aims to enhance the understanding of cellular morphology and the practical application of staining techniques in microscopy.

The main goal is to facilitate the microscopic observation of oral epithelium cells, emphasizing the differences between cells observed in their natural state and those where the nucleus is stained with Lugol's solution.

3.2.1 Educational Goals:

- ***Microscopy Skills:*** Participants will learn how to properly use a microscope, focusing on the critical aspects of slide preparation and adjustment for clear observation.
- ***Cell Morphology Insight:*** This session aims to deepen the understanding of the structure of oral epithelium cells, enabling participants to distinguish cellular components under different conditions.
- ***Staining Technique Application:*** Introduces the concept and application of staining with Lugol's solution, demonstrating its importance in enhancing the visibility of specific cell structures, such as the nucleus.
- ***Observation and Documentation:*** Cultivates the ability to meticulously observe, accurately document, and interpret the microscopic details of cells, which are key skills in scientific research and reporting.
- ***Biological Concepts Application:*** Through practical experience, participants will apply theoretical knowledge of cell structure and function, reinforcing their learning through the direct observation of cells.

This laboratory session not only teaches the basics of microscopy and cell staining but also offers an invaluable hands-on experience.

By observing oral epithelium cells under different conditions, participants will gain a comprehensive understanding of cell morphology, the significance of staining in biological observation, and the application of microscopy in the study of cellular structures.

3.2.2 Protocol

1. Turning on the microscope: Turn on the microscope by pressing the two switches located at the front of the device.

2. Preparing the slides: Place two clean slides on a piece of white paper on your workspace.

3. Applying the samples: Use the dropper to gently drop buccal epithelial cells onto each slide.

4. Preparing water: Fill a small beaker halfway with cold water.

5. Preparing the first slide:

a. Add a drop of water to the first slide using a dropper.

b. Cover the slide with a cover slip.

c. Carefully blot away excess water with absorbent paper.

6. Preparing the second slide:

a. Drop a drop of iodine solution (lugol) onto the second slide.

b. Cover it with a cover slip.

c. Blot away excess iodine solution with absorbent paper.

7. Observing the first slide:

a. Place the slide prepared with water (first slide) on the microscope stage.

b. Start observation at a 40X magnification.

8. Adjusting the microscope:

a. Use the "microscope" button on the tablet for the microscope view.

b. Refine focus with the coarse adjustment knob if necessary.

c. Gradually increase magnification from 40X to 100X, then to 400X, adjusting focus as needed.

9. Observing the second slide:

a. Replace the first slide with the second slide containing cells and iodine solution.

b. Observe at 400X magnification to identify a cell nucleus, which should appear colored orange by the iodine solution.

10. Recording observations: Document or record important observations.

11. Concluding the observation:

a. Decrease magnification by turning the turret back to the smallest objective.

b. Lower the stage using the coarse adjustment knob to move the objective away from the slide.

12. Turning off the microscope: Turn off the device by switching off the two switches at the front.

3.2.3 Anticipated Outcomes:

In this lab, participants engage in a meticulous process to prepare and observe buccal epithelial cells under a microscope. This exercise not only enhances understanding of cell structure but also hones laboratory skills.

- ***Cell visualization***: Participants will successfully prepare slides with buccal epithelial cells and use a microscope to observe these cells at various magnifications. The water-prepared slide will provide a clear view of the cells' general structure, while the iodine-stained slide will highlight specific cell components, like the nucleus, making them more distinguishable.
- ***Staining effectiveness***: The iodine solution will stain the cell components, particularly the nucleus, enabling observers to note the distinct parts of the cell. This contrast is crucial for understanding cell compartmentalization and function.
- ***Microscopy skills***: Through adjusting the microscope's focus and changing magnifications, participants will gain practical experience in using this essential scientific tool, learning to identify and record significant cellular details.

<u>Significance and Lessons Learned:</u>

- ***Cellular biology insights***: Observing buccal epithelial cells provides a concrete understanding of cell theory, illustrating the cell's structural and functional units. This hands-on experience cements theoretical knowledge with practical observation.
- ***Technical proficiency***: Mastery in preparing slides, handling delicate laboratory equipment, and conducting precise observations are key skills developed in this lab. These are fundamental in various scientific investigations, where careful preparation and acute observational abilities are paramount.
- ***Analytical skills***: Interpreting the observed cellular structures fosters analytical thinking, as participants correlate cell morphology with function, enhancing their understanding of biological processes at the microscopic level.
- ***Safety and protocol adherence***: The emphasis on safety measures and protocol adherence instills a sense of responsibility and rigor, essential attributes for any scientific endeavor.

Ultimately, this laboratory exercise is not just about observing cells; it's an integrated learning experience that develops a range of skills and deepens understanding of fundamental biological principles. Participants leave with a greater appreciation for the microscopic world and its relevance to broader biological contexts.

3.2.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to microscopy and simple cell observations.
- **Activities**: Using microscopes, preparing simple slides, observing natural and stained cells, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate skills in microscopy and understanding cell morphology.
- **Activities**: Preparing and staining slides, using microscopes, observing and documenting cell morphology, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced microscopy skills and in-depth analysis of cell structure.
- **Activities**: Mastering microscope use, preparing and staining slides, detailed observation and analysis, meticulous documentation, adhering to advanced safety protocols.

3.2.5 Laboratory essentials

Instrument(s):

Beaker (50 ml).
Droppers.
Microscope.
Microscope blades.
Microscope sliders.
Paper towel.
Tweezers.

Product(s):

Epithelium
Lugol (2%)

3.3 Observation of plant cells (Grades 6 to 12)

This laboratory session is aimed at guiding participants through the process of microscopic observation of vegetable cells, with a focus on Elodea leaves. The workshop is structured around observing these cells under two distinct conditions: in their natural state with the addition of water and in a stained state using Lugol's solution to accentuate the cell nuclei. The comparison is intended to enrich participants' understanding of plant cell morphology and the practical use of staining techniques in the realm of microscopy.

The primary objective is to enable the microscopic examination of Elodea cells, drawing attention to the differences between the cells observed in their natural aqueous environment and those highlighted with Lugol's iodine solution.

3.3.1 Educational Goals

- ***Microscopy Skills:*** Participants will be instructed on the correct usage of microscopes, emphasizing slide preparation and the fine-tuning needed for clear cell observation.
- ***Plant Cell Morphology Insight:*** The session is designed to enhance knowledge of the structural aspects of vegetable cells, particularly Elodea, allowing participants to identify various cellular components in unstained and stained preparations.
- ***Staining Technique Application:*** Introducing the staining technique with Lugol's solution, the workshop demonstrates its crucial role in making specific cellular structures, like the nucleus, more visible for easier identification.
- ***Observation and Documentation:*** Aims to develop participants' skills in detailed observation, precise documentation, and the interpretation of microscopic images, which are essential for conducting and reporting scientific research.
- ***Biological Concepts Application:*** Through this hands-on approach, participants will directly apply their theoretical understanding of plant cell structure and function, reinforcing their learning with actual cell observations.

This laboratory session not only covers the fundamentals of microscopy and the application of cell staining techniques but also provides a valuable practical experience.

Observing Elodea cells under varying conditions, participants will gain an in-depth understanding of plant cell morphology, appreciate the importance of staining in biological observation, and learn about the application of microscopy in exploring the intricate world of cellular structures.

3.3.2 Protocol

1. Turning On the Microscope: Turn on the microscope by flipping the two switches located at the front of the device.

2. Setting Up the Slides: Place two clean slides on a piece of white paper on your workspace.

3. Sample Placement: Gently place a small Elodea leaf on each slide using tweezers.

4. Adding Liquid: Fill a beaker halfway with cold water to prepare the slides.

5. Preparing the First Slide:

a. Add a drop of water to the first slide.

b. Cover the slide with a cover slip.

c. Blot away excess water with absorbent paper.

6. Preparing the Second Slide:

a. Drop a drop of iodine solution (lugol) onto the second slide to stain the cell nuclei.

b. Cover in the same way and blot away excess iodine solution.

7. Microscopic Observation:

a. Start by observing the first slide under an initial magnification of 40X, adjust the focus if necessary.

b. Gradually increase magnification to 100X, then to 400X, adjusting the focus for a clear image.

c. Then observe the second slide prepared with iodine solution under a magnification of 400X. Look for a cell nucleus, which should appear colored orange.

8. Documentation: Record or note important observations, especially the differences between cells observed with and without iodine.

9. Concluding the Experiment:

a. Turn off the microscope by switching the switches back to the off position.

b. Clean and organize your workspace.

3.3.3 Anticipated Outcomes

In this laboratory exercise focused on observing waterweed (Elodea) cells under a microscope, participants are expected to gain valuable insights into plant cell structures and enhance their microscopy skills. The outcomes of this exercise are pivotal for understanding cellular components and processes in plants, providing a hands-on experience that reinforces theoretical knowledge with practical observation.

- ***Cell structure visualization:*** Participants will observe the basic structure of plant cells, including the cell wall, which is distinctive in providing structural support and shape to the cells. Unlike animal cells, plant cells have this rigid outer layer.
- ***Chloroplast observation:*** Elodea cells contain numerous chloroplasts, which are vital for the process of photosynthesis. Observing these chloroplasts under the microscope,

participants can see the green pigments that are crucial for the plant's ability to convert light energy into chemical energy.

- ***Nucleus identification:*** With the aid of iodine staining on the second slide, the nucleus of the plant cells should become more visible. This staining helps highlight the nucleus, which is the control center of the cell, housing genetic material.
- ***Cellular organization:*** Participants will get a sense of how cells are organized within a plant, how they align next to each other, and how they interact to form tissues.

The significance of this exercise extends beyond mere observation. It provides a concrete understanding of plant biology, emphasizing the complexity and efficiency of cellular mechanisms. The visualization of live cells enhances comprehension of plant cell functions, particularly photosynthesis, and the role of each cellular component.

Lessons Learned:

- ***Technical skills:*** Participants improve their microscopy skills, learning to prepare slides and adjust the microscope for clear observation, which are fundamental techniques in biological research.
- ***Scientific methodology***: The exercise reinforces the importance of careful observation and documentation, essential components of the scientific method.
- ***Comparative biology***: By directly observing plant cells, participants can compare and contrast them with animal cells, deepening their understanding of cell biology.
- ***Appreciation of nature***: Seeing the intricate details of plant cells can foster a greater appreciation for the complexity and beauty of life at the microscopic level.

In conclusion, this laboratory exercise is not just about observing cells; it's about connecting with the building blocks of life in plants, understanding their functions, and appreciating the interconnectedness of all biological systems. Through such practical experiences, theoretical knowledge is solidified, and the marvels of the natural world are unveiled, inspiring curiosity and respect for life at the cellular level.

3.3.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to microscopy and simple plant cell observations.
- **Activities**: Using microscopes, preparing simple slides with Elodea leaves, observing natural and stained cells, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate skills in microscopy and understanding plant cell morphology.
- **Activities**: Preparing and staining slides with Elodea leaves, using microscopes, observing and documenting cell morphology, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced microscopy skills and in-depth analysis of plant cell structure.
- **Activities**: Mastering microscope use, preparing and staining slides with Elodea leaves, detailed observation and analysis of cellular components, meticulous documentation, adhering to advanced safety protocols.

3.3.5 Laboratory essentials

Instrument(s):

Beaker (50 ml).
Droppers.
Microscope.
Microscope blades.
Microscope sliders.
Paper towel.
Tweezers.

Product(s):

Lugol (2%)
Waterweed

4 SOLUTION PREPARATION

4.1 Solution preparation by dissolution (Grades 6 to 12)

This laboratory session is designed to introduce participants to fundamental chemistry techniques through the preparation of a sweet solution with a specific concentration of 25 g/l in a final volume of 100 ml. The focus is on teaching the essential skills of calculating the necessary quantities to achieve a desired concentration, accurately weighing solids using laboratory scales, and mastering the methods for dissolving and diluting solutes in solvents.

The main goal is to guide participants through the process of preparing a 25 g/l sugar solution in a 100 ml volume, emphasizing the calculation of solute mass, precise weighing, solution preparation, and dilution techniques. This exercise aims to underline the importance of accuracy and methodology in chemical solution preparation.

4.1.1 Educational Goals

- ***Chemical Calculation Proficiency:*** Participants will learn how to calculate the mass of solute needed to prepare a solution of a specific concentration, enhancing their understanding of molarity and solution preparation.
- ***Precision Weighing Skills:*** The session aims to develop skills in using a balance for precise weighing of solutes, highlighting the importance of accuracy in the mass measurement of substances.
- ***Solution Preparation Techniques:*** Introduces participants to the techniques for dissolving solutes effectively in solvents to achieve a uniform solution, focusing on the initial dissolution in a lesser volume and subsequent dilution to the final desired volume.
- ***Dilution and Mixing Methods:*** Emphasizes the importance of thorough mixing and accurate volume adjustment to ensure a homogeneous solution, teaching participants the practical aspects of solution dilution.
- ***Application of Solution Chemistry Principles:*** Through hands-on practice, participants will apply fundamental principles of solution chemistry, gaining insights into the preparation and characterization of chemical solutions.

This laboratory session not only imparts the basics of solution preparation and concentration calculation but also offers invaluable hands-on experience. By preparing a sugar solution with a specific concentration, participants will gain a comprehensive understanding of the meticulous nature of chemical solution preparation, from the initial calculations to the final dilution and mixing.

This practical application of chemistry principles is essential for studies and research in the field, fostering a deeper appreciation for the precision and methodology required in scientific experimentation.

4.1.2 Protocol

Two 100 mL beakers are on your right, identified as A and B.

1. Preparation of solution A

a) Calculation of the necessary mass of crystals: Calculate the mass of juice crystals needed to achieve a concentration of 25 g/L in 100 mL of solution. This mass is designated by m_crystals.

b) Preparation of the Balance: Ensure the balance scale is zeroed before beginning.

c) Weighing the Boat: Weigh the empty boat on the balance scale and note its mass (m_boat).

d) Adjustment of the Sliders: Set the balance sliders to correspond to the sum of the mass of the boat and the required mass of sugar crystals (m_boat + m_crystals).

e) Adding the Crystals: Use a spatula to add sugar crystals into the boat until equilibrium is achieved (the needle aligned with zero).

2. Preparation of the solution:

a) Pour about 50 mL of water into a 100 mL volumetric flask.

b) Transfer the sugar crystals from the boat to the volumetric flask using a funnel.

c) Dissolving the Sugar: Place the stopper on the volumetric flask and shake in a circular motion until the sugar crystals are completely dissolved.

d) Adjustment of Volume: Top up with water to precisely reach the final volume of 100 mL. Use a dropper for accurate adjustments.

3. Finalization of the solution:

a) Place the stopper on the volumetric flask and gently mix the solution.

b) Pour Solution A into the beaker labeled A.

4. Comparison and cleaning:

a) Visually compare Solution A with prepared control solutions.

b) Rinse the volumetric flask after use to prepare it for future experiments.

c) Repeat the experiment, with beaker B, to prepare a 5% w/v solution with a final volume of 100 mL.

4.1.3 Anticipated Outcomes

The first solution (Solution A) should have a concentration of 25 g/L, achieved by dissolving 2.5 g of sugar crystals in 100 mL of water.

The second solution (Solution B) should have a 5% m/v concentration, which means 5 g of sugar crystals are dissolved in enough water to make 100 mL of the final solution.

Participants should be able to visually compare Solution A with control solutions to understand concentration differences.

Observing the dissolving process, noting how sugar crystals integrate into the water to form a homogeneous solution.

Lessons Learned:

Precision in measurement: Understanding the importance of accurately measuring mass and volume to achieve desired concentrations.

Proper use of equipment: Gaining familiarity with laboratory equipment like balances, volumetric flasks, and pipettes, and learning their correct usage.

Solution preparation: Learning the step-by-step process of dissolving solids in liquids to create solutions with specific concentrations.

Chemistry principles:

Molarity and percent solutions: Understanding these two ways of expressing concentration - molarity (g/L in this case) and percent mass/volume (m/v) - and how to calculate the amount of solute needed for a desired concentration.

Dissolution: Observing the process by which a solid (sugar crystals) dissolves in a solvent (water) to form a solution, which is a physical change.

Mixtures: Recognizing that solutions are homogeneous mixtures where the solute is evenly distributed within the solvent.

This experience is a hands-on way to learn about solution preparation, a fundamental skill in chemistry, while also emphasizing the importance of methodical and safe laboratory practices.

4.1.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to solution preparation and simple measurements.
- **Activities**: Observing the process of preparing a sugar solution, basic weighing and mixing, simple calculations, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of solution preparation techniques and measurements.
- **Activities**: Calculating solute mass, weighing sugar, preparing and mixing solutions, observing the importance of precision and thorough mixing, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced proficiency in solution preparation and precise analytical skills.
- **Activities**: Calculating the exact mass of solute needed, using precision balances, preparing and diluting solutions, ensuring accurate volume adjustments, detailed recording and analysis of the process, adhering to advanced safety protocols.

4.1.5 Laboratory essentials

Instrument(s):

Beaker (50ml, 100ml, 250ml & 1000ml).
Dropper.
Erlenmeyer (25 ml).
Funnel.
Gaugeated flask (100ml).
Glass Rod.
Graduated Cylinders (10ml & 50ml).
Spatulas.
Test tubes.
Triple beam scale.

Product(s):

Distilled water
Juice crystals (powder)

4.2 Change in the solubility of a solid (Grades 6 to 12)

This laboratory session delves into the concept of solubility, examining how various solutes—such as table salt, sugar, chalk powder, sodium bicarbonate, and cornstarch—dissolve in water and, potentially, in ethanol or oil at varying temperatures. The aim is to uncover the effect of temperature on the solubility of different substances in each solvent, thereby understanding the dynamic relationship between temperature, solute, and solvent in the dissolution process.

4.2.1 Educational Goals

- ***Understanding Solubility:*** Participants will explore the fundamental concept of solubility, learning how a solvent's capacity to dissolve a solute is influenced by temperature and the chemical nature of both the solute and the solvent.
- ***Temperature's Impact on Solubility:*** The session aims to demonstrate that the solubility of most solids in water increases with temperature, facilitating a greater dissolution of the solute.
- ***Chemical Interaction Insights:*** Through the comparison of different solutes' solubility in various solvents, participants will gain insights into the significance of chemical interactions in dissolution processes.

This session not only illuminates the basics of solubility but also offers an invaluable hands-on experience. By investigating the solubility of various substances under different conditions, participants will achieve a comprehensive understanding of how temperature and chemical properties influence solubility.

This exploration underscores the importance of chemical interactions in solubility, offering a practical application of chemistry principles essential for studies and research in the field.

4.2.2 Protocol

Water measurement

a) Use a graduated cylinder to measure 100 mL of cold water and pour it into a 100 mL beaker.

Preparation for heating

a) Place a magnetic stir bar in the beaker. Position the beaker on the heating plate without turning it on.

Thermometer installation

a) Secure a thermometer in the beaker without it touching the bottom, using a universal clamp and stand.

Weighing salt

a) Using a spatula, add 10 g of table salt to the weighing boat and verify the weight.

b) Pour the salt into the cold water in the beaker.

Salt dissolution

a) Turn on the magnetic stirrer to mix well.

b) Add successive 10 g portions of salt until reaching a total mass of 30 g, waiting each time for complete dissolution.

c) Continue adding 2 g of salt at a time until the salt no longer dissolves and starts to accumulate at the bottom of the beaker.

Heating

a) Turn on the heating plate and set it to 75°C to heat the solution.

b) Observe if the accumulated salt dissolves as the temperature increases.

