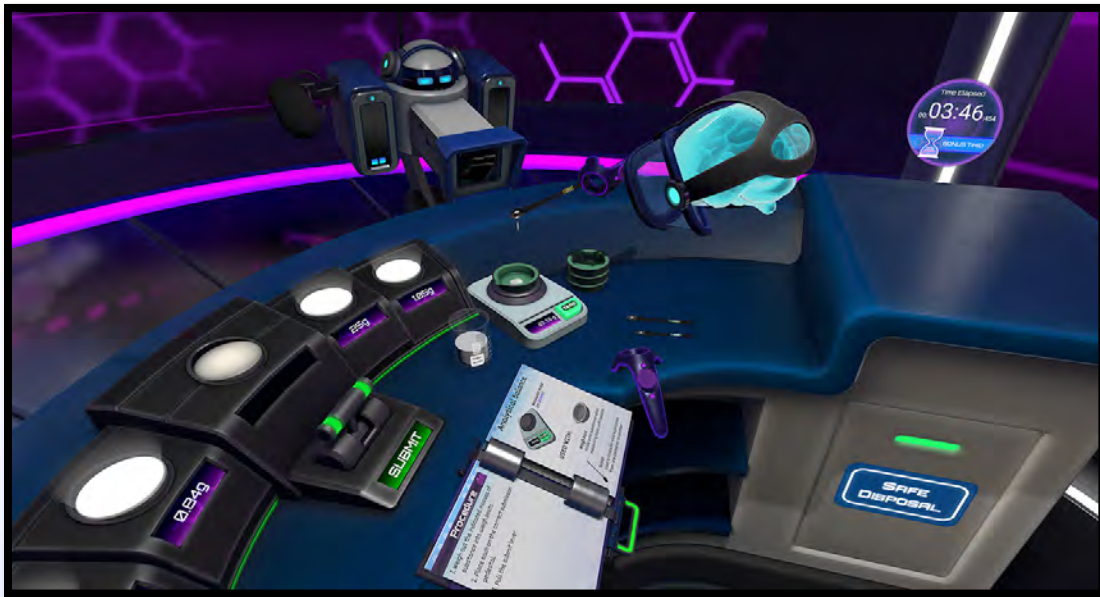




A Virtual Reality Lab Experience

Classroom Guide



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Letter to Educators

Dear Educator –

Hello from Schell Games! We are a game studio based in Pittsburgh, Pennsylvania that makes all sorts of interactive experiences, including educational games.

We created **HoloLAB Champions** as a way for players to engage playfully with chemistry lab equipment in virtual reality. Our primary goals were to:

- Encourage players to see themselves as someone who DOES belong in a lab and who could be successful in a lab-related career
- Give players “hands-on” exposure and experience working with lab equipment in a space where they can safely try, fail, and play

There are a variety of ways you can incorporate HoloLAB Champions into your classroom, including:

- As a stand-alone single-player game for students to play on their own
- As a small-group work station
- As a collaborative whole-class experience

This guide includes some suggestions on these different approaches along with some supporting materials, including lesson handouts, technical guides, and detailed information on the game content. These curricular materials were created with the input of chemistry educators. We hope they give you a strong starting place for understanding HoloLAB Champions and how you might leverage it for your own students.

We know that a virtual reality experience could never fully replace real-world lab practice. In some ways, the HoloLAB experience closely mirrors reality, but in other ways, it differs significantly. Our intent is for **HoloLAB Champions** to augment the classroom lab experience, giving your students an additional way to learn and practice their basic lab skills.

We would love to hear from you! Let us know how you’re using HoloLAB Champions in your classroom. You can email hlc@schellgames.com or connect with