Replicating the experiment

a) Repeat the same steps with sugar, chalk powder, baking soda, and cornstarch to compare the solubility of these substances. Also, explore using ethanol as alternative solvent.

b) Properly empty the contents of the glassware into the recovery bin and clean with distilled water between experiments.

4.2.3 Anticipated Outcomes

Solubility of table salt as a function of temperature

The results indicate an increase in the solubility of table salt with the rise in temperature. Initially, all the added salt dissolved in water at room temperature (solubility is 36g/100mL), but when more salt was added beyond a certain point, it started to settle at the bottom, indicating the solubility limit had been reached. Upon heating, the solubility increased, allowing more salt to dissolve.

Solubility of different substances in water

Table salt: dissolves in water (36g/100mL at 25C).

Sugar: dissolves in water (91g/100mL at 25C).

Chalk powder: insoluble and settles at the bottom over time.

Sodium bicarbonate: dissolves in water (9.6g/100mL at 25C).

Corn starch: insoluble and settles at the bottom over time.

Solubility in different solvents

In alcohol and oil, all the above substances are insoluble.

Observation of solubility factors

Students will observe how the nature of the solute, the solvent, and temperature affect solubility. For example, they will see that salt dissolves in water but not in oil or alcohol.

Solubility with temperature changes

They will experimentally determine how the solubility of table salt changes with temperature, noting that solubility increases as the temperature rises.

Understanding solubility

Students learn that not all solutes dissolve in all solvents and that the solubility of a substance depends on the chemical nature of both the solute and the solvent.

Effect of temperature

The experiment demonstrates that temperature can significantly influence the solubility of a substance, with higher temperatures generally increasing the solubility of solids in liquids.

Solubility concepts

The experiment illustrates the concept of solubility, showing that it is a property of a substance that can vary depending on the solvent and conditions like temperature.

Nature of Solutes and Solvents

Students observe firsthand that the chemical nature of solutes and solvents determines solubility, highlighting the concept of "like dissolves like" in chemistry.

Temperature's effect on solubility: The experiment provides a practical understanding of how temperature influences the solubility of substances, aligning with the principle that solubility for most solids increases with temperature.

4.2.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to solubility and simple observations.
- **Activities**: Observing how different solutes dissolve in water, simple comparisons of solubility at different temperatures, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of solubility and the effect of temperature.
- **Activities**: Measuring solubility of various solutes in water and other solvents, observing the impact of temperature on solubility, recording observations, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced understanding of solubility, temperature effects, and chemical interactions.
- **Activities**: Conducting detailed experiments to measure solubility of different solutes in water, ethanol, and oil at various temperatures, analyzing the chemical interactions affecting solubility, meticulous documentation and analysis of results, adhering to advanced safety protocols.

4.2.5 Laboratory essentials

Instrument(s):

Beakers (50ml, 100ml, 500ml & 1000ml).
Electronic Scale.
Graduated Cylinders (70ml & 100ml).
Hot plate.
Lab Stand & Clamps.
Magnetic stirrer.
Spatulas.
Test Tubes.
Thermometers.
Timer.
Tweezers.

Product(s):

Baking soda (powder)
Calcium carbonate (powder)
Ethanol
Glucose (powder)
Olive oil
Sodium chloride (powder).
Starch (powder).

4.3 The law of mass conservation (Grades 9 to 12)

This laboratory session is centered around the chemical reaction between calcium chloride and ammonium oxalate, focusing on the precise preparation of the reactive solutions and the observation of mass changes resulting from their interaction. The experiment is designed to provide a clear demonstration of the reaction mechanism and the formation of a precipitate, highlighting the principles of stoichiometry and the conservation of mass in chemical reactions.

4.3.1 Educational Goals

- ***Preparation and Reaction of Chemical Solutions:*** Participants will learn to accurately prepare solutions of calcium chloride and ammonium oxalate and mix them to initiate a chemical reaction, emphasizing the procedural aspects of chemical experimentation.
- ***Observation of Mass Changes:*** The experiment aims to illustrate the concept of mass conservation in chemical reactions by measuring the mass changes before and after the reaction, providing tangible evidence of the reaction's outcome.
- ***Understanding Precipitation Reactions:*** Through the formation of a precipitate from the reaction, participants will explore the principles behind precipitation reactions, including solubility rules and the role of ionic compounds in aqueous solutions.
- ***Analytical Skills Development:*** This session is designed to enhance participants' analytical skills in observing, documenting, and interpreting the results of chemical reactions, fostering a deeper understanding of chemical processes and their quantitative aspects.

By engaging in this laboratory session, participants will gain hands-on experience with the chemical reaction between calcium chloride and ammonium oxalate, from the preparation of solutions through to the observation of the reaction's effects.

This practical exploration will not only demonstrate the principles of precipitation and mass conservation but also provide valuable insights into the meticulous nature of conducting chemical experiments. Through this process, participants will enhance their understanding of key chemistry concepts, reinforcing their knowledge and skills in the discipline.

4.3.2 Protocol

1. Initial weighing of the beaker: Weigh an empty 50 mL beaker and record its mass.

2. Initial weighing of the graduated cylinder: Weigh an empty 10 mL graduated cylinder and record its mass.

3. Measurement of calcium chloride: Using the graduated cylinder, accurately measure 5 mL of calcium chloride solution.

4. Transfer of calcium chloride: Pour the measured calcium chloride solution into the 50 mL beaker.

5. Rinsing of the graduated cylinder: Use a wash bottle to rinse the graduated cylinder with distilled water.

6. Measurement of ammonium oxalate: Accurately measure 5 mL of ammonium oxalate solution with the same graduated cylinder.

7. Weighing of the calcium chloride solution: Weigh the beaker now containing the calcium chloride solution and note the mass.

8. Weighing of the ammonium oxalate solution: Weigh the graduated cylinder containing the ammonium oxalate solution and note the mass.

9. Using the data collected in the previous steps, calculate the mass of the 2 liquids.

10. Combination of solutions: Gently pour the ammonium oxalate solution into the beaker containing the calcium chloride solution.

11. Mixing: Gently mix the solutions for 5 seconds with a glass rod. Note any changes in appearance.

12. Final weighing: Weigh the beaker containing the mixture of the two reactive solutions.

13. Using the data collected in steps 10 to 12, calculate the combined mass of the 2 mixed liquids.

14. Compare the mass of the liquids before and after mixing and note your observations.

4.3.3 Anticipated Outcomes

- The 50mL beaker weighs 100g, and the 10mL graduated cylinder weighs 22.5g.
- 5mL CaCl2 0.2M = 0.111 g + 5g H2O = 5.11g
- 5mL of CaCl2 in the 50mL beaker weighs 105.11g
- 5mL (NH4)2C2O4 = 0.124g + 5g H2O = 5.12g
- 5mL of ammonium oxalate in the 10mL graduated cylinder weighs 27.12g
- 5mL of calcium chloride and 5mL of ammonium oxalate, in the 50mL beaker, weighs 110.23g
- Subtracting the weight of the 50mL beaker, we observe that the weight of mixed solutions is still the same, even if there's a precipitate on the bottom.

The reaction between calcium chloride ($CaCl_2$) and ammonium oxalate in an aqueous solution result in the formation of calcium oxalate and ammonium chloride. In this reaction, calcium chloride reacts with ammonium oxalate to produce calcium oxalate, which precipitates out of the solution as a solid, and ammonium chloride, which remains in the aqueous phase. Calcium oxalate is poorly soluble in water, which is why it precipitates out of the solution. This type of reaction is an example of a double displacement reaction, where the cations and anions of the reactants switch places to form new products.

- ***Conservation of mass***: Despite the chemical reaction and the formation of a precipitate (calcium oxalate), the total mass of the system (solutions, beaker, and cylinder) remains constant before and after the reaction, illustrating the law of conservation of mass.
- ***Formation of precipitate***: The visible formation of calcium oxalate as a solid precipitate demonstrates a chemical change, while the total mass remains constant.

Lessons learned:

- ***Precision in measurement***: The experiment emphasizes the importance of precise measurements in scientific experiments, from weighing equipment and substances to measuring liquid volumes.
- ***Observing chemical changes***: Students learn to observe and record physical changes (like the formation of a precipitate) that indicate a chemical reaction has occurred.
- ***Interpreting results***: Understanding the concept of conservation of mass in the context of a chemical reaction, even when the system undergoes visible physical changes.

Chemistry principles:

- ***Law of conservation of mass:*** This experiment demonstrates that in a closed system, the mass remains constant regardless of the processes occurring within. The total mass before the chemical reaction is equal to the total mass after the reaction.
- ***Chemical reactions:*** The formation of calcium oxalate and ammonium chloride from calcium chloride and ammonium oxalate is an example of a double displacement reaction, a common type of chemical reaction where ions exchange partners.
- ***Solubility and precipitation***: The experiment shows how solubility rules apply in chemical reactions, with calcium oxalate being insoluble in water and forming a precipitate, while ammonium chloride remains dissolved.

By comparing the mass of the reactants and products, students can see firsthand that the mass remains constant, thus reinforcing the principle of mass conservation in a tangible and practical way.

4.3.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to chemical reactions and mass conservation.
- **Activities**: Observing the mixing of solutions, simple demonstration of mass conservation using scales, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of chemical reactions, stoichiometry, and mass conservation.
- **Activities**: Preparing solutions of calcium chloride and ammonium oxalate, measuring mass before and after the reaction, observing and recording the formation of a precipitate, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced understanding of stoichiometry, precipitation reactions, and the law of mass conservation.
- **Activities**: Accurately preparing and mixing solutions, detailed measurement of mass changes before and after the reaction, analyzing the formation and composition of the precipitate, meticulous documentation and interpretation of results, adhering to advanced safety protocols.

4.3.5 Laboratory essentials

Instrument(s):

Beaker (50ml, 100ml, 250ml & 1000ml).
Dropper.
Erlenmeyer (25 ml).
Funnel.
Gaugeated flask (100ml).
Glass Rod.
Graduated Cylinders (10ml & 50ml).
Spatulas.
Test tubes.
Triple beam scale.

Product(s):

Ammonium oxalate (NH4)2C2O4.
Calcium chloride
Distilled water

4.4 Preparing a solution (Grades 9 to 12)

This laboratory session is divided into two significant parts, focusing on the preparation of a concentrated solution of potassium permanganate and its subsequent dilution to achieve a desired concentration. The aim is to impart the skills needed to prepare solutions of specific concentrations through dissolution and then adjust those concentrations via dilution, showcasing fundamental techniques in solution chemistry.

- ***Preparation of a Concentrated Solution:***
  To prepare a potassium permanganate solution with a concentration of 80 g/l through the process of dissolution.
- ***Dilution of the Concentrated Solution:***
  To prepare 250 ml of a diluted potassium permanganate solution with a target concentration of 17.5 g/l.

4.4.1 Educational Goals

- ***Solution Preparation Techniques:*** Participants will learn the step-by-step process of dissolving potassium permanganate to create a solution with a specific concentration, enhancing their understanding of solute-solvent interactions.
- ***Concentration Adjustment via Dilution:*** The session will demonstrate how to adjust the concentration of a solution by dilution, highlighting the mathematical and practical aspects of dilution techniques.
- ***Precision in Measurement:*** Emphasizes the importance of precise measurement and manipulation of measuring instruments in the preparation of chemical solutions, fostering accuracy and attention to detail.
- ***Understanding of Dissolution and Dilution:*** Participants will gain insights into the critical roles of dissolution and dilution in achieving desired solution concentrations, understanding the underlying principles of these processes.

Through this laboratory experience, participants will acquire foundational chemistry skills in the preparation and adjustment of solution concentrations. By engaging in the precise preparation of a potassium permanganate solution and its careful dilution, participants will learn to accurately manipulate measuring instruments and appreciate the significance of dissolution and dilution in creating solutions of specific concentrations.

This session offers practical application of chemistry principles essential for studies and research in the field, reinforcing the meticulous nature required in scientific experimentation.

4.4.2 Protocol

1. Dissolution

a) Weighing the solute: Use an electronic scale to weigh approximately 8 g of potassium permanganate.

b) Transfer to a volumetric flask: Pour the weighed potassium permanganate into a 100 mL volumetric flask.

c) Adding distilled water: Measure 50 mL of distilled water with a graduated cylinder and pour this water into the flask containing the potassium permanganate.

d) Place a stopper on the flask.

e) Shake the solution to dissolve the solute, then remove the stopper.

f) Volume adjustment: Fill up the volume in the flask to the calibration mark (100 mL) with distilled water.

g) Final mixing: Replace the stopper and shake the flask well by inversion to homogenize the solution.

h) Concentration verification: Compare the color of your solution to that of reference samples to confirm the concentration.

2. Dilution

i) Measure the stock solution: Measure 54.7 mL of the stock potassium permanganate solution (prepared earlier) using a 70 mL graduated cylinder.

j) Transfer to a new volumetric flask: Pour this measured amount into an empty 250 mL volumetric flask.

k) Fill up the flask to 250 mL with distilled water.

l) Place a stopper on the flask and mix well by inversion to homogenize the solution.

m) Concentration verification: Compare the color of the diluted solution to that of reference samples to check the final concentration.

4.4.3 Anticipated Outcomes

- The first steps create a solution of potassium permanganates concentrated at 80g/L (8g/100mL).
- Using 54.7mL of a homogenous solution represents 4.376g of potassium permanganates, in 250mL of liquid.
- The new concentration is therefore 17.51g/L (4.376g/250mL).
- The control solutions of $KMnO_4$ have the following concentrations: #1=17.5g/L (0.11M); #2 = 35g/L (0.22M); #3 = 62.5g/L (0.39M); #4 = 70g/L (0.44M); #5 = 80g/L (0.5M); #6 = 86g/L (0.54M).
- Solution preparation: By dissolving 8 g of potassium permanganate in 100 mL of water, a solution with a concentration of 80 g/L is obtained. This should visually match the color of control solution #5.
- Dilution: The dilution process reduces the concentration from 80 g/L to approximately 17.5 g/L when 54.7 mL of the original solution is diluted to 250 mL. This diluted solution should visually match the color of control solution #1.

<u>Lessons Learned:</u>

- Accuracy and precision: The importance of accurate measurements when weighing the solute and measuring volumes during solution preparation and dilution to achieve the desired concentration.
- Understanding dilution: The dilution process demonstrates how the concentration of a solution changes when the volume of the solvent is increased while the amount of solute remains constant.
- Solution concentration: Learning to calculate and understand different concentrations of solutions and their importance in various chemical applications.
- Observation skills: Developing the ability to compare the color intensity of solutions to determine their concentration, an essential skill in qualitative analysis.

<u>Chemistry Principles:</u>

- Molarity and concentration: The experiment illustrates how to calculate molarity and concentration, fundamental concepts in solution chemistry. Molarity is the number of moles of solute per liter of solution, and concentration is generally the amount of solute dissolved in each volume of solvent.
- Dissolution: This process demonstrates how solutes dissolve in solvents to form solutions, depending on the nature of the solute and solvent, temperature, and other factors.
- Law of conservation of mass: Even though the solution undergoes dilution, the total amount of solute (potassium permanganate) remains constant, illustrating the law of conservation of mass.
- Colorimetric analysis: Using color intensity to determine concentration is an application of colorimetry, a technique often used in chemistry to quantify the concentration of colored compounds in solution.

Through this protocol, students gain hands-on experience with the practical applications of theoretical concepts in solution chemistry, enhancing their understanding and skills in the laboratory.

4.4.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to solution preparation and simple measurements.
- **Activities**: Observing the process of dissolving potassium permanganate, simple demonstrations of dilution, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of solution preparation and concentration adjustment.
- **Activities**: Preparing a concentrated potassium permanganate solution, performing simple dilution calculations, measuring and adjusting solution concentrations, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced proficiency in solution preparation and precise analytical skills.
- **Activities**: Accurately preparing an 80 g/l potassium permanganate solution, performing precise dilution to achieve a 17.5 g/l concentration in 250 ml, using advanced measurement techniques, detailed recording and analysis of the process, adhering to advanced safety protocols.

4.4.5 Laboratory essentials

Instrument(s):

Electronic Scale.
Gaugeated flask (100ml & 250 ml).
Graduated cylinder (50ml & 70ml).
Spatula.

Product(s):

Distilled water.
Potassium permanganate (powder).

5 ACID BASE NEUTRALISATION

5.1 pH (Grades 6 to 12)

This laboratory session is dedicated to teaching and practicing the identification of acid-base properties and the measurement of pH in various substances, encompassing both liquids and solids. The main objective is to acquaint students with the necessary laboratory techniques for determining pH levels and to enhance their understanding of the acid-base behavior of substances through a variety of tools and methodologies.

5.1.1 Educational Goals

- ***Understanding pH Concepts:*** Participants will delve into the concept of pH and its role in reflecting the acid-base character of a substance, aiming to deepen their understanding of chemical properties.
- ***Utilization of pH Indicators:*** Students will be introduced to using different pH indicators, such as litmus papers (red and blue), pH indicator paper, and universal indicators, for qualitatively determining the acid-base nature of solutions.
- ***Precision with pH Meters:*** The session will teach students the accurate use of digital pH meters for precise pH measurements, highlighting the importance of exactitude in chemical analysis.
- ***Solution Preparation Skills:*** Participants will develop skills in manipulating and preparing solutions for pH testing, enhancing their practical chemistry capabilities.
- ***Observation and Measurement Techniques:*** The laboratory will foster students' practical understanding of how to observe and measure chemical properties in a controlled setting.

This laboratory session provides a comprehensive exploration of pH measurement techniques, essential for grasping the chemical properties of substances. By combining theoretical insights with hands-on activities, students will not only familiarize themselves with various methods of determining pH but also refine their laboratory skills.

This experience highlights the significance of precise pH measurement in understanding the acid-base behavior of substances, offering valuable insights into the practical application of chemistry principles.

5.1.2 Protocol

Part 1: Identifying the acidic or basic nature of liquid substances

a) Measuring the solution: Use a graduated cylinder to measure 20 mL of the test solution (solution #1).

b) Transferring to a beaker: Pour the measured 20 mL into a 50mL beaker.

c) Test with Litmus paper: Immerse separately a red litmus paper and a blue litmus paper in the solution.

d) Test with pH indicator paper: Also dip a pH indicator paper.

e) Analyzing the results: Compare the obtained colors with the pH chart to determine the acidic or basic character.

f) Cleaning and repeating: Rinse the graduated cylinder and repeat the steps for solutions #2 and #3.

Part 2: Using universal indicator for pH

a) Sampling the solution: With a dropper, take 1 mL of the solution (solution #1).

b) Placing in the well plate: Place the solution in a well of a spot plate.

c) Adding indicator: Add a drop of universal pH indicator.

d) Mixing: Gently stir with a glass rod.

e) Interpretation: Compare the resulting color with the pH chart.

f) Repetition: Repeat the steps for solutions #2 and #3.

Part 3: Accurate measurement of pH with a pH meter

a) Immersing the electrode: Insert the pH meter electrode into the solution (solution #1).

b) Reading pH: Record the value displayed on the digital dial.

c) Cleaning the electrode: Rinse and dry the electrode before moving on to solutions #2 and #3.

Part 4: Determining the pH of a solid substance

a) Weighing the substance: Weigh approximately 1.8 g of ammonium sulfate.

b) Preparing the solution: Dissolve the powder in 100 mL of water in a 250 mL beaker.

c) Stirring: Mix with a glass rod.

d) Tests with Litmus and pH indicator papers: Perform pH tests as described in Part 1.

e) Measuring with a pH Meter: As in Part 3, measure the pH with the pH meter for increased accuracy.

5.1.3 Anticipated Outcomes

- Red litmus paper turns blue if the solution is alkaline.
- Blue litmus paper turns red if the solution is acidic.
- The tested solution 1 is 5% v/v acetic acid. The pH is about 2.4.
- The tested solution 2 is 0.1M NaOH. The pH is about 13.
- The tested solution 3 is distilled water. The pH is about 7.
- The solubility of ammonium sulfate is 700g/L, so it will dissolve completely.
- The pH of the ammonium sulfate solution is about 4.7.

5.1.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to pH concepts and simple measurements.
- **Activities**: Observing pH changes using litmus paper, simple demonstrations of acidic and basic solutions, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of pH and acid-base properties.
- **Activities**: Using pH indicator paper and universal indicators to test various substances, measuring pH with digital pH meters, preparing solutions for pH testing, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced understanding of pH concepts, precise measurement techniques, and chemical analysis.
- **Activities**: Using a variety of pH indicators, precise measurement of pH with digital meters, preparing and manipulating solutions for testing, detailed observation and recording of results, adhering to advanced safety protocols.

5.1.5 Laboratory essentials

Instrument(s):

Beakers (50ml, 250ml & 1000ml).
Bucket plate.
Droppers.
Electronic Scale.
Erlenmeyer (250ml).
Glass Rod.
Graduated Cylinders (25ml & 100ml).
Hot plate.
Magnetic stirrer.
Paper towel.
PH meter.
Pipette.
Spatulas.
Test Tubes.
Thermometers.
Timer.

Product(s):

Ammonium sulfate (powder)
Distilled water
pH indicator (liquid)
Unknown liquids (#1, #2 & #3)

5.2 Acid-base titration 1 (Grades 9 to 12)

This laboratory session introduces students to the colorimetry technique for determining the pH of a lake water sample, utilizing known pH standards and a pH indicator. The objectives are designed to give students practical experience in environmental chemistry, focusing on assessing the acidity or basicity of aquatic solutions.

5.2.1 Educational Goals

- ***Colorimetry Scale Preparation:*** Teach students to create a colorimetry scale for pH using a chemical indicator, enabling visual comparison of pH levels in various solutions.
- ***Developing Practical Skills:*** Enhance students' ability to handle standards for constructing a visual pH reference, emphasizing the manipulation and preparation of solutions.
- ***Lake Water pH Determination:*** Apply the colorimetry scale to determine the lake water sample's pH by visually comparing the color change induced by the pH indicator.
- ***Results Validation:*** Use more precise equipment, such as a pH meter, to validate the colorimetry findings and ensure the accuracy of visual assessments.

This session offers an in-depth exploration of colorimetry as a method for estimating aquatic solutions' pH, crucial in environmental and analytical chemistry. It highlights the importance of corroborating visual methods with precise measurement tools, providing reliable and accurate results.

Through this laboratory, students gain essential competencies in environmental chemistry, underlining the practical application of chemistry principles in real-world scenarios.

5.2.2 Protocol

Prepare a colorimetry scale using the pH indicator at your disposal.

a) Locate the 50mL beaker filled with lake water, collected earlier this morning.

b) Take 25mL of pH3 solution and place it in test tube 1.

c) Repeat step b) with the pH 4,5,6 and 7 solutions and test tubes 2,3,4 and 5.

d) Add 5 drops of indicator to each of the test tubes using the dropper.

e) Mix the contents of the test tubes with a glass rod, or by putting a stopper and gently mixing from right to left.

f) Collect 25 mL of the lake water sample, place it in test tube #6, and add 5 drops of the same indicator used for the colorimetric scale.

g) Mix the contents of the test tube with a glass rod, or by putting a cap on and gently shaking it from right to left.

2. Compare the color of the colorimetric scale thus created with the color chart on the counter.

a) Determine the pH of the lake water using this scale. If the pH appears to be above 7, empty and clean the contents of test tubes 1 and 2, and continue the scale with pH 8 and 9, using these test tubes.

b) Compare again the pH of the lake water using this new scale (pH 5 to 9).

3. Validate the pH of each solution with the pH meter.

Insert the electrode of the pH meter into the lake water solutions.

Note the value displayed on the digital dial of the pH meter.

5.2.3 Anticipated Outcomes

The lake water should have a pH between 3 an 9, different each time the experience is restarted.

5.2.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to pH and simple observations.
- **Activities**: Observing pH changes using color indicators, simple demonstrations of acidic and basic solutions, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of pH and colorimetry techniques.
- **Activities**: Creating a colorimetry scale using pH standards and indicators, comparing the pH of lake water samples visually, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced understanding of pH determination and colorimetry.
- **Activities**: Preparing a detailed colorimetry scale, accurately determining the pH of lake water samples, validating results using a pH meter, detailed recording and analysis, adhering to advanced safety protocols.

5.2.5 Laboratory essentials

Instrument(s):

Beakers (50ml, 250ml & 1000ml).
Bucket plate.
Droppers.
Electronic Scale.
Erlenmeyer (250ml).
Glass Rod.
Graduated Cylinders (25ml & 100ml).
Hot plate.
Magnetic stirrer.
Paper towel.
PH meter.
Pipette.
Spatulas.
Test Tubes.
Thermometers.
Timer.

Product(s):

Distilled water
pH solutions (#3 to #9)
Lake water sample.

5.3 The pH of strong and weak acids (Grades 9 to 12)

This laboratory session is structured into two significant segments aimed at enhancing understanding and practical skills in chemistry, particularly in solution preparation and acid-base property analysis.

The first part focuses on preparing diluted acid solutions using dilution techniques, teaching participants how to adjust solution concentrations by adding distilled water. This process is fundamental for creating samples with varying concentrations from concentrated stock solutions, highlighting the importance of precise concentration manipulation for diverse chemical applications.

The second part involves using a pH meter to measure the pH of the solutions prepared earlier, allowing an examination of their acid-base behavior, and understanding the impact of acid concentration on pH levels, thereby determining their acidity or basicity.

5.3.1 Educational Goals

- ***Solution Preparation Techniques:*** Participants will learn the basics of preparing solutions, including the critical practice of diluting concentrated solutions to achieve desired concentrations, emphasizing the significance of concentration control in chemistry.
- ***Understanding Acid-Base Behavior:*** Through pH measurement, students will explore how varying acid concentrations affect solution pH, gaining insights into the acidity or basicity of solutions.
- ***pH Measurement and Interpretation:*** The session aims to enhance skills in using pH meters for accurate pH determination and to develop the ability to interpret pH results, fostering a deeper comprehension of acidic and basic solution properties.

By participating in this laboratory, students will become familiar with essential chemistry practices, from manipulating solution concentrations to analyzing acid-base properties through pH measurement. Understanding how to adjust solution concentrations and measure their pH equips students with vital practical skills in chemistry, alongside a more profound understanding of acids and bases in solution.

This comprehensive approach ensures a well-rounded educational experience, underlining the practical application of theoretical chemistry concepts in real-world scenarios.

5.3.2 Protocol

Part 1: Preparation of diluted solutions

Step 1: Identify the four beakers, numbered from 1 to 4.

Step 2: Pour 1.00 M acetic acid (CH3COOH) solution into beaker 1 until it is half full.

Step 3: Using a pipette, take 5.0 mL of the 1.00 M acetic acid solution from beaker 1 and transfer it to a 50 mL graduated cylinder.

Step 4: Add distilled water to the graduated cylinder until the final volume reaches 50 mL.

Step 5: Pour the solution from the graduated cylinder into beaker 2 until it is half full.

Step 6: Clean the pipette and graduated cylinder with distilled water.

Step 7: Repeat the dilution process by taking 5.0 mL of the solution from beaker 2, and dilute it to 50 mL with distilled water in the graduated cylinder.

Step 8: Transfer this new diluted solution into beaker 3 until it is half full.

Step 9: For beaker 4, fill it half with a 0.10 M hydrochloric acid (HCl) concentrated solution.

Part 2: Measurements

Step 10: Use a pH meter to measure the pH of each of the solutions contained in beakers 1 to 4.

Step 11: Between each measurement, rinse and dry the pH meter electrodes with distilled water.

Step 12: Consult and record your results in the table provided on the tablet.

Step 13: Properly dispose of the used solutions by pouring them into the designated waste container. Avoid disposing of them down the sink.

5.3.3 Anticipated Outcomes

- The beaker 1 contains CH3COOH 1M, and the pH is approximately 2.37.
- The beaker 2 contains CH3COOH 0.1M, and the pH is approximately 2.87.
- The beaker 3 contains CH3COOH 0.01M, and the pH is approximately 3.37.
- The beaker 4 contains HCl 0.1M, and the pH is approximately 1.

5.3.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to acid and base concepts and simple dilution.
- **Activities**: Observing changes in pH with simple dilution, basic demonstrations of strong and weak acids, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of solution preparation and pH measurement.
- **Activities**: Preparing diluted acid solutions from concentrated stock, measuring pH with pH meters, observing the impact of dilution on pH, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced understanding of acid-base behavior, precise dilution techniques, and pH analysis.
- **Activities**: Accurately preparing various diluted acid solutions, using pH meters for precise pH measurement, analyzing the relationship between acid concentration and pH levels, detailed recording and interpretation of results, adhering to advanced safety protocols.

5.3.5 Laboratory essentials

Instrument(s):

Beakers (50ml, 250ml & 1000ml).
Bucket plate.
Droppers.
Electronic Scale.
Erlenmeyer (250ml).
Glass Rod.
Graduated Cylinders (25ml & 100ml).
Hot plate.
Magnetic stirrer.
Paper towel.
PH meter.
Pipette.
Spatulas.
Test Tubes.
Thermometers.
Timer.

Product(s):

Distilled water.
Ethanoic acid 1.0M (CH3COOH).
Hydrochloric acid (HCl).

6 GASES

6.1 The pressure of gases (Grades 9 to 12)

This laboratory session is centered on the measurement of gas pressure using a pressure gauge. The procedure involves sequentially connecting the pressure gauge to various gas cylinders (referred to as "candies" in this context), then opening the cylinder valve to allow the gas to flow into the pressure gauge. By observing the movement of the pressure gauge needle, the pressure of the gas within each cylinder can be determined. After recording the pressure measurement, the cylinder valve is closed, and the pressure gauge is disconnected.

This process is repeated for each cylinder to be tested. The primary aim of this laboratory is to acquaint students with the practical use of a pressure gauge for measuring gas pressure and to enhance their skills in handling and manipulating laboratory equipment.

6.1.1 Educational Goals

- ***Understanding Gas Pressure Measurement:*** Participants will learn the principles of measuring gas pressure using a pressure gauge, focusing on the operational aspects of the equipment.
- ***Equipment Manipulation Techniques:*** The session aims to develop proficiency in the safe and effective manipulation of laboratory equipment, including the proper connection, operation, and disconnection of a pressure gauge to gas cylinders.
- ***Observational Skills:*** Enhance students' ability to accurately observe and interpret the readings of a pressure gauge, vital for determining gas pressure within cylinders.
- ***Safety and Precision:*** Emphasize the importance of safety precautions and precision in conducting experiments involving gas pressure measurements, reinforcing best practices in laboratory procedures.

By engaging in this laboratory, students will gain hands-on experience with measuring gas pressure using a pressure gauge, from setting up the equipment to interpreting and recording pressure readings. This session not only teaches the technical aspects of using a pressure gauge but also reinforces the importance of methodical equipment manipulation and safety in the laboratory.

Through this practical exploration, students will enhance their understanding of gas behavior under pressure and acquire essential skills in conducting physical science experiments.

6.1.2 Protocol

Measuring the pressure of a gas

To measure the pressure of a gas, we can use a manometer.

1) Connect the manometer to the hose of cylinder #1.

2) Open the valve of the cylinder.

3) Check the manometer needle to determine the pressure of the contained gas.

4) Close the valve of the cylinder.

5) Detach the hose from the manometer.

6) Repeat the procedures for the other 3 cylinders.

6.1.3 Anticipated Outcomes

- The air canister #1 contains 280 kPa of air.
- The air canister #2 contains 345 kPa of air.
- The air canister #3 contains 460 kPa of air.
- The air canister #4 contains 130 kPa of air.

Significance and lessons learned:

- ***Conceptual understanding***: The experiment aids in understanding the concept of pressure and how it is measured, providing a practical application of theoretical knowledge.
- ***Technical skills***: Handling gas cylinders and manometers develops technical competency, critical for students and professionals in scientific fields.
- ***Safety awareness***: The emphasis on safety protocols reinforces the importance of caution and preparedness in a laboratory, skills that are transferable to any scientific endeavor.
- ***Analytical skills***: Interpreting the manometer readings to determine gas pressure fosters analytical thinking, an invaluable skill in problem-solving and research.

In essence, this experiment is not merely about reading numbers of a device; it's about integrating knowledge, developing practical skills, and fostering a meticulous approach to scientific investigation. Participants learn to correlate the observed manometer readings with the known pressures in the gas cylinders, providing a clear, hands-on understanding of pressure measurement in gases.

6.1.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to gas pressure concepts and simple measurements.
- **Activities**: Observing the use of a pressure gauge, simple demonstrations of gas pressure, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of gas pressure measurement and equipment handling.
- **Activities**: Connecting a pressure gauge to gas cylinders, measuring and recording gas pressure, observing needle movement, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced understanding of gas pressure principles, precise measurement techniques, and equipment manipulation.
- **Activities**: Accurately connecting and operating a pressure gauge, measuring and recording gas pressures from various cylinders, analyzing pressure readings, adhering to advanced safety protocols, and ensuring precise handling of laboratory equipment.

6.1.5 Laboratory essentials

Instrument(s):

Gas tank.
Manometer.

Product(s):

None

6.2 The relationship between the volume and pressure of a gas 1 (Grades 9 to 12)

This laboratory session is designed to explore the relationship between the pressure and volume of a gas, employing a syringe and a dial pressure gauge for the experiment. The procedure involves attaching the syringe to an air cylinder and adjusting the air volume in the syringe to 55.0 ml. Subsequently, the syringe is connected to the dial pressure gauge in a waterproof seal, and the air volume is incrementally increased by 5.0 ml steps, with the pressure reading taken at each interval.

This experiment serves as a practical application of Boyle's Law, which posits that the pressure of a gas is inversely proportional to its volume at a constant temperature.

6.2.1 Educational Goals

- ***Practical Application of Boyle's Law:*** Participants will directly apply Boyle's Law to understand the inverse relationship between gas pressure and volume.
- ***Precision in Equipment Handling:*** The session will teach students the accurate use of syringes and pressure gauges, emphasizing the importance of precision for reliable measurements.
- ***Observational and Analytical Skills:*** Students will enhance their skills in observing variations in pressure with changes in volume and analyzing these observations to confirm the validity of Boyle's Law.
- ***Understanding Gas Thermodynamics:*** Through hands-on experimentation, participants will reinforce their conceptual knowledge of gas thermodynamics, particularly the principles governing the behavior of gases under varying pressures and volumes.

This laboratory provides participants with an invaluable opportunity to experiment with the principles of Boyle's Law, reinforcing theoretical knowledge through practical application. By manipulating the syringe and pressure gauge to measure how gas pressure varies with volume, students gain a deeper understanding of gas behavior.

This session not only improves their ability to handle laboratory equipment and collect data accurately but also deepens their comprehension of the fundamental concepts in the thermodynamics of gases, offering a solid foundation for further studies in physics and chemistry.

6.2.2 Protocol

1. Pull the syringe plunger so that it contains exactly 55.0 mL of air.

2. Connect the syringe to the dial manometer using the appropriate fittings. The setup must be perfectly airtight and able to withstand significant pressure.

3. Pull on the plunger to increase the volume by 5.0 mL. Read the pressure measurement on the manometer.

4. Repeat step 3 several times (in 5.0 mL intervals) until reaching a volume of 100.0 mL.

Note: Keep the interaction button of the syringe pressed to counteract the difference in pressure.

6.2.3 Anticipated Outcomes

- ***Volume-pressure relationship***: As the volume of the gas in the syringe increases, the pressure it exerts should decrease, and vice versa, illustrating an inverse relationship. This is expected to be observed as a continuous decrease in pressure readings on the manometer as the volume in the syringe is incrementally increased.
- ***Data pattern***: Plotting the pressure against volume should yield a hyperbolic curve if the temperature remains constant, which is a graphical representation of Boyle's Law. The product of pressure and volume at each point should be roughly constant, assuming ideal gas behavior.
- ***Accuracy and precision***: The precision of the measurements, as well as the airtightness of the setup, are crucial for the validity of the results. Any leakage or measurement error could significantly skew the data, impacting the demonstration of the pressure-volume relationship.

Significance of the experiment:

- ***Understanding gas laws***: This experiment is pivotal in reinforcing the conceptual understanding of gas laws, particularly Boyle's Law, in a tangible and interactive manner. It bridges theoretical knowledge with practical application.
- ***Skills development***: The procedure enhances technical skills such as precise measurement, operation of laboratory equipment (e.g., syringes and manometers), and data analysis, which are transferable to a wide range of scientific endeavors.
- ***Scientific reasoning***: The experiment encourages analytical thinking by requiring students or participants to predict, observe, and rationalize the outcomes based on the principles of physics and chemistry.
- ***Safety and protocol adherence***: Emphasizing safety and protocol adherence prepares participants for future laboratory work, underlining the importance of meticulousness and responsibility in scientific investigations.

This experiment, therefore, is not just a demonstration of a fundamental physical principle but also a comprehensive exercise in scientific methodology, critical thinking, and practical skills development, all of which are essential for proficiency in the scientific field.

6.2.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to gas pressure and volume concepts.
- **Activities**: Observing changes in pressure and volume using simple demonstrations, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of Boyle's Law and gas behavior.
- **Activities**: Adjusting air volume in a syringe, measuring pressure with a dial pressure gauge, recording observations, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced understanding of Boyle's Law, precise measurement techniques, and gas thermodynamics.
- **Activities**: Accurately adjusting and measuring air volume and pressure, analyzing the inverse relationship between pressure and volume, detailed recording and interpretation of results, adhering to advanced safety protocols, reinforcing concepts of gas behavior under varying conditions.

6.2.5 Laboratory essentials

Instrument(s):

Electronic scale.
Nail.
Syringe.
Wood clamp.

Product(s):

Gaz tank with compressed air.

6.3 The relationship between the volume and pressure of a gas 2 (Grades 9 to 12)

This laboratory session is meticulously designed to explore the relationship between the pressure and volume of a gas using the Boyle's Law apparatus. The experiment starts with securely attaching the air pump hose to the Boyle device, ensuring an airtight seal with the oil in the tank to isolate the air. As air is pumped into the system, the internal pressure increases, which participants can monitor via the pressure gauge.

When the pressure gauge indicates approximately 700 kPa, the air tap is closed, and the pressure and volume of the gas are recorded after allowing a minute for the compressed air to cool down. This process provides a hands-on application of Boyle's Law, which posits that the pressure and volume of a gas are inversely proportional at a constant temperature.

6.3.1 Educational Goals

- ***Understanding Boyle's Law:*** Through practical application, participants will explore Boyle's Law, gaining insight into the inverse relationship between gas pressure and volume.
- ***Precision in Equipment Handling:*** The lab aims to enhance students' proficiency in using the Boyle's Law apparatus, focusing on the accurate measurement of pressure and volume.
- ***Analytical Skills Enhancement:*** Students will develop their analytical skills by conducting successive measurements and plotting a graph of absolute pressure against the inverse of the air column volume, observing a linear relationship that confirms Boyle's Law.
- ***Gas Thermodynamics Principles:*** This session provides a comprehensive understanding of the fundamental principles of gas thermodynamics, reinforcing the theoretical knowledge through experimental verification.

By engaging in this laboratory, participants will gain a deeper understanding of and the ability to experimentally verify Boyle's Law, enhancing their skills in handling laboratory equipment and analyzing experimental data. The session offers a direct observation of the relationship between gas pressure and volume, solidifying the participants' grasp of the fundamental principles governing gas behavior.

This practical exploration not only confirms the validity of Boyle's Law but also strengthens participants' overall understanding of the dynamics of gas thermodynamics.

6.3.2 Protocol

1. Locate the Boyle's apparatus.

2. Connect the air pump hose to the Boyle's apparatus.

The connection of the oil reservoir to the air column must be such that there are no leaks and the air is completely isolated by the oil.

3. Ensure that the tap of the Boyle's apparatus is open.

4. After connecting the hose to the Boyle's apparatus, start pumping air through the air pump. Pump until the pressure gauge reaches about 500 kPa.

When air moves into the oil reservoir, the pressure inside the system increases. This can be observed on the pressure gauge.

5. Close the air tap once the oil stops rising and the pressure gauge reading is steady.

6. You can detach the air hose from the Boyle's apparatus.

7. Wait 1 minute for the compressed air to cool down and note the pressure reading and the volume reading.

8. Now, press the button on the Boyle's apparatus to let the air escape from the system. This will lower the oil in the column.

Note the volume of the air column (in ml) and the pressure gauge reading (in kPa).

You will obtain a plot of the pressure gauge reading as a function of the volume of the air column. Remember to add the atmospheric pressure to the gauge pressure to get the absolute pressure. A graph of the absolute pressure against the inverse of the volume of the air column should show a linear relationship.

6.3.3 Anticipated Outcomes

Participants are guided through an experiment that visually and quantitatively demonstrates Boyle's Law. This law states that the pressure of a given mass of an enclosed gas is inversely proportional to its volume at a constant temperature, provided the gas behaves ideally.

- ***Pressure and volume relationship:*** As participants pump air into the Boyle's apparatus, they'll observe an increase in pressure as indicated by the pressure gauge, corresponding with a decrease in the volume of the air column. This inverse relationship between pressure and volume is the crux of Boyle's Law.
- ***Data analysis:*** Upon completing the experiment, the collected data points of pressure and volume should ideally form a hyperbolic curve when plotted. However, when plotting the absolute pressure against the inverse of the volume, the relationship should linearize, offering a clear visual representation of Boyle's Law.
- ***Understanding physical laws:*** The experiment provides a tangible way to understand and apply a fundamental gas law, reinforcing the theoretical knowledge through practical application.

Significance and lessons learned:

- ***Real-world applications***: The experiment highlights the significance of Boyle's Law in various scientific and engineering fields, such as chemistry, physics, and environmental science. Understanding how pressure and volume interact is crucial in scenarios ranging from the functioning of internal combustion engines to the behavior of gases in the atmosphere.

- ***Critical thinking and problem solving:*** Participants learn to set up experimental apparatus, collect data systematically, and analyze results. Such skills are invaluable in scientific inquiry and problem-solving across numerous disciplines.
- ***Precision and accuracy:*** The experiment underscores the importance of precision in experimental setup and accuracy in measurement. Ensuring airtight connections and correctly reading gauges are practical skills that extend beyond the laboratory.
- ***Application of theoretical knowledge:*** By engaging with the physical apparatus and observing real-time changes in gas behavior, learners can better grasp abstract concepts, making the theoretical knowledge more accessible and memorable.

Overall, the experiment offers a comprehensive learning experience, combining hands-on skills with theoretical understanding, thereby enhancing the educational journey in the field of physical sciences.

6.3.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to gas pressure and volume concepts.
- **Activities**: Observing changes in pressure and volume using simple demonstrations, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of Boyle's Law and gas behavior.
- **Activities**: Using the Boyle's Law apparatus to adjust and measure air pressure and volume, recording observations, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced understanding of Boyle's Law, precise measurement techniques, and gas thermodynamics.
- **Activities**: Accurately using the Boyle's Law apparatus, measuring and recording pressure and volume, plotting graphs to observe the linear relationship between pressure and the inverse of volume, detailed analysis of results, adhering to advanced safety protocols, reinforcing concepts of gas behavior under varying conditions.

6.3.5 Laboratory essentials

Instrument(s):

Air pump.
Boyle apparel.

Product(s):

None

6.4 The relationship between a gas's temperature and its volume (Grades 9 to 12)

This experimental protocol is designed to measure the volumetric thermal expansion coefficient of a liquid by observing changes in the height of an oil drop within a capillary tube as temperature varies. The experiment starts with setting up the apparatus, including securing the universal clamps, preheating the capillary tube, and preparing beakers with cold water and ice.

Measurements of the oil drop's height are taken at various temperatures, using a thermometer and a stopwatch, while carefully adjusting the water temperature on the heating plate.

6.4.1 Educational Goals

- ***Understanding Volumetric Expansion:*** Participants will explore how the volume of a liquid changes with temperature, aiming to determine the liquid's volumetric thermal expansion coefficient.
- ***Temperature Measurement Techniques:*** The experiment introduces methods for accurately measuring temperature and the height of a liquid in a capillary tube, enhancing participants' familiarity with temperature-related measurements.
- ***Laboratory Instrument Manipulation:*** Students will practice using various laboratory instruments, improving their hands-on skills in conducting experiments.
- ***Fundamentals of Liquid Thermodynamics:*** Through this procedure, participants will gain insights into the basic principles of thermodynamics as they apply to liquids, including the relationship between temperature and volume.

This laboratory experience is crucial for understanding how temperature affects a liquid's volume and for mastering precise measurement techniques in a laboratory setting.

Participants will develop practical skills in handling laboratory equipment, observing physical phenomena, and analyzing experimental data. Furthermore, this experiment underscores the significance of methodological rigor and accuracy in scientific experimentation, ensuring reliable and meaningful results.

Through engaging in this activity, participants not only learn about the thermodynamics of liquids but also appreciate the meticulous nature required in scientific research, enhancing their overall competency in experimental physics and chemistry.

6.4.2 Protocol

1. Attach a universal clamp to each of the two universal stands above the heating plate.

2. Drop a few drops of oil on the watch glass.

3. Light the Bunsen burner and heat the capillary tube with thermal gloves by keeping it exposed to the blue flame and moving it back and forth for about 20 seconds.

4. Place the hot open (clear) end of the capillary tube onto the drops of oil prepared in step #2. The oil should rise by itself into the capillary tube.

5. Return the tube to its upright position (open end up) and wait for it to cool. Then, secure the capillary tube to the right-hand stand using a universal clamp and turn off the Bunsen burner.

6. Place the 250 mL beaker on the heating plate without turning it on, placing the magnetic stirrer inside the beaker.

7. Secure the thermometer to the left-hand stand using a universal clamp and place it vertically in the 250 mL beaker. Ensure neither the tube nor the thermometer touch the beaker's sides.

8. Position the ruler behind the capillary tube to measure the height of the oil drop.

9. In the ice beaker, add tap cold water until the level reaches 250 mL.

10. Pour the cold water and ice into the beaker containing the capillary tube, ensuring the water level is above that of the oil drop.

11. Observe the water temperature and the height of the bottom of the oil drop once the temperature stabilizes.

12. Start the stirrer on the heating plate and time to measure the height of the drop and the water temperature.

13. Turn on the heating plate to low intensity (20°C) and wait for the temperature to increase by about ten degrees.

14. Observe the water temperature and the height of the oil drop again once stabilized.

15. Repeat steps 12 to 14, increasing the temperature by 10 degrees each time until the setup no longer allows for reliable measurements.

16. Turn off the heating plate and wait for complete cooling before concluding the experiment.

Note: The inside of the capillary tube has a radius of 0.5 mm.

6.4.3 Anticipated Outcomes

Participants explore Charles's Law, which states that the volume of a gas is directly proportional to its temperature when pressure and the amount of gas are held constant. This experiment provides a visual and quantitative understanding of how gas volume changes in response to temperature variations.

- ***Temperature-volume relationship:*** As the temperature of the gas (in this case, air within the capillary tube) increases, the volume, indicated by the height of the oil drop, is expected to increase. Conversely, when the temperature decreases, the volume should decrease. This relationship is a direct demonstration of Charles's Law. The inside of the capillary tube has a radius of 0.5 mm.
- ***Data collection and analysis***: By systematically recording the temperature and corresponding oil drop height at various temperatures, participants will create a dataset

that, when graphed, should show a linear relationship between temperature (in Kelvin) and volume, affirming Charles's Law.

- ***Observation skills***: Participants will refine their observation skills, noting how minute changes in temperature can result in measurable changes in the volume of gas.

Significance and Lessons Learned:

- ***Understanding gas behavior***: The experiment deepens the understanding of fundamental gas laws, specifically Charles's Law, showing how gases expand when heated and contract when cooled in a controlled environment.
- ***Real-world relevance***: The principles demonstrated are applicable in various real-world scenarios, such as understanding the behavior of air in weather balloons, automotive engines, and even in meteorology for weather prediction.
- ***Scientific methodology***: Participants learn the importance of precise measurements and the need to control variables to isolate the effects of temperature on gas volume. This reinforces the scientific method's role in experimental design and data analysis.
- ***Critical thinking***: Analyzing the results, participants will engage in critical thinking, especially if the outcomes deviate from the expected linear relationship, prompting investigation into possible sources of error or non-ideal gas behavior.
- ***Practical skills***: Handling laboratory equipment like Bunsen burners, capillary tubes, and thermal gloves develops practical skills and reinforces the importance of laboratory safety protocols.

This experiment offers a comprehensive learning experience, merging theoretical knowledge with practical skills, enhancing participants' understanding of gas laws and their competence in conducting scientific investigations.

6.4.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to temperature and volume concepts.
- **Activities**: Observing simple demonstrations of how temperature affects the volume of liquids, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of volumetric expansion and temperature measurement.
- **Activities**: Measuring temperature and liquid height in a capillary tube, recording changes in volume with temperature, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced understanding of volumetric expansion, precise measurement techniques, and thermodynamics principles.
- **Activities**: Setting up and using the apparatus to measure the volumetric thermal expansion coefficient, accurately measuring temperature and liquid height, analyzing the relationship between temperature and volume, detailed recording and interpretation of results, adhering to advanced safety protocols, reinforcing concepts of liquid thermodynamics.

6.4.5 Laboratory essentials

Instrument(s):

Beaker (250ml).
Bunsen burner.
Capillary tube.
Dropper.
Hot plate.
Lab Stand & Clamps.
Magnetic stirrer.
Ruler.
Thermometers.
Timer.
Watch glass.

Product(s):

Olive oil.

6.5 Relationship Between Gas Solubility and Temperature (Grades 9 to 12)

This laboratory session is centered on exploring the impact of temperature on carbonated water, specifically examining how temperature variations influence the solubility of carbon dioxide (CO2) in water.

Utilizing three separate test tubes filled with sparkling water, each is placed in a distinct temperature setting: one in cold water with ice cubes, another in hot water, and the third at room temperature. The test tubes are allowed to acclimate to their respective temperatures before observations are made.

6.5.1 Educational Goals

- ***Observation of Temperature Effects on Carbonated Water:*** Participants will observe and note the differences in CO2 release and the appearance of sparkling water at various temperatures, aiming to compare the effects directly.
- ***Understanding Gas Solubility in Liquids:*** The experiment is designed to illustrate how temperature affects the solubility of gases in liquids, with a focus on how temperature variations alter water's capacity to dissolve CO2.
- ***Application of Thermodynamics and Chemical Kinetics:*** This laboratory provides a practical context for applying concepts from thermodynamics and chemical kinetics, enhancing participants' understanding of these fundamental principles.

Through this laboratory experience, participants will gain insights into the pronounced effects of temperature on the physical and chemical properties of liquids, particularly the dissolution phenomenon of gases in liquids.

Additionally, the experiment emphasizes the importance of conducting controlled experiments by carefully manipulating variables such as temperature, thereby strengthening experimental methodology skills.

Furthermore, meticulous observation and thorough documentation of results are highlighted as crucial steps for drawing meaningful conclusions in chemistry. This session not only fosters a deeper understanding of the interplay between temperature and gas solubility but also enhances participants' competencies in experimental design and analysis, underscoring the significance of precise scientific inquiry.

6.5.2 Protocol

1. Locate the three test tubes of carbonated water (with carbon dioxide (CO_2)).

2. Fill one beaker with ice and cold water and the other beaker with hot water.

3. Using tongs and a universal stand, place the first test tube in a beaker containing cold water and ice cubes.

4. Using tongs and a universal stand, place the second test tube in a beaker containing hot water.

5. Leave the third test tube on the countertop at room temperature.

6. Wait 30 seconds for the test tubes to become sufficiently cold or hot before continuing.

7. Open the test tube left at room temperature and note your observations.

8. Open the test tube in the hot water and note your observations.

9. Open the test tube in the ice water and note your observations.

6.5.3 Anticipated Outcomes

Initially, the partial pressure of CO_2 above the liquid in the test tubes is 150 kPa. An increase in temperature will decrease the solubility of CO_2 in water. As there will be less CO_2 dissolved in a warm liquid, there will be reduced effervescence in the warm container and increased effervescence in the cold container, compared to the container at room temperature.

The solubility of gases in liquids generally decreases with an increase in temperature. This behavior is opposite to that observed for most solids dissolved in liquids. When the temperature rises, the molecules of the solvent (the liquid) and the solute (the gas) gain more kinetic energy. This translates into faster and more vigorous movements of the liquid's molecules, making it more difficult to keep the gas molecules in solution. The interactions between the gas and liquid molecules become less effective as the gas molecules are more easily 'ejected' from the liquid. This relationship is particularly important in natural and industrial processes.

For example, in lakes and oceans, the water's capacity to retain dissolved oxygen decreases as the temperature rises, which can have consequences for aquatic life. Similarly, in industrial systems where gases are dissolved in liquids, temperature management is crucial to maintaining the desired gas concentrations.

6.5.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to gas solubility and temperature effects.
- **Activities**: Observing CO2 release from sparkling water at different temperatures, simple discussions on how temperature affects gas solubility, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of gas solubility in liquids and temperature effects.
- **Activities**: Preparing test tubes with sparkling water at different temperatures, observing and recording CO2 release, understanding how temperature affects gas solubility, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced understanding of gas solubility, thermodynamics, and chemical kinetics.
- **Activities**: Setting up experiments with sparkling water at various temperatures, accurately measuring and recording observations of CO2 release, analyzing the relationship between temperature and gas solubility, detailed recording and interpretation of results, adhering to advanced safety protocols, reinforcing concepts of thermodynamics and chemical kinetics.

6.5.5 Laboratory essentials

Instrument(s):

Beakers (100ml & 1000ml).
Electronic Scale.
Test Tubes.

Product(s):

Carbonated water (CO2).

7 CHEMICAL KINETICS AND THERMODYNAMICS

7.1 Reaction rate and enthalpy (Grades 9 to 12)

This laboratory session is designed to delve into the principles of thermochemistry through the exploration of the exothermic reaction between magnesium (Mg) and hydrochloric acid (HCl).

Participants will engage in measuring temperature changes resulting from this chemical reaction, using these measurements to discuss concepts such as enthalpy and the conservation of energy.

7.1.1 Educational Goals

- ***Understanding Exothermic Reactions:*** Students will observe the temperature increase that characterizes exothermic reactions, where energy is released as heat, providing a tangible example of this type of chemical reaction.
- ***Application of Energy Conservation Law:*** The experiment serves as a practical illustration of the law of energy conservation, demonstrating how energy is transformed from one form to another—in this case, from chemical energy to thermal energy.
- ***Calculation of Enthalpy:*** By measuring temperature changes during the reaction, students will learn to calculate the reaction's enthalpy, offering a quantitative view of the energy released or absorbed during a chemical process.
- ***Experimental Precision:*** Emphasizes the importance of precision in weighing reagents, measuring volumes and temperatures to achieve reliable and reproducible results.
- ***Safety Protocols:*** Highlights the necessity of adhering to safety protocols when handling reactive and corrosive substances like HCl and magnesium, and the use of personal protective equipment such as safety glasses, gloves, and lab coats.

This laboratory provides a hands-on opportunity to explore exothermic reactions and the fundamental principles of thermochemistry. By analyzing the temperature changes during the reaction between magnesium and hydrochloric acid, students gain a comprehensive understanding of reaction enthalpy and the conservation of energy in chemical processes.

This session not only reinforces foundational chemistry principles but also enhances students' skills in experimental precision and safety, contributing to their overall competence in scientific experimentation.

7.1.2 Protocol

1. Place the weighing boat on the balance scale.

2. Press the tare button to zero out the scale.

3. Weigh the desired amount of magnesium powder (Mg) - about 0.2g.

4. Place the reagent in the calorimeter.

5. Measure the desired amount of hydrochloric acid (HCl) 1 M (50 to 150 mL).

6. Record the initial temperature of the HCl.

7. Insert the thermometer into the hole located on the right on top of the lid.

8. Start the stopwatch by pressing the red button.

9. Pour the 1 M HCl into the calorimeter.

10. Place the lid on the calorimeter.

11. Activate the stirrer by pressing the green button on the calorimeter lid.

12. The temperature versus time graph is on the tablet (graph tab).

13. Record the final temperature when the reaction ends (between 70 and 250 seconds).

14. The results can be found in the results tab on the tablet.

15. Empty the contents of the calorimeter into the recycling bin and clean with distilled water.

** *Note: the reaction is accelerated 2 times faster, to more easily observe the complete reaction.*

7.1.3 Anticipated Outcomes

Using approx. 0,2 g of Magnesium and 50 to 150 mL of 1M HCl, the reaction should take between 140 and 500 seconds, which is too long for an AR experience. For convenience, the reaction speed has been accelerated 2 times.

The molar enthalpy of reaction, for the reaction $Mg(s) + 2\ HCl\ (aq) = MgCl_2(aq) + H_2(g)$ is -440kJ for each mole of Mg(s). The energy released should be about 6.3 kJ, with a 15 °C temperature increase. Because Mg(s) is the limiting reagent, using smaller volume will increase time to reach reaction completion, given the smaller amount of HCl participating in the reaction.

7.1.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to exothermic reactions and temperature changes.
- **Activities**: Observing temperature increase during the reaction between magnesium and hydrochloric acid, simple discussions on energy release, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of exothermic reactions, energy conservation, and temperature measurement.
- **Activities**: Conducting the reaction between magnesium and hydrochloric acid, measuring temperature changes, understanding energy transformation, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced understanding of thermochemistry, reaction enthalpy, and experimental precision.
- **Activities**: Accurately conducting the reaction, measuring and recording temperature changes, calculating enthalpy, analyzing energy conservation, detailed recording and interpretation of results, adhering to advanced safety protocols, reinforcing concepts of thermochemistry and energy conservation.

7.1.5 Laboratory essentials

Instrument(s):

Beaker (1000ml).
Calorimeter
Electronic Scale.
Graduated Cylinders (70ml & 250ml).
Spatulas.
Thermometers.
Timer.
Tweezers.

Product(s):

HCl 1.0M (solution)
Magnesium (powder)

7.2 Reaction rate between molecules (Grades 9 to 12)

This laboratory session is structured into two distinct parts, with each focusing on different reactions involving magnesium to illustrate the principles of chemical reactions and thermochemistry.

Part 1: involves reacting powdered magnesium with 1M hydrochloric acid (HCl) in a calorimeter to measure the initial and final temperatures and observe the thermal changes that occur. This part emphasizes the exothermic nature of the reaction between magnesium and hydrochloric acid.

Part 2: repeats the procedure used in Part 1 but substitutes magnesium with magnesium oxide (MgO) powder to explore the reaction between MgO and hydrochloric acid. This comparison aims to highlight the differences in reactivity and thermal changes between magnesium and its oxide when reacting with hydrochloric acid.

7.2.1 Educational Goals

- ***Measurement Techniques:*** Students will practice precise mass and volume measurements using balances and graduated cylinders, alongside temperature measurements with thermometers.
- ***Reaction Observations:*** The experiment provides an opportunity to observe and compare the reactions of magnesium and magnesium oxide with hydrochloric acid, highlighting the differing behaviors of these two reagents.
- ***Understanding Chemical Reactions:*** By modifying components like the reagent, students can explore how changes in experimental conditions affect the outcomes of chemical reactions.
- ***Thermochemistry Concepts:*** Participants will gain a practical understanding of thermochemistry, learning about the heat changes associated with chemical reactions.

Through this laboratory experience, students will not only familiarize themselves with standard experimental procedures in chemistry but also enhance their skills in manipulating laboratory equipment and interpreting experimental data. Moreover, this session offers a practical application of theoretical chemistry concepts to real-world scenarios, reinforcing the understanding of fundamental principles within the discipline.

By engaging in these experiments, students acquire a deeper comprehension of chemical reactions, the importance of precise measurement, and the impact of varying experimental conditions on the results, thereby solidifying their foundational knowledge and skills in chemistry.

7.2.2 Protocol

Magnesium

1. Place the weighing boat on the balance scale.

2. Press the tare button to zero out the scale.

3. Weigh the desired amount of magnesium powder (Mg) - about 0.4g.

4. Place the reactant in the calorimeter.

5. Measure the desired amount of 1 M hydrochloric acid (HCl) (100 mL).

6. Note the initial temperature of the HCl.

7. Insert the thermometer into the hole located on the right on top of the lid.

8. Start the stopwatch by pressing the red button.

9. Pour the 1 M HCl into the calorimeter.

10. Place the lid on the calorimeter.

11. Activate the stirrer by pressing the green button on the calorimeter lid.

12. The temperature vs. time graph is on the tablet (graph tab).

13. Note the final temperature when the reaction ends (about 230 seconds).

14. Results can be found in the results tab on the tablet.

15. Empty the contents of the calorimeter into the recycling bin and clean with distilled water.

Magnesium Oxide

16. Weigh about 0.4 g of magnesium oxide (MgO) powder.

17. Repeat steps 4 to 15 with MgO.

18. Note the difference between the two molecules.

** *Note: the reaction is accelerated 2 times faster, to more easily observe the complete reaction.*

7.2.3 Anticipated Outcomes

Using approx. 0,41 g of magnesium and 100 mL of 1M HCl, the reaction should take approx. 490 seconds, or 98 seconds accelerated 2 times.

The molar enthalpy of reaction, for the reaction Mg(s) + 2 HCl (aq) = $MgCl_2$(aq) + H_2(g) is -440kJ for each mole of Mg(s). The energy released should be about 7.57 kJ, with a 18 °C temperature increase. Because Mg(s) is the limiting reagent, using smaller volume will increase time to reach reaction completion, given the smaller amount of HCl participating in the reaction.

The molar enthalpy of reaction of MgO is -120kJ for each mole of MgO(s). The energy released should be 2.06 kJ, with a 5 °C temperature increase. Using approx. 0,43 g of magnesium oxide and 100 mL of 1M HCl, the reaction should take approx. 10-15 seconds less than Mg(s), when accelerated 2 times.

7.2.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to chemical reactions and temperature changes.
- **Activities**: Observing temperature changes during reactions, simple comparisons of reactions involving magnesium and magnesium oxide, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of chemical reactions, measurement techniques, and thermochemistry.
- **Activities**: Conducting reactions with magnesium and hydrochloric acid, measuring temperature changes, comparing reactions with magnesium oxide, understanding heat changes in reactions, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced understanding of thermochemistry, precise measurement techniques, and reaction dynamics.
- **Activities**: Accurately conducting reactions with magnesium and magnesium oxide in hydrochloric acid, measuring and recording temperature changes, comparing reactivity and heat changes, analyzing experimental conditions and their effects, detailed recording and interpretation of results, adhering to advanced safety protocols, reinforcing concepts of chemical reactions and thermochemistry.

7.2.5 Laboratory essentials

Instrument(s):

Beaker (1000ml).
Calorimeter
Electronic Scale.
Graduated Cylinders (70ml & 250ml).
Spatulas.
Thermometers.
Timer.
Tweezers.

Product(s):

HCl 0.1M (solution)
Magnesium (powder)
Magnesium oxide (powder).

7.3 The influence of contact surface on reaction rate 1 (Grades 9 to 12)

This laboratory session is designed to compare the reactivity and behavior of magnesium in two different forms—powder and ribbon—when reacting with hydrochloric acid (HCl). By measuring the reaction time and temperature changes, students can delve into the concepts of reaction surface area, reaction rate, and activation energy.

7.3.1 Educational Goals

- ***Surface Area and Reaction Speed:*** Students will learn how the difference in contact surface area between magnesium powder and ribbon affects the reaction speed, with the powder's larger surface area typically resulting in a faster reaction.
- ***Activation Energy:*** The experiment highlights the role of activation energy in chemical reactions and demonstrates how the physical form of reactants can influence this critical energy threshold.
- ***Control of Chemical Reactions:*** Emphasizes the significance of controlling experimental variables to accurately compare the reactivity of different forms of magnesium with HCl.
- ***Thermodynamics and Kinetics:*** Through temperature measurements, students will explore thermodynamics and chemical kinetics concepts, observing the heat release and the rate at which reactions occur.

By conducting a comparative analysis of magnesium powder and ribbon reacting with hydrochloric acid, students gain insights into the factors that influence reaction rates.

This laboratory underscores the importance of surface area, activation energy, and precise control and measurement in studying chemical reactions, enhancing students' understanding of fundamental chemistry principles.

7.3.2 Protocol

Part 1: Reaction of magnesium powder with hydrochloric acid

1. Place the weighing boat on the balance scale.

2. Press the tare button to zero out the scale.

3. Weigh the desired amount of magnesium powder (Mg) - about 0.6g.

4. Place the reactant in the calorimeter.

5. Measure the desired amount of 1 M hydrochloric acid (HCl) (100 mL).

6. Note the initial temperature of the HCl.

7. Insert the thermometer into the hole located on the right on top of the lid.

8. Start the stopwatch by pressing the red button.

9. Pour the 1 M HCl into the calorimeter.

10. Place the lid on the calorimeter.

11. Activate the stirrer by pressing the green button on the calorimeter lid.

12. The temperature vs. time graph is on the tablet (graph tab).

13. Note the final temperature when the reaction ends (about 220 seconds).

14. Results can be found in the results tab on the tablet.

15. Empty the contents of the calorimeter into the recycling bin and clean with distilled water.

Part 2: Reaction of magnesium ribbon with hydrochloric acid

16. Weigh about 0.6 g of magnesium ribbon (or an equivalent piece).

17. Repeat steps 4 to 15, comparing with the magnesium ribbon.

18. Note the time required until the end of the reaction, determined by the temperature stabilization.

***Note: the reaction is accelerated 10 times faster to more easily observe the complete reaction.*

7.3.3 Anticipated Outcomes

Using approx. 0,62 g of magnesium and 100 mL of 1M HCl, the reaction should take approx. 840 seconds, or 84 seconds accelerated 10 times.

The molar enthalpy of reaction, for the reaction $Mg(s) + 2\ HCl\ (aq) = MgCl_2(aq) + H_2(g)$ is -440kJ for each mole of Mg(s). The energy released should be about 11.3 kJ, with a 27 ℃ temperature increase. Because Mg(s) is the limiting reagent, using smaller volume will increase time to reach reaction completion, given the smaller amount of HCl participating in the reaction.

Using approx. 0,55 g of magnesium ribbons and 100 mL of 1M HCl, the reaction should take approx. 1410 seconds, or 141 seconds accelerated 10 times.

7.3.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to reaction rate and surface area concepts.
- **Activities**: Observing reactions of magnesium powder and ribbon with hydrochloric acid, noting simple differences in reaction speed, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of surface area effects on reaction rate and basic thermodynamics.
- **Activities**: Conducting reactions with magnesium powder and ribbon in hydrochloric acid, measuring reaction times and temperature changes, comparing reactivity of different forms of magnesium, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced understanding of reaction kinetics, surface area effects, and thermodynamics.
- **Activities**: Accurately conducting reactions with magnesium powder and ribbon, measuring and recording reaction times and temperature changes, analyzing the impact of surface area on reaction rate and activation energy, detailed recording and interpretation of results, adhering to advanced safety protocols, reinforcing concepts of chemical kinetics and thermodynamics.

7.3.5 Laboratory essentials

Instrument(s):

Beaker (1000ml).
Calorimeter
Electronic Scale.
Graduated Cylinders (70ml & 250ml).
Spatulas.
Thermometers.
Timer.
Tweezers.

Product(s):

HCl 0.1M (solution).
Magnesium (powder).
Magnesium (pieces).

7.4 The influence of contact surface on reaction rate 2 (Grades 9 to 12)

This laboratory session is focused on examining how the concentration of acid and the physical form of calcium carbonate (CaCO3) influence reaction rates.

Through experiments using various acids at different concentrations and comparing the reactivity of solid and powdered forms of CaCO3, students will gain insights into chemical kinetics and acid reactivity.

7.4.1 Educational Goals

- ***Chemical Kinetics Understanding:*** Students will explore how the contact surface and concentration of reactants affect reaction speed, demonstrating the fundamental principles of chemical kinetics.
- ***Acid Reactivity Comparison:*** The experiment allows students to observe the varying reactivities between acids like hydrochloric acid and ethanoic acid, emphasizing the impact of acid type on the reaction.
- ***Chemical Principles Application:*** Through the experimental results, students will deepen their understanding of key chemical concepts, including reaction kinetics, solution concentration, and the nature of reactants.
- ***Practical Application Skills:*** The laboratory experience teaches students how to effectively manipulate and control chemical reactions, providing valuable insights applicable in both experimental and industrial settings.

By investigating the effects of acid concentration and the physical state of calcium carbonate on reaction rates, students will enhance their comprehension of the principles that govern chemical reaction speeds.

This understanding is crucial for predicting and controlling reactions across various scientific and industrial applications, enriching students' knowledge, and practical skills in chemistry.

7.4.2 Protocol

Preparation

a) Fill each 50 mL beaker halfway as indicated below:

Beaker A, C, D, and E: with hydrochloric acid (HCl) at 1.00 mol/L.

Beaker B: with acetic acid (CH3COOH) at 1.00 mol/L.

Beaker F: with hydrochloric acid (HCl) at 0.10 mol/L.

Experiment 1

b) Weigh about 2.7 g of calcium carbonate (CaCO3) powder on the balance, and repeat to obtain two samples.

c) Place beaker A on the left heating plate and beaker B on the right one.

d) Insert magnetic stirrers into beakers A and B.

e) Activate the magnetic stirrers.

f) Start the stopwatch to measure the reaction time.

g) Simultaneously add the CaCO3 samples to beakers A and B.

h) Observe and time the reaction until completion.

i) Transfer the contents of beakers A and B into a recovery container.

Experiment 2

j) Weigh a solid piece of CaCO3 of about 3.00 g, and separately weigh about 2.7g of CaCO3 powder.

k) Place beaker C on the left heating plate and beaker D on the right.

l) Repeat steps d) to i) for these beakers.

Experiment 3

m) Weigh about 2.7 g of CaCO3 powder for two samples again.

n) Place beaker E on the left heating plate and beaker F on the right.

o) Repeat steps d) to i) for these beakers.

7.4.3 Anticipated Outcomes

Experiment 1:

Reaction time: calcium carbonate ($CaCO_3$) reacts with 1M hydrochloric acid (HCl) for approximately 35 seconds, and with 1M ethanoic acid (CH_3COOH) for about 75 seconds.

Observation: HCl reacts faster with $CaCO_3$ than CH_3COOH due to its stronger acidic nature, which facilitates a quicker release of gas.

Conclusion: the rapid reaction with HCl compared to CH_3COOH illustrates the impact of acid strength on reaction rates.

Experiment 2:

Reaction time: $CaCO_3$ in powder form reacts in about 65 seconds, whereas in lump form, it takes around 100 seconds.

Observation: the increased surface area of powdered $CaCO_3$ accelerates the reaction, allowing more acid molecules to interact with the carbonate.

Conclusion: this experiment underscores the significance of surface area in determining the speed of chemical reactions.

Experiment 3:

Reaction time: $CaCO_3$ reacts with 0.1 M HCl for approximately 350 seconds.

Observation: a more concentrated HCl solution yields a faster reaction rate due to the greater availability of H+ ions.

Conclusion: demonstrates how reactant concentration influences the rate of reaction, with higher concentrations facilitating faster reactions.

Lessons learned:

Surface area effect: the reaction rate varies significantly with the surface area of reactants, demonstrating the importance of physical state in chemical kinetics.

Acid strength: the intrinsic strength of an acid determines its reactivity, with stronger acids catalyzing faster reactions.

Concentration's role: the concentration of reactants is directly proportional to the reaction rate, emphasizing the importance of molecular interactions in chemical processes.

Observational skills: accurate observation and data recording are crucial for drawing valid conclusions from experimental results.

Rate of reaction: the experiments collectively highlight how various factors like reactant nature, physical state, and concentration govern the speed of chemical reactions.

Acid-base reaction: the interaction between an acid and a base to produce salt, water, and carbon dioxide exemplifies fundamental acid-base reactions.

Collision theory: aligning with the collision theory, these experiments illustrate that reaction rates are influenced by the frequency and intensity of reactant collisions.

Overall conclusion: the experiments provide valuable practical insights into reaction kinetics, reinforcing the understanding of how different variables influence the rate of chemical reactions.

7.4.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to reaction rates, surface area, and concentration concepts.
- **Activities**: Observing reactions of solid and powdered calcium carbonate with different acids, noting simple differences in reaction speed, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of surface area effects, concentration effects, and acid reactivity.
- **Activities**: Conducting reactions with solid and powdered calcium carbonate using different concentrations of hydrochloric acid and ethanoic acid, measuring reaction times, comparing reactivity of different acids and forms of CaCO3, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced understanding of chemical kinetics, surface area effects, and concentration effects on reaction rates.
- **Activities**: Accurately conducting reactions with various forms of calcium carbonate and acids, measuring and recording reaction times and comparing the impact of different acid concentrations and types, analyzing experimental results to understand the influence of surface area and concentration on reaction rates, detailed recording and interpretation of results, adhering to advanced safety protocols, reinforcing concepts of chemical kinetics and practical application skills.

7.4.5 Laboratory essentials

Instrument(s):

Beakers (50ml, 100ml, 500ml & 1000ml).
Electronic Scale.
Graduated Cylinders (70ml & 100ml).
Hot plate.
Lab Stand & Clamps.
Magnetic stirrer.
Spatulas.
Test Tubes.
Thermometers.
Timer.
Tweezers.

Product(s):

Acetic acid 1.0M (CH3COOH).
Calcium carbonate (pieces).
Calcium carbonate (powder).
HCl 0.1M (solution).
HCl 1.0M (solution).

7.5 The influence of concentration on reaction rate 1 (Grades 9 to 12)

This laboratory session is designed to quantify the volume of gas produced from the reaction between powdered magnesium and hydrochloric acid at varying concentrations. Through this procedure, students will delve into the principles of chemical stoichiometry, reaction kinetics, and the influence of reactant concentration on reaction speed.

7.5.1 Educational Goals

- ***Stoichiometry and Gas Production:*** Students will explore the stoichiometric relationships between solid reactants and gaseous products in chemical reactions, enhancing their understanding of mass-to-gas conversions.
- ***Chemical Kinetics Exploration:*** The experiment allows observation of how varying concentrations of hydrochloric acid influence the rate of gas production, providing a practical example of reaction kinetics.
- ***Experimental Technique Development:*** Participants will refine their skills in using laboratory equipment for measuring gas volumes, improving their experimental methodology.
- ***Data Interpretation Skills:*** Students will learn to analyze experimental results to derive insights into chemical kinetics laws, fostering their ability to understand and apply chemical principles.

By engaging in this laboratory, students gain practical insights into the impact of reagent concentration on the speed of chemical reactions. They learn to accurately measure gas production during a reaction and analyze how different variables affect this process.

The experience reinforces the importance of precise experimental practices and data analysis in understanding fundamental chemistry principles, equipping students with the skills necessary for conducting experimental research.

7.5.2 Protocol

Part 1: Gas burette setup

a) Fill a 1-liter beaker with 800 mL of tap water.

b) Position this beaker next to the stand.

c) Install a universal clamp above the center of the beaker to support the gas burette.

d) Fill the gas burette with water.

e) While holding the burette upside down, block its opening with your thumb.

f) Place the inverted gas burette in the clamp, ensuring its opening is close to the bottom of the beaker.

g) Gently release your thumb to allow the burette to be immersed without losing water.

h) Adjust the setup if necessary to prevent water loss from the burette.

i) Attach a "J" shaped plastic connector under the opening of the gas burette.

Part 2: Reaction preparation

j) Measure 100 mL of 0.5 M hydrochloric acid (HCl) and pour into an Erlenmeyer flask.

k) Place the weighing boat on the balance scale and press tare to zero out.

l) Weigh the desired amount of magnesium powder (Mg) - about 0.2 g.

m) Insert the magnetic stirrer into the Erlenmeyer.

n) Start the stopwatch by pressing the red button.

o) Add the magnesium to the Erlenmeyer, then seal with a stopper fitted with a glass elbow.

p) Connect the rubber tube to the glass elbow and to the Erlenmeyer stopper, and place the Erlenmeyer on the heating plate without turning it on.

q) Activate the stirrer by pressing the button on the heating plate.

Part 3: Starting the reaction and data collection

r) Observe the formation of gas bubbles and their rise in the burette.

s) Note the volume of dihydrogen gas (H2) collected after the end of the reaction (about 245 seconds).

t) Empty the glassware contents into the recycling bin and clean with distilled water.

Part 4: Analysis of results and comparisons

u) Data on the amount of dihydrogen formed over time will be accessible via a graph in the tablet's graph tab.

v) Repeat the previous steps for hydrochloric acid concentrations of 1M and 2M, and compare the reaction times.

*** Note: the reaction is accelerated 2 times faster to more easily observe the complete reaction.*

7.5.3 Anticipated Outcomes

Using approx. 0,2 g of Magnesium and 100 mL of 0.5M HCl, the reaction should take approx. 468 seconds (234 secs accelerated x2), and the volume of H_2 produced should be approx. 212 mL.

At 1 M HCl, the reaction should take approx. 212 seconds (106 secs accelerated x2).

At 2 M HCl, the reaction should take approx. 100 seconds (50 secs accelerated x2).

7.5.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to reaction rates and gas production concepts.
- **Activities**: Observing gas production from reactions of powdered magnesium with different concentrations of hydrochloric acid, simple discussions on how concentration affects reaction speed, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of stoichiometry, reaction kinetics, and gas production.
- **Activities**: Conducting reactions with powdered magnesium and varying concentrations of hydrochloric acid, measuring the volume of gas produced, observing how concentration affects reaction rate, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced understanding of stoichiometry, reaction kinetics, and data interpretation.
- **Activities**: Accurately conducting reactions with powdered magnesium and different concentrations of hydrochloric acid, measuring and recording the volume of gas produced, analyzing the impact of reactant concentration on reaction rate, detailed recording and interpretation of results, adhering to advanced safety protocols, reinforcing concepts of chemical kinetics and stoichiometry.

7.5.5 Laboratory essentials

Instrument(s):

Beaker (500 ml, 1000 ml).
Electronic scale.
Elbow holed cap.
Erlenmeyer (250 ml).
Gaz burette.
Graduated cylinders (250 ml).
Hot plate.
Lab Stand & Clamps.
Magnetic stirrer.
Plastic connector.
Spatula.
Thermometers.
Timer.

Product(s):

HCl 0.5M (solution)
HCl 1.0M (solution)
HCl 2.0M (solution)
Magnesium (powder)

7.6 The influence of concentration on reaction rate 2 (Grades 9 to 12)

This protocol is centered on evaluating how the concentration of hydrochloric acid affects its reaction time with powdered magnesium and the resultant temperature changes.

Through this experimental setup, students will have the opportunity to delve into the principles of chemical kinetics, thermodynamics, and stoichiometry.

7.6.1 Educational Goals

- ***Chemical Kinetics:*** Gain an understanding of how the concentration of hydrochloric acid influences the speed of its reaction with magnesium, providing insights into reaction rates.
- ***Thermodynamics:*** Observe and record the temperature changes during the reaction to identify its exothermic or endothermic nature, enhancing comprehension of energy changes in chemical processes.
- ***Experimental Skills:*** Develop precision in measuring liquids and solids and in monitoring chemical reactions, improving experimental technique and accuracy.
- ***Analysis and Interpretation:*** Learn to analyze time-based and thermal data to understand the impact of reactant concentration on the reaction, fostering analytical and interpretive skills in chemistry.

By investigating the effect of hydrochloric acid concentration on its reaction with magnesium, this experience offers valuable insights into the dynamics of chemical reactions.

Students will not only observe firsthand the influence of reactant concentration on reaction rate and temperature changes but also apply these observations to understand the interplay between chemical kinetics and thermodynamics.

The skills and knowledge acquired through this laboratory are fundamental for designing chemical processes and for a deeper understanding of chemical reactions, preparing students for advanced studies and research in chemistry.

7.6.2 Protocol

Part 1: reaction with 1M HCl

1. Place the weighing boat on the balance scale.

2. Press the tare button to zero out the scale.

3. Weigh the desired amount of magnesium powder (Mg) - about 0.4g.

4. Place the reactant in the calorimeter.

5. Measure the desired amount of 1 M hydrochloric acid (HCl) (100 mL).

6. Note the initial temperature of the HCl.

7. Insert the thermometer into the hole located on the right on top of the lid.

8. Start the stopwatch by pressing the red button.

9. Pour the 1 M HCl into the calorimeter.

10. Place the lid on the calorimeter.

11. Activate the stirrer by pressing the green button on the calorimeter lid.

12. The temperature vs. time graph is on the tablet (graph tab).

13. Note the final temperature when the reaction ends (about 220 seconds).

14. Results can be found in the results tab on the tablet.

15. Empty the contents of the calorimeter into the recycling bin and clean with distilled water.

Part 2: reaction with 2M HCl

16. Measure 100 mL of 2M hydrochloric acid (HCl).

17. Repeat steps 4 to 15, comparing the two concentrations of HCl.

18. Observe and note the time needed for the reaction to reach completion, as previously indicated by temperature stabilization.

***Note: the reaction is accelerated 2 times faster to more easily observe the complete reaction.*

7.6.3 Anticipated Outcomes

Using approx. 0,41 g of magnesium and 100 mL of 1M HCl, the reaction should take approx. 490 seconds, or 245 seconds accelerated 2 times.

The molar enthalpy of reaction, for the reaction $Mg(s) + 2\ HCl\ (aq) = MgCl_2(aq) + H_2(g)$ is -440kJ for each mole of Mg(s). The energy released should be about 7.57 kJ, with a 18 °C temperature increase. Because Mg(s) is the limiting reagent, using smaller volume will increase time to reach reaction completion, given the smaller amount of HCl participating in the reaction.

Using HCl 2M will accelerate the reaction, which should take approx. 330 seconds, or 165 seconds accelerated 2 times.

7.6.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to reaction rates, temperature changes, and concentration effects.
- **Activities**: Observing reactions of powdered magnesium with hydrochloric acid at different concentrations, noting simple differences in reaction speed and temperature changes, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of reaction kinetics, thermodynamics, and concentration effects.
- **Activities**: Conducting reactions with powdered magnesium and varying concentrations of hydrochloric acid, measuring temperature changes, observing how concentration affects reaction rate and temperature, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced understanding of chemical kinetics, thermodynamics, and data analysis.
- **Activities**: Accurately conducting reactions with powdered magnesium and different concentrations of hydrochloric acid, measuring and recording temperature changes and reaction times, analyzing the impact of reactant concentration on reaction rate and thermal changes, detailed recording and interpretation of results, adhering to advanced safety protocols, reinforcing concepts of chemical kinetics, thermodynamics, and stoichiometry.

7.6.5 Laboratory essentials

Instrument(s):

Beaker (1000ml).
Calorimeter
Electronic Scale.
Graduated Cylinders (70ml & 250ml).
Spatulas.
Thermometers.
Timer.
Tweezers.

Product(s):

HCl 2.0M (solution).
HCl 1.0M (solution).
Magnesium (powder).

7.7 Hess's Law (Grades 9 to 12)

This laboratory session is designed as a comprehensive exploration of chemical reactions and thermal exchanges through four distinct experiments, each aimed at understanding different aspects of thermochemistry and chemical kinetics.

7.7.1 Educational Goals

- ***Volume and Temperature Measurement Techniques:*** Students will refine their skills in using graduated cylinders for volume measurements and thermometers for temperature observations, enhancing their precision and accuracy in experimental chemistry.
- ***Observation of Chemical Reactions:*** Participants will gain insights into the nature of chemical reactions, specifically how the mixing of different substances can lead to thermal changes, illustrating the principles of thermochemistry.
- ***Exploration of Reaction Variations:*** By altering components such as solvents or reactants, students will explore how experimental conditions affect reaction outcomes, fostering a deeper understanding of chemical kinetics.
- ***Thermochemistry and Kinetics Concepts:*** This laboratory aims to provide a practical understanding of thermochemistry and chemical kinetics, emphasizing the thermal effects of chemical reactions and the factors influencing reaction rates.

Through these experiences, students will not only become familiar with standard experimental procedures in chemistry but also gain practical experience in manipulating laboratory equipment and interpreting experimental data.

This hands-on approach to learning allows students to apply theoretical knowledge of chemistry to real-world scenarios, reinforcing their comprehension of fundamental principles within the discipline.

The laboratory session highlights the importance of precise measurement and control in chemical experimentation, offering valuable lessons in the thermal behavior of chemical reactions and the impact of varying experimental conditions.

7.7.2 Protocol

Experiment 1: Water + Alcohol

1. Measure 200 mL of water using the graduated cylinder.

2. Pour the water from the graduated cylinder into the calorimeter.

3. Record the initial temperature of the water.

4. Measure 200 mL of ethanol using the graduated cylinder.

5. Pour the ethanol into the calorimeter and then place the calorimeter lid on top.

6. Activate the agitator of calorimeter.

7. Carefully observe the temperature change and note the maximum (or minimum) temperature reached.

8. Empty the calorimeter into the sink and rinse it with room temperature distilled water.

9. Rinse the graduated cylinder with distilled water.

Experiment 2: Water + CaCO3

10. Measure 100.0 mL of water using the 100 mL graduated cylinder.

11. Pour the water from the graduated cylinder into the calorimeter.

12. Record the initial temperature of the water.

13. Weigh approximately 20g of CaCO3(s) using the weighing boat.

14. Pour the CaCO3 into the calorimeter.

15. Attach the calorimeter lid.

16. Activate the stirrer button on the calorimeter lid.

17. Carefully observe the temperature change and note the maximum (or minimum) temperature reached.

18. Empty the calorimeter into the waste beaker and rinse it with room temperature distilled water.

Experiment 3: Water + NH4Cl

19. Repeat Experiment 2, substituting CaCO3 with 10g of ammonium chloride (NH4Cl).

20. Rinse the graduated cylinder with distilled water.

Experiment 4: HCl + NaOH

21. Measure 50.0 mL of 0.5M sodium hydroxide (NaOH) using the graduated cylinder and pour it into the calorimeter.

22. Rinse the graduated cylinder with distilled water.

23. Take the initial temperature of the solution by immersing the digital thermometer in it. The results are in the table.

24. Measure 50.0 mL of 0.5M hydrochloric acid using the graduated cylinder and pour it into the calorimeter.

25. Attach the lid of the calorimeter to the calorimeter.

26. Activate the stirrer button on the calorimeter lid.

27. After a few seconds, note the temperature difference between that recorded by the thermometer (displayed in the table) and that recorded by the calorimeter's thermometer.

7.7.3 Anticipated Outcomes

Experiment 1:

Water + Ethanol: Expect an exothermic reaction. The temperature should increase, ideally by about 18-20°C, indicating energy release. When ethanol (C_2H_5OH) is mixed with water (H_2O), the two liquids form a solution. This process involves the breaking and forming of intermolecular forces. Initially, the hydrogen bonds between water molecules and the van der Waals forces between ethanol molecules are broken. New hydrogen bonds form between the water and ethanol molecules. The formation of these new intermolecular forces releases energy, resulting in an exothermic reaction that increases the temperature of the solution. The specific heat capacities of the substances and the total energy released during the formation of the new bonds contribute to the observed temperature change.

Experiment 2:

Water + $CaCO_3$: Since $CaCO_3$ is insoluble in water, no significant temperature change is expected, indicating no reaction.

Experiment 3:

HCl + $CaCO_3$: This should result in a reaction where $CaCO_3$ reacts with HCl to produce calcium chloride, water, and carbon dioxide, leading to a temperature increase of about 5 to 8 °C. This experiment involves an acid-base reaction where hydrochloric acid (HCl) reacts with calcium carbonate ($CaCO_3$) to form calcium chloride ($CaCl_2$), water (H_2O), and carbon dioxide (CO_2). This is a typical acid-carbonate reaction, which is usually exothermic. The breaking of the $CaCO_3$ lattice and the formation of new products releases energy, which may result in a temperature increase in the solution.

Experiment 4:

HCl + NaOH: An exothermic neutralization reaction is expected. The temperature should rise, ideally by about 5-7 °C, indicating the release of energy. This experiment features a neutralization reaction, a type of exothermic reaction where an acid (HCl) and a base (NaOH) react to form water (H_2O) and a salt (NaCl). During the reaction, the hydrogen ions (H^+) from the acid react with the hydroxide ions (OH^-) from the base to form water. This reaction releases energy, increasing the temperature of the mixture.

In each experiment, the observed temperature changes are indicators of the energy dynamics involved in the chemical processes, reflecting the exothermic or endothermic nature of the reactions.

7.7.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to chemical reactions, temperature changes, and measurement techniques.
- **Activities**: Observing simple thermal changes during chemical reactions, using thermometers and graduated cylinders, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of thermochemistry, chemical kinetics, and measurement accuracy.
- **Activities**: Conducting reactions, measuring volumes and temperatures, observing how different reactants and solvents affect reaction outcomes, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced understanding of thermochemistry, Hess's Law, and experimental precision.
- **Activities**: Accurately measuring volumes and temperatures, conducting detailed experiments to explore the thermal effects of chemical reactions, analyzing how changes in reactants and solvents influence reaction rates, detailed recording and interpretation of results, adhering to advanced safety protocols, reinforcing concepts of chemical kinetics and thermodynamics.

7.7.5 Laboratory essentials

Instrument(s):

Beaker (500ml & 1000ml).
Calorimeter
Electronic Scale.
Graduated Cylinders (70ml & 250ml).
Spatulas.
Thermometers.
Timer.
Tweezers.

Product(s):

Calcium carbonate
Ethanol.
HCl 0.3M (solution).
HCl 0.5M (solution).
Sodium hydroxide 0.5M.

8 CHEMICAL BALANCE

8.1 The qualitative aspect of chemical equilibrium (Grades 9 to 12)

This laboratory session is meticulously designed to delve into the interactions between various salt solutions and the formation of precipitates, thereby examining direct and reversible chemical reactions.

8.1.1 Educational Goals

- ***Precipitation reactions:*** Students will deepen their understanding of how ions in solutions interact to form insoluble compounds, showcasing the dynamics of precipitation reactions.
- ***Solubility concepts:*** Through observation, participants will explore the effects of salt solubility in water on precipitate formation, enhancing their grasp of solubility principles.
- ***Reversible reactions:*** The session aims to provide insights into reversible chemical reactions by studying both direct and reverse processes, thus fostering a comprehensive understanding of chemical equilibrium.
- ***Development of laboratory skills:*** Students will enhance their practical skills in handling solutions, observing chemical reactions, and documenting scientific findings, emphasizing the importance of precision and accuracy in experimental chemistry.

Through this series of experiments, students will not only familiarize themselves with standard chemical procedures but also gain valuable practical experience in manipulating laboratory equipment and interpreting experimental outcomes.

This hands-on approach enables the application of theoretical chemistry knowledge to real-world scenarios, reinforcing foundational principles of the discipline.

The laboratory session underscores the significance of meticulous measurement and control in chemical experimentation, providing essential lessons in the study of chemical reactions, particularly focusing on the thermal behavior of reactions and the influence of varying experimental conditions on reaction outcomes.

8.1.2 Protocol

Part 1: Preparation of solutions

a) Dissolve about 16 g of NaCl in 50 mL of warm water in a 50 mL beaker to prepare an aqueous solution of sodium chloride.

b) Observe the initial appearance of the three studied solutions: sodium chloride, calcium chloride, and sodium sulfate.

c) Briefly stir each solution with a glass rod to homogenize.

Part 2: Study of the equilibrium reaction CaCl2 (aq) + Na2SO4(aq) = 2 NaCl (aq) + CaSO4(s)

Part 2-1

a) Measure 10 mL of distilled water and pour it into test tube #1.

b) Using a pipette, measure 5 mL of 0.005M CaCl2 solution and pour it into test tube #1.

c) Vigorously shake the contents of the test tube.

d) Observe the appearance of the solution while stirring with a glass rod.

e) Using a pipette, measure 5 mL of 0.005M Na2SO4 solution and pour it into test tube #1.

f) Vigorously shake the contents of the test tube.

g) Observe the appearance of the solution while stirring with a glass rod.

Part 2-2

h) Using a pipette, measure 5 mL of 0.005M CaCl2 solution and pour it into test tube #1.

i) Vigorously shake the contents of the test tube.

j) Observe the appearance of the solution while stirring with a glass rod.

k) Using a pipette, measure 5 mL of 0.005M Na2SO4 solution and pour it into test tube #1.

l) Vigorously shake the contents of the test tube.

m) Observe the appearance of the solution while stirring with a glass rod.

Part 2-3

n) Using a pipette, measure 5 mL of distilled water and pour it into test tube #1.

o) Vigorously shake the contents of the test tube.

p) Observe the appearance of the solution while stirring with a glass rod.

Part 2-4

q) Using a pipette, measure 5 mL of 0.005M CaCl2 solution and pour it into test tube #1.

r) Vigorously shake the contents of the test tube.

s) Observe the appearance of the solution while stirring with a glass rod.

t) Using a pipette, measure 5 mL of 0.005M Na2SO4 solution and pour it into test tube #1.

u) Vigorously shake the contents of the test tube.

v) Observe the appearance of the solution while stirring with a glass rod.

w) Comment on your observations.

Part 3: Study of the direct reaction

a) Measure 10 mL of the supernatant from test tube #1, and pour it into test tube #2.

b) Using a dropper, measure 1 mL of 0.005M CaCl2 solution and pour it into test tube #2.

c) Vigorously shake the contents of the test tube.

d) Observe the appearance of the solution while stirring with a glass rod.

e) Using a dropper, measure 1 mL of 0.005M Na2SO4 solution and pour it into test tube #2.

f) Vigorously shake the contents of the test tube.

g) Observe the appearance of the solution while stirring with a glass rod.

h) Comment on your observations.

Part 4: Adding reactants (Na+ and Cl-) to favor the reverse reaction

a) Measure 50 mL of NaCl solution prepared in part 1, and pour it into test tube #3.

b) Observe the appearance of the solution while stirring with a glass rod.

c) Add about 5g of NaCl to test tube #3.

d) Vigorously shake the contents of the test tube.

e) Observe the appearance of the solution while stirring with a glass rod.

f) Measure 20 mL of the supernatant from test tube #3, and pour it into test tube #4.

g) Observe the appearance of the solution while stirring with a glass rod.

h) Using a pipette, measure 5 mL of 0.005M CaCl2 solution and pour it into test tube #4.

i) Vigorously shake the contents of the test tube.

j) Observe the appearance of the solution while stirring with a glass rod.

k) Using a pipette, measure 5 mL of 0.005M Na2SO4 solution and pour it into test tube #4.

l) Vigorously shake the contents of the test tube.

m) Observe the appearance of the solution while stirring with a glass rod.

n) Comment on your observations.

o) Dispose of the contents of the test tubes into the black recovery bin and rinse thoroughly with distilled water to remove any chemical residues.

8.1.3 Anticipated Outcomes:

Appearance of initial solutions:

- NaCl solution: An incolor and transparent solution.

- $CaCl_2$ solution: An incolor and transparent solution.
- Na_2SO_4 solution: An incolor and transparent solution.

Part 2: Study of the equilibrium reaction CaCl2 (aq) + Na2SO4(aq) = 2 NaCl (aq) + CaSO4(s)

- a) to g) The solution is clear, indicating we are below the solubility threshold of CaSO4, which is 0.2 g/L (CaSO4 is in solution). The concentration of CaSO4 is 0.17g/L. 0.000025 moles of CaCl2 and Na2SO4 reacted together.
- h) Adding CaCl2 will increase the concentration of Ca2+ ions, but the SO42- ions stay at the same concentration (limiting reactants), thus no new CaSO4(s) is formed.
- m) A white precipitate forms (CaSO4(s)), indicating the direct reaction is favored, and the solubility threshold is exceeded. The concentration of CaSO4 is 0.23g/L.0.00005 moles of CaCl2 and Na2SO4 reacted together.
- p) Adding 5 mL of H2O brings the total volume to 35 mL, thus returning below the solubility threshold for CaSO4(s). The white precipitate disappears. The concentration of CaSO4 is 0.19g/L. 0.00005 moles of CaCl2 and Na2SO4 reacted together.
- q) to w) A white precipitate forms (CaSO4(s)), indicating the direct reaction is favored, and the solubility threshold is exceeded again. The concentration of CaSO4 is 0.23g/L. 0.000075 moles of CaCl2 and Na2SO4 reacted together.

General comments: While we cannot measure directly the quantities of Ca2+, SO42-, and CaSO4(s), we measure indirectly the direct reaction by observing the precipitation of CaSO4(s). However, to visually measure this experiment, we have to exceed its solubility threshold. These observations indicate that the reaction between the compounds leads to the formation of a precipitate, which likely corresponds to calcium sulfate (CaSO4), demonstrating the occurrence of a chemical reaction and the establishment of a chemical equilibrium where reactants and products coexist.

Part 3: Study of the direct reaction

- The supernatant liquid contains small amounts of Ca2+ and SO42- ions, proportional to the solubility threshold of CaSO4(s) (as well as Cl- and Na+ ions). Adding more reactants will favor the direct reaction and bring the concentration of CaSO4 above its solubility threshold. A white precipitate forms. This ongoing formation of precipitate suggests that the ions Ca2+ and SO42- remain active in the reaction mixture, reinforcing the concept of chemical equilibrium where reactants and products coexist, and the reaction can proceed in both forward and reverse directions.

Part 4: Adding reactants (Na+ and Cl-) to favor the reverse reaction

- b) The initial solution concentration of NaCl is 320 g/L, which is near its solubility threshold of 360 g/L.
- e) Adding 5g to the solution increases the concentration to 420 g/L, thus exceeding the threshold and forming a precipitate of NaCl(s).

- m) We mix a saturated solution of CaSO4 (aq) with a saturated solution of NaCl (aq), as well as Cl- and Na+ ions originating from CaCl2(aq) and Na2SO4(aq). Theoretically, we could obtain precipitates in the form of NaCl(s), Na2SO4(s), CaCl2(s), or CaSO4(s). However, considering the concentrations of each ion and the total volume of the solution (30 mL), we are below the solubility threshold of each solid product. While we can theorize that direct reactions are favored, we cannot confirm this with this part of the experiment.
- Coexistence of ions: even after the reaction reaches equilibrium, the presence of unreacted Ca^{2+} and SO_4^{2-} ions indicates the dynamic nature of the equilibrium, where forward and reverse reactions occur at the same rate.
- The experiment demonstrates that despite the formation of a precipitate, indicating a reaction, there are still reactants present in the solution, which is a hallmark of chemical equilibrium.
- The addition of more reactants leads to further formation of the precipitate, illustrating Le Chatelier's Principle, where the system adjusts to minimize the change (addition of reactants).

Lessons learned

Chemical equilibrium: understanding that at equilibrium, the forward and reverse reactions continue to occur at equal rates, allowing the coexistence of reactants and products.

Dynamic nature of equilibria: equilibrium does not mean the reactions have stopped but that they are occurring at equal rates in both directions.

Reversibility: the experiment underlines that chemical equilibria are reversible, and the presence of products and reactants is essential for the equilibrium state.

Control of reaction conditions: the experiment emphasizes the importance of controlled experimental conditions to study equilibrium, ensuring reactants are in the correct stoichiometric ratios.

Chemistry principles

Equilibrium concept: the experiment illustrates the basic concept of chemical equilibrium, showing that reactions can reach a state where the rate of the forward reaction equals the rate of the reverse reaction.

Precipitation reaction: the formation of a solid precipitate from aqueous solutions demonstrates a common type of chemical reaction where ions combine to form an insoluble compound.

Le Chatelier's principle: this principle is indirectly observed as the system adjusts to changes (addition of more reactants) by forming more products.

Reaction reversibility: highlighting that many chemical reactions are reversible, which is a foundational concept for understanding chemical equilibrium.

This experiment offers a practical demonstration of chemical equilibrium, showcasing how, under equilibrium conditions, reactants and products coexist and how the system responds to changes, reinforcing key concepts in chemical kinetics and equilibrium.

8.1.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to chemical reactions and observation of precipitates.
- **Activities**: Simple observations of salt solutions forming precipitates, understanding basic concepts of solubility, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of precipitation reactions, solubility, and reversible reactions.
- **Activities**: Conducting experiments to form precipitates, observing effects of salt solubility, exploring reversible reactions, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced understanding of chemical equilibrium, precipitation reactions, and experimental precision.
- **Activities**: Accurately conducting experiments to study precipitation reactions, measuring and analyzing solubility effects, exploring both direct and reversible reactions, detailed recording and interpretation of results, adhering to advanced safety protocols, reinforcing concepts of chemical equilibrium and solubility principles.

8.1.5 Laboratory essentials

Instrument(s):

Beakers (50ml, 250ml & 1000ml)
Electronic scale
Glass rod
Graduated cylinders (10ml & 70ml)
Hot plate
Lab stand & clamps
Magnetic stirrer
Spatulas
Test Tubes
Thermometers

Product(s):

Droppers
Distilled water
Sodium chloride (crystals)
Sodium sulfate 0.005M (solution)
Calcium chloride 0.005M (solution)

8.2 Le Chatelier's Principle (Grades 9 to 12)

This laboratory session delves into the chemical reactions between potassium thiocyanate (KSCN) and iron nitrate ($Fe(NO_3)_3$), focusing on observing the color changes and precipitate formation that occur under varying conditions, including temperature changes and the addition of different reagents.

8.2.1 Educational Goals

- ***Chemical Reactions:*** Students will explore the interaction between iron and thiocyanate ions to form colorful complexes, enhancing their understanding of reaction mechanisms.
- ***Temperature Effects:*** The experiment allows observation of how temperature variations impact the speed and direction of chemical reactions, demonstrating the influence of thermal energy on chemical processes.
- ***Analytical Chemistry Applications:*** Participants will learn about the application of complexation reactions in chemical analysis, gaining insights into analytical techniques.
- ***Development of Experimental Skills:*** Students will refine laboratory techniques, including solution handling, experimental condition adjustment, and qualitative reaction observation, improving their practical chemistry skills.

Through this experiment, students will gain a practical understanding of complex chemistry, observing firsthand how variables such as reagent concentration and temperature can affect chemical reactions.

This hands-on experience enhances knowledge of inorganic and analytical chemistry's fundamental principles, illustrating the dynamic nature of chemical interactions and the critical role of experimental conditions in determining reaction outcomes.

8.2.2 Protocol

1. Preparation of base solutions

a) Measure 50 mL of 0.001M KSCN solution using a graduated cylinder.

b) Pour the measured solution into a 50 mL beaker.

c) Add 12 drops of 0.5M Fe(NO3)3 solution to the beaker.

d) Stir the mixture with a glass rod.

e) Distribute the obtained solution into eight test tubes (about 6 mL per test tube).

2. Changing the equilibrium point

f) Add about 1.5 to 2g of KSCN powder to test tube #2 using a spatula.

g) Add between 1.5 and 2g of iron nitrate crystals to test tube #3.

h) Add between 1.5 and 2g of KSCN to test tube #4.

i) Shake test tubes #2, #3, and #4.

j) Add between 1.5 and 2g of iron nitrate crystals to test tube #4.

k) Shake test tube #4.

l) Add 1 or 2 drops of KOH to test tube #5 and shake.

m) Add between 1.5 and 2g of Na2HPO4 to test tube #6 and shake.

n) Prepare an ice bath by filling a 250ml beaker halfway with water and ice and then place test tube #7 in it.

o) Fill another 250 mL beaker with water and place it on a heating plate to immerse test tube #8.

p) Insert the magnetic stirrer into the beaker on the heating plate and start the stirrer.

q) Heat the water to about 80°C.

r) Stir test tube #7 while it is immersed in the ice bath.

s) Observe the changes in each test tube, noting differences in color or precipitation.

t) Turn off the heating plate and magnetic stirrer once the experiment is completed.

u) Shake all the test tubes one last time to homogenize the reactions.

v) Record the colors of test tubes #2 to #8, referencing control test tube #1.

w) Rinse the used equipment with distilled water after retrieving the magnetic stirrer.

8.2.3 Anticipated Outcomes

- Test tube #1: Serves as the reference color, consistently described as reddish or reddish-brown, for the equilibrium mixture of Fe^{3+}, SCN^{-}, and $FeSCN^{2+}$.
- Test tube #2: Shows a darker reddish-brown or darker red color, indicating an increase in $FeSCN^{2+}$ concentration when KSCN is added, demonstrating a shift in equilibrium toward product formation.

- Test tube #3: Maintains the reference reddish-brown color, indicating no additional $FeSCN^{2+}$ formation, as SCN- is the limiting reactant.
- Test tube #4: Exhibits a very dark reddish-brown or darkest red color, the most intense among all, suggesting a significant increase in $FeSCN^{2+}$ due to the addition of both $Fe(NO_3)_3$ and KSCN, marking a substantial shift toward products.
- Test tube #5: Presents a light brown color with a red precipitate, indicating the formation of $Fe\ (OH)_3$ from Fe^{3+} reacting with OH^-.
- Test tube #6: Presents a light brown color with a brownish precipitate, indicating the formation of FePO4 from Fe^{3+} reacting with PO4-.
- Test tube #7: Displays a darker reddish-brown or paler red color upon cooling, suggesting the favored formation of $FeSCN^{2+}$, consistent with an exothermic process.
- Test tube #8: Shows a lighter reddish-brown or lighter brown color upon heating, indicating a shift toward reactants, favoring the endothermic dissociation of $FeSCN^{2+}$ into Fe^{3+} and SCN^-.

The experiment vividly demonstrates Le Chatelier's Principle, showing how the system responds to changes in concentration, temperature, and the presence of additional reactants or products. The color changes in each test tube provide a qualitative measure of the shifts in equilibrium, highlighting the dynamic nature of chemical equilibria and the factors that influence them. This approach allows for a visual understanding of equilibrium shifts, reinforcing the theoretical concepts with tangible evidence.

Adding reactants (KSCN or $Fe(NO_3)_3$) shifts the equilibrium toward more product formation ($FeSCN^{2+}$), as evidenced by the darker color.

Removing a reactant or product (as in test tube #5 and #6) shifts the equilibrium to compensate, here reducing $FeSCN^{2+}$ concentration.

Temperature changes also affect the equilibrium; cooling favors exothermic reactions, while heating favors endothermic reactions.

Lessons learned

Le Chatelier's Principle: the experiment vividly demonstrates how a system at equilibrium responds to external changes to maintain balance.

Equilibrium shifts: understanding that the addition of a reactant or product shifts the equilibrium toward one side, while its removal shifts it toward the other.

Effect of temperature: observing how temperature changes influence equilibrium, offering insight into the exothermic or endothermic nature of reactions.

Chemistry principles behind

Chemical equilibrium: the dynamic balance where the rate of the forward reaction equals the rate of the reverse reaction.

- Color change as an indicator: the change in color intensity serves as a qualitative indicator of the shift in equilibrium concentrations.
- Precipitation reactions: the formation of $Fe(OH)_3$ demonstrates how precipitate formation can be used to deduce changes in ion concentrations in a reaction mixture.

This experiment provides a hands-on understanding of how equilibria respond to changes in conditions, illustrating the adaptability of chemical systems to maintain balance, aligning with Le Chatelier's Principle.

8.2.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to chemical reactions and observation of color changes.
- **Activities**: Simple observations of color changes when mixing potassium thiocyanate and iron nitrate, understanding basic concepts of chemical reactions, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of reaction mechanisms, temperature effects, and basic analytical chemistry.
- **Activities**: Conducting experiments to observe color changes and precipitate formation, measuring temperature effects on reaction rates, exploring basic analytical techniques, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced understanding of Le Chatelier's Principle, complexation reactions, and analytical chemistry applications.
- **Activities**: Accurately conducting experiments with potassium thiocyanate and iron nitrate, observing and recording the impact of varying conditions, analyzing the effects of temperature and reagent concentration, detailed recording and interpretation of results, adhering to advanced safety protocols, reinforcing concepts of chemical equilibrium and reaction mechanisms.

8.2.5 Laboratory essentials

Instrument(s):

Beakers (50ml, 250ml & 1000ml).
Droppers.
Electronic Scale.
Glass Rod.
Graduated Cylinders (10ml & 70ml).
Hot plate.
Lab Stand & Clamps.
Magnetic stirrer.
Spatulas.
Test Tubes.
Thermometers.

Product(s):

Iron nitrate (solution)
Iron nitrate (crystals)
Potassium hydroxide (solution)
Potassium thiocyanate (solution)
Potassium thiocyanate (powder)
Sodium hydrogen phosphate (powder)

9 ELECTROCHEMISTRY

9.1 Water electrolysis (Grades 9 to 12)

This laboratory session meticulously outlines an experiment focused on observing chemical reactions between various salt solutions to investigate the formation of precipitates.

Through a series of structured parts, the experiment delves into both direct and reversible reactions.

9.1.1 Educational Goals

- ***Precipitation Reactions:*** Participants will gain insights into how ions in solutions interact to form insoluble compounds, deepening their understanding of precipitation reactions.
- ***Solubility:*** The experiment allows students to observe the effects of salt solubility in water and its impact on precipitate formation, enhancing comprehension of solubility principles.
- ***Reversible Reactions:*** Students will explore the concept of reversible chemical reactions by examining both direct and reverse processes, fostering a broader understanding of chemical dynamics.
- ***Laboratory Skills Development:*** This session aims to hone students' practical skills in handling solutions, observing chemical reactions, and accurately documenting scientific findings.

By engaging in this experiment, students will not only observe the critical role of precipitation reactions within the fields of analytical and inorganic chemistry but also acquire hands-on experience in how ions in solutions interact to create new compounds.

This practical exploration into precipitation, solubility, and reversible reactions not only reinforces theoretical knowledge but also enhances laboratory competencies, preparing students for further scientific endeavors.

9.1.2 Protocol

1. Light a piece of wood then turn it into a red-hot ember by shaking it.

2. Insert the ember into test tubes 1 and 2 without touching the sides. Note the result.

3. Pour about 10mL of water into test tubes 1 and 2.

4. Place the test tubes back on the stand.

5. Fill the 1L beaker with at least 750mL of water.

6. Fill the two test tubes to the brim with water and insert their stoppers.

7. Attach the universal clamps to the universal stands, one clamp per stand. The 1L beaker should be positioned under the 2 clamps, at the center.

8. Immerse the two test tubes upside down in the 1L beaker (the opening of the test tubes must always remain submerged during this part of the experiment) and secure them to the universal clamps.

9. Remove the stoppers from the test tubes while keeping them submerged. Ensure that air bubbles have not lodged at their upper end.

10. Insert an electrode inside each of the test tubes (Test tube 1 will be positive and test tube 2 will be negative).

11. Attach the crocodile clip of the red wire to the electrode in test tube 1 and the crocodile clip of the black wire to the electrode in test tube 2.

12. Using the two conducting wires equipped with crocodile clips, connect electrode 1 to the positive terminal (right) of the current generator and the other (electrode 2) to its negative terminal (left). The terminals are white and located at the bottom of the front face of the generator.

13. Measure 15 mL of hydrochloric acid using the graduated cylinder.

14. Pour the contents of the graduated cylinder into the 1L beaker.

15. Stir the mixture for a few seconds using the glass rod.

16. Connect and turn on the current generator. Start the stopwatch.

17. Allow the reaction to occur for about 1 minute. Stop the stopwatch.

18. Turn off and unplug the generator.

19. Seal the test tubes under water with the rubber stoppers.

20. Take test tube 1 out of the water, stopper down, and secure it to the left stand using its clamp.

21. Light a piece of wood then turn it into a red-hot ember by shaking it, then bring it close to test tube 1 (positive).

22. Remove the stopper from test tube 1 and while keeping the opening of the test tube 1 facing down, quickly insert the ember without touching the sides.

23. Place the test tube back on the stand.

The reaction is recorded in the results table.

24. Repeat steps 20 to 23 with test tube 2.

9.1.3 Anticipated Outcomes

Participants embark on an experiment designed to explore the electrochemical decomposition of water into hydrogen and oxygen gases. This experiment not only demonstrates a fundamental chemical reaction but also integrates concepts of electrochemistry, gas collection, and reactivity tests.

Gas generation: When the current passes through the water in the presence of hydrochloric acid (which acts as an electrolyte), electrolysis occurs. This process splits water molecules into hydrogen and oxygen gases, collected in the two test tubes.

Observation of gas reactivity: The red-hot ember introduced into test tube 1 (rich in oxygen from the electrolysis process) should reignite or glow brighter, demonstrating oxygen's role in supporting combustion. In contrast, when the ember is introduced into test tube 2 (containing hydrogen), there might be a gentle pop sound due to hydrogen's flammability and its tendency to react explosively with oxygen in the air when ignited.

Significance and lessons learned:

Understanding electrolysis: This experiment provides a clear visualization of electrolysis, an important chemical process with applications ranging from industrial chemical production to the development of clean energy technologies.

Chemical principles and safety: Participants learn to handle chemicals and conduct experiments safely while observing firsthand the reactive properties of hydrogen and oxygen, two fundamental elements in chemistry.

Practical skills: The experiment enhances skills in setting up experimental apparatus, conducting controlled reactions, and interpreting observable results, which are critical competencies in scientific research and laboratory work.

Conceptual connections: By linking theoretical knowledge with practical experience, the experiment reinforces understanding of chemical reactions, stoichiometry (the 2:1 volume ratio of hydrogen to oxygen produced in water electrolysis), and the basic principles of electrochemistry.

This lab exercise not only deepens the understanding of chemical and physical properties of water and its constituent gases but also exemplifies the interconnected nature of scientific concepts, demonstrating how they can be applied to understand and manipulate the natural world.

9.1.4 Summary of Assignment by Grade Range

Grades 3-5 (Ages 8-10)

- **Focus**: Basic introduction to electrolysis and simple observations of gas formation.
- **Activities**: Observing water electrolysis and noting the formation of bubbles (hydrogen and oxygen gases), simple discussions on the process of electrolysis, basic safety instructions.

Grades 6-8 (Ages 11-13)

- **Focus**: Intermediate understanding of electrolysis, chemical reactions, and gas production.
- **Activities**: Conducting water electrolysis, measuring gas production at electrodes, understanding the basic principles of electrolysis, following detailed safety protocols.

Grades 9-12 (Ages 14-18)

- **Focus**: Advanced understanding of electrolysis, chemical reactions, and stoichiometry.
- **Activities**: Accurately conducting water electrolysis, measuring and recording gas volumes, analyzing the reaction mechanisms, detailed recording and interpretation of results, adhering to advanced safety protocols, reinforcing concepts of chemical reactions and gas production.

9.1.5 Laboratory essentials

Instrument(s):

Beaker (750 ml & 1000 ml).
Electrical wires.
Glass rod.
Graduated cylinder (25 ml).
Lab power supply.
Lab stand & Clamps.
Test tubes.
Test tubes electrodes.
Timer.
Wood pieces.

Product(s):

HCl 1.0M (solution).

This laboratory session meticulously outlines an experiment focused on observing chemical reactions between various salt solutions to investigate the formation of precipitates.

Through a series of structured parts, the experiment delves into both direct and reversible reactions.

9.1.6 Educational Goals

- ***Precipitation Reactions:*** Participants will gain insights into how ions in solutions interact to form insoluble compounds, deepening their understanding of precipitation reactions.
- ***Solubility:*** The experiment allows students to observe the effects of salt solubility in water and its impact on precipitate formation, enhancing comprehension of solubility principles.
- ***Reversible Reactions:*** Students will explore the concept of reversible chemical reactions by examining both direct and reverse processes, fostering a broader understanding of chemical dynamics.
- ***Laboratory Skills Development:*** This session aims to hone students' practical skills in handling solutions, observing chemical reactions, and accurately documenting scientific findings.

By engaging in this experiment, students will not only observe the critical role of precipitation reactions within the fields of analytical and inorganic chemistry but also acquire hands-on experience in how ions in solutions interact to create new compounds.

This practical exploration into precipitation, solubility, and reversible reactions not only reinforces theoretical knowledge but also enhances laboratory competencies, preparing students for further scientific endeavors.

10 Activities soon to be released

Electricity / Setting up an electrical circuit

AUGUST 2024

Electricity / Setting up an electrical circuit

Biology / Observation of saliva

Biology / Observation of stools

Biology / Observation of lake water

Biology / Observation of the anatomy of a shark

Chemical and Physical Properties / Centrifugation

Multiplayer

Compatibility with Pico 3 / 4

Audio protocol (English only)

FALL 2024

Chemical and Physical Properties / Radioactive elements for radiotherapy

Preparation of Solutions / Injectable preparation

Optics / The area of an illuminated zone as a function of the distance from the light source

Optics / The law of specular reflection

Optics / The analysis of the functioning of a telescope

Optics / The refractive index of a transparent substance

Optics / The relationship between the critical angle and the refractive index of a substance

Optics / The modeling of an optical microscope

Optics / The refraction of lasers

Voice control

PROTEUS VR

USER GUIDE

LABS

11 Welcome to Proteus Labs

We extend our sincerest gratitude for selecting Proteus Labs as your companion in enriching the practical component of your science curriculum. At Proteus Labs, we are dedicated to continually enhancing our library, ensuring you have access to an extensive range of engaging activities.

Proteus Labs stands unparalleled as the premier Virtual Reality laboratory simulation available in the market, distinguished by its exclusive features:

- ***Empirical Foundation:***
  Every result is derived from empirical research and authentic chemical equations, ensuring accuracy and reliability.
- ***Interactive Instruments:***
  Experience full interactivity with all laboratory instruments, designed for an immersive learning environment.
- ***Automated Lab Journal:***
  Benefit from an auto-filling lab journal, conveniently delivered to you via email or USB, for effortless record-keeping and review.
- ***Multiplayer Capability:***
  Engage in collaborative experiments with up to five users in the same lab environment simultaneously, fostering teamwork and peer learning.
- ***Advanced Protocols:***
  Access pre-built and custom protocols, set to expand your experimental possibilities from March 2024 onwards.
- ***Wide Compatibility***:
  Designed for seamless integration with leading mobile VR headsets, including Meta Quest 2, 3, and Pro, ensuring a broad access spectrum.

By choosing Proteus Labs, you are embarking on a journey of discovery and innovation. We are excited to support you in exploring the vast potential of VR in scientific education.

12 Installing Proteus Labs

To embark on your journey with Proteus Labs, please follow these simple steps to download the application:

- ***Navigate to the Oculus Store:*** Open the Oculus Store on your device.
- ***Search for Proteus Labs:*** In the search bar, enter "Proteus Labs" (ensure you include the space between the words for accurate results).
- ***Locate the App in App Lab:*** Scroll down to the "App Lab" section, located at the bottom of the search results.
- ***Download the Application:*** Click on "See the App" to proceed. The download is complimentary and will commence immediately upon your confirmation.

We have designed this process to be as seamless as possible, ensuring you can quickly and efficiently set up Proteus Labs and start exploring the virtual laboratory environment. Should you encounter any issues during the installation process, our support team is readily available to assist you.

13 Navigating The Virtual Lab In Proteus Labs

Welcome to the intuitive and seamless virtual lab experience at Proteus Labs. To cater to diverse user preferences and ensure enhanced accessibility, we offer two distinct modes of interaction: Controller Mode and Hand Tracking Mode.

Controller Mode:

With precision-engineered controllers, tasks become straightforward and intuitive. Each controller is ergonomically designed to provide comfort and responsive control. Key functions include:

- *Grip:* Grab objects in the VR environment using the hand trigger.
- *Special action:* Perform context-sensitive actions with the index trigger.
- *Menu:* Open the VR application or system menu with the Oculus button.

Action	Controller Button
Grip	Hand Trigger
Special Action	Index Trigger
Menu	Oculus Button

Hand Tracking Mode:

For a more naturalistic approach, engage with the VR lab using your own hands. This innovative feature recognizes and translates your hand gestures into dynamic actions:

- *Grip (A):* Grasp objects by forming a fist with your pinky, ring, and middle fingers.
- *Special action (B):* Activate different actions with an open hand.
- *Menu (C):* Access the menu by pinching your index finger and thumb together while your hand faces the headset.

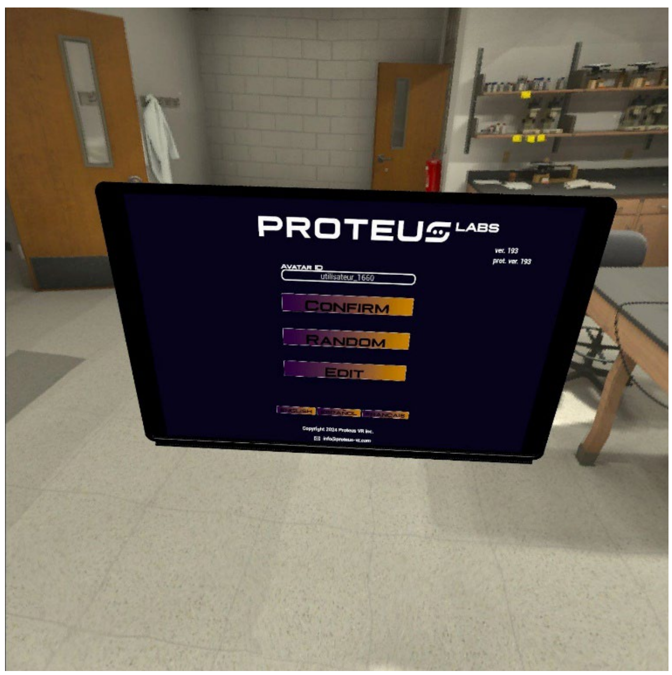
A	B	C
		

Proteus Labs provides an adaptable and effortless interaction experience. Whether you choose the tactile precision of our controllers or the unencumbered freedom of hand gestures, our system is designed to naturally integrate with your preferred style of interaction. Our aim is to ensure that you can focus on learning and exploration in our virtual lab with ease and comfort.

14 Accessing The Start Menu On Proteus Labs

Upon initiating Proteus Labs on your registered device, you will be presented with the Start Menu, which includes several options for customization and setup:

- ***Avatar ID:*** Enter your unique Avatar ID for individual identification within the lab. This ID will also be used for engaging in multiplayer activities.
- ***Confirm Button:*** After entering your Avatar ID, click the green check mark to confirm your entry and proceed.
- ***Random Button:*** If you prefer a randomly generated Avatar ID, simply press the 'Random' button for an auto-assigned identifier.
- ***Edit Button:*** To change your current Avatar ID, use the 'Edit' button to adjust.
- ***Language Selection:*** Choose from various languages to personalize your experience in the lab according to your language preference.



Each feature is designed to optimize your entry into the virtual lab, ensuring a tailored and smooth start to your scientific exploration in Proteus Labs.

15 Selecting Your Category Of Interest

Following the initial setup in the Start Menu, you will arrive at the main hub of Proteus Labs where you can select the specific category that aligns with your interests or study needs. Our categories are organized to help you find the perfect activity or experiment with ease:

To choose a category within Proteus Labs:

Controllers:

Aim your controller at the desired category's cover displayed on the screen. A single click will select it.

Hand Tracking:

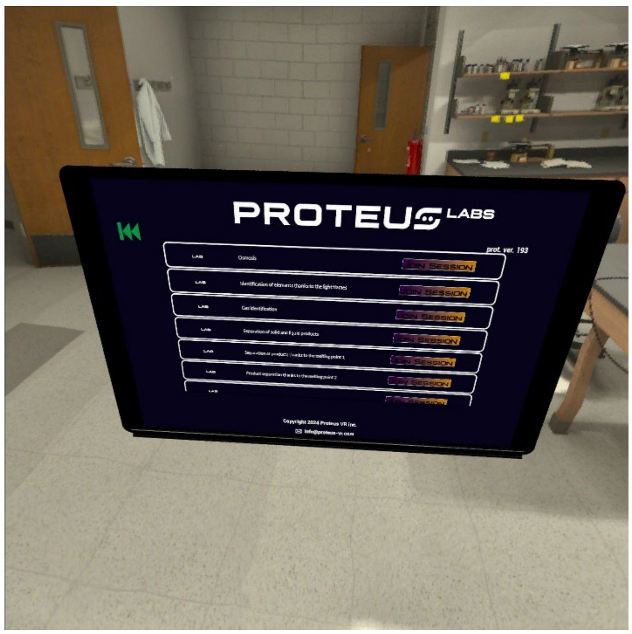
Simply reach out and touch the cover representing your chosen category. This direct contact will confirm your selection and take you to the respective activities and simulations.

16 Engaging With Activities

Once you've selected a category, a curated list of activities will be displayed. Here’s how to join an activity:

Look for the 'Join session' option next to the activity you're interested in. A simple click on 'Join session' will enroll you into the activity, ready to begin your virtual lab experience.

Selecting an activity is designed to be as straightforward as possible, allowing you to dive right into the heart of Proteus Labs without any unnecessary complexity.



17 Inside the Lab: Navigating Your Activities

Proteus Labs is designed to provide a consistent and intuitive experience across all our virtual lab activities. Here's what to expect when you start an activity:

- ***Ready-to-Use Lab Space:***
  Each activity begins in a fully equipped laboratory space, complete with all the essential equipment you'll need to conduct your experiments.
- ***Instrument Selection:***
  While the necessary tools are provided, additional instruments are available for you to choose from. This feature is intended to encourage exploration and decision-making, mirroring the experience of a real lab environment.
- ***Future Updates:***
  We are continually improving our platform. In forthcoming updates, we plan to offer you the opportunity to prepare and customize your material setup before commencing an activity, further enhancing the learning experience.

By simulating a realistic lab environment, Proteus Labs aims to empower students to learn through both guided instruction and exploratory practice.

18 Utilizing The Tablet In Lab Activities

Within each virtual lab activity at Proteus Labs, a digital tablet is provided as an essential tool for your scientific exploration. This interactive tablet is your gateway to a wealth of resources and functionalities designed to enhance your learning experience:

- ***Protocol Access:***
  Detailed step-by-step instructions for each experiment are readily available on the tablet, guiding you through the process.
- ***Results Visualization:***
  View your experiment results in both tabular and graphical formats, allowing for comprehensive data analysis.
- ***Lab Journal:***
  Keep track of your observations, notes, and conclusions within the digital journal feature, streamlining documentation and reflection.
- ***Options Menu:***
  Customize your lab experience and access additional settings through the tablet's options menu.

The tablet is designed to be intuitive and user-friendly, ensuring that you have all the necessary information and tools at your fingertips as you navigate through each lab activity.

19 Protocol Guidance On The Tablet

Each lab activity in Proteus Labs comes with a protocol that is pre-loaded onto the digital tablet you will find in your virtual workspace. This protocol serves as your comprehensive guide, offering step-by-step instructions to ensure you can confidently navigate through the experiments. Here's what you need to know:

- ***Pre-loaded Protocol:***
  As you commence an activity, the protocol ready on your tablet provides detailed instructions for conducting the experiment, ensuring you have immediate access to the necessary guidance.
- ***Fixed Protocol:***
  The protocol for each activity is fixed and cannot be altered from the tablet. This design choice ensures that the integrity of the educational content is maintained, providing a consistent learning experience across all lab activities.

The protocol feature is tailored to support your learning journey, offering clear, accessible instructions that align with the educational goals of each lab activity.

20 Understanding The Log Feature

The Log is an integral component of the digital tablet provided in each lab activity within Proteus Labs. It meticulously records every action performed by the user, offering a comprehensive overview of:

- ***User Actions:***
  Each selection, adjustment, and input made during the lab activity is captured in real-time, providing a detailed account of your experimental process.
- ***Reflective Learning Tool:***
  This feature serves as a powerful reflective learning tool, allowing users to review their actions, understand the outcomes, and identify areas for improvement or further exploration.

The Log is designed to enhance the learning experience by providing tangible insights into your interaction within the virtual lab, ensuring that every step of your scientific inquiry is documented for review and analysis.

21 Detailed Results Recording In Proteus Labs

Proteus Labs goes beyond traditional documentation with the lab journal by segmenting and detailing results in three specialized sections. This structured approach allows for focused analysis and understanding of specific experimental variables. The sections are as follows:

21.1 Graph1: Temperature vs. Time

- ***Description:*** This graph tracks the relationship between temperature and time during your experiment.
- ***Requirement***: For accurate recording in this section, a thermometer must be present in the solution. This ensures that temperature data is reliably captured as your experiment progresses.

21.2 Graph2: Gas Volume vs. Time

- ***Description:*** Analyze how the volume of gas changes over time under the conditions of your experiment.
- ***Requirement:*** Results in this section are contingent on the setup of a complete burette montage. This setup is crucial for the precise measurement of gas volume changes.

21.3 Graph3: Volume vs. Pressure and 1/Volume vs. Pressure

- ***Description:*** Explore the correlation between volume and pressure within your experimental setup.
- ***Requirement:*** Data for this graph are derived from using Boyle's apparatus, an essential tool for experiments investigating the principles of pressure and volume.

Each of these sections is designed to provide a comprehensive view of your experimental results, emphasizing the importance of proper setup and instrumentation. By categorizing the results in this manner, Proteus Labs ensures a rich, data-driven understanding of the scientific principles at play.

22 Exploring The Options Menu In Proteus Labs

The Options Menu in Proteus Labs is designed to enhance your lab experience by providing a suite of tools and resources at your fingertips. Here's an overview of the features available:

Periodic Table:

Engage with an interactive periodic table by pointing and clicking on any element using the laser pointer. Each element displays comprehensive details about its characteristics, enriching your understanding and reference capabilities during experiments.

Send results:

Results Sharing: Easily share your experimental results via email or directly to your Learning Management System (LMS) folder by selecting the 'Send Results' option.

Reset Lab:

With a single click, you can reset the entire lab to its original state. This feature is invaluable for starting a new experiment from scratch or clearing the workspace for a different activity.

Connection Menu:

Navigate back to the main menu at any time by selecting this option. Please note that leaving the session will close your current activity, so ensure you've saved all necessary data or completed your tasks before exiting.

These options are integrated into Proteus Labs to support a seamless, efficient, and interactive learning environment, enabling you to focus on exploration and discovery without limitations.

23 Understanding Activity Constraints In Proteus Labs

Proteus Labs offers a dynamic and engaging virtual lab environment, designed to maximize learning through interactive experiences. However, to ensure optimal performance across all devices, certain limitations have been implemented. These include:

23.1 "Floor is Lava" Mechanism:

In our immersive virtual environment, the "Floor is Lava" feature is always active. This playful yet practical feature ensures that any object dropped or falling to the ground will automatically return to its original location.

This mechanism prevents loss of essential items and maintains the continuity of your experiments.

23.2 Inanimate Objects:

While Proteus Labs provides a variety of animated objects necessary for conducting experiments, not all objects in the virtual lab are interactive. This decision is made to accommodate the processing capabilities of mobile devices, ensuring a smooth and accessible experience for all users.

Selective Interactivity:
It's important to note that some objects, while not interactive in certain activities, may become interactive in others. This variability adds depth to the learning experience, encouraging exploration and adaptability.

Availability and Limitations:
For detailed information on which objects are available for interaction and their respective limitations, please refer to Appendix 2 of this guide.

By understanding these constraints, users can navigate the virtual lab more effectively, focusing on the interactive elements that are central to the learning experience offered by Proteus Labs.

24 Annex 1: Instruments And Containers

This annex provides detailed instructions and limitations for the use of various instruments and containers in the virtual lab environment of Proteus Labs.

24.1 Balance

How to Interact: Place the product on the balance. Only the left/right tare buttons are active.

Limits: Maximum weight of 320.0g with a precision of 0.1g.

24.2 Weight paper

Usage: Can hold ribbons and powders.

Limits: Maximum weight of 10.00g.

24.3 Timer

Functionality: Starts all ready-to-activate reactions. Stopping the timer does not halt the reactions.

Reactions Tracked: Endothermic/Exothermic, Gas Production.

24.4 Spatulas, Tweezers, and Ice tongs

Functionality:

Spatula: Picks up powders, ribbons, and ice cubes.

Tweezers: Picks up ribbons and ice cubes.

Ice Tongs: Exclusively for ice cubes.

Limits: Spatulas and tweezers have weight limits for picking up items, varying by material (pale grey: 0.3g, copper: 0.2g, dark grey: 0.1g; Tweezers: 0.1g for ribbons).

24.5 Thermometers

Usage: Measure temperature by placing in a solution. Can be attached to containers.

Limits:

Numeric: Max 150°C, Min -50°C.

Analog: Max 115°C, Min -20°C.

24.6 pH Meter

Functionality: Measures pH when placed in a solution. Use the special action button to take a measurement.

Limits: pH range from 0 to 14.

24.7 Calorimeter

Usage:

Green Button: Activates magnetic stirrer for consistent results.

Front Button: For cleaning/emptying contents.

Limits: Maximum volume of 500mL solution.

24.8 Graduated cylinders / Beakers / Erlenmeyers

Functionality: Use for precise volume measurements and gas production capture. Accepts caps and holed caps.

Sizes and Uses:

Cylinders: 10/70/250mL; use meniscus for volume accuracy.

Beakers: 250/500mL for general use.

Erlenmeyer Flask: For burette montage and gas capture.

Test Tubes

Usage: General use, accepts caps and holed caps.

Limits: Maximum liquid volume of 50mL.

24.9 Pipette and Dropper

Usage: Fill and distribute liquid with the trigger or thumbstick button. Pipette dispenses 5mL; dropper dispenses 0.05mL per use.

Limits: Pipette max volume 5mL; Dropper max volume 1mL (20 drops).

24.10 Burette

Usage: Fill and submerge in liquid for water retention experiments. Use trigger or thumb button for operation.

Specific Requirement: Must be submerged in at least 400mL of liquid.

Hotplate and Magnetic Agitator

Functionality:

Blue Button: Activates magnetic agitator.

Red Button: Controls hotplate power.

Limits: Heats water-based liquids up to 100°C.

Boyle’s Apparatus

Usage: For pressure experiments. Follow steps for attaching air pump, opening tap, and starting readings.

Limits: Maximum air pressure 700 kPa.

24.11 Stirring / Shaking liquids

Procedure: Use glass stirrer or shake capped containers for reactions.

Note: Test tubes and Erlenmeyer flasks require caps before shaking.

24.12 Lab Protection

Usage: Gloves, protective glasses, and lab coat can be worn by grabbing them. Removal is done by touching the pad or hanger.

This annex is intended to provide users with a comprehensive understanding of the tools at their disposal within the virtual lab, ensuring a productive and safe learning environment.

25 A Few Facts About Proteus Labs!

- The chemical device "ProteusEngine" normally runs 1 time/sec, but 10 times/sec when mixing liquids together.
- This machine is made up of about 50 algorithms that regulate the different chemical reactions simultaneously.
- Each mixture of solids, liquids, or gases has a quantity (in moles), an energy (in Joules), and 25 physical and chemical properties.
- Thus, it is always possible to measure properties at any time, such as temperature, pH, appearance, conductivity, etc.
- The temperatures of the experiments vary between -10 and 150 v C.
- The chemical equilibrium of the solutions is regulated by the solubility product constant (Kps) and the equilibrium law (Kc), so the equilibrium is influenced by the concentration of the reactants and products. Hess' law is taken into account, as well as the contact surface.
- The influence of temperature on chemical equilibrium is regulated by the Arrhenius equation.
- The relationship between pressure, volume, molar concentration, and temperature is governed by the ideal gas law.
- Products can be transferred from one phase to another (liquid, solid, gaseous) depending on their temperature and pressure, taking into account the latent heats of melting and vaporization.
- The stoichiometry of reactions is respected at all times.
- Most of the experiments were redone in our laboratories, so it was possible to correct some protocols.
- The microscopic observations were made in our laboratories, with specimens collected from lakes in Quebec.
- Most of the reactions take place in real time, however some experiments are accelerated to be able to proceed with the measurement in a reasonable amount of time.
- The set of experiments uses 121 different products.
- The development of the app took 3 years to a team of 4 people.
- It is a unique app in the world, the only scientific app in augmented reality.
- The app has received numerous awards, including the MEI (now IQ) Innovation Award, Epic Games' MegaGrant, as well as an Oculus Launchpad nomination.
- The Proteus team is supported by the Centech Propulsion incubator in Montreal.
- A specialized version of Proteus Labs was used in the ProtUdeS research project, led by Professor Fatima Bousadra, from the Faculty of Education at the Université de Sherbrooke.

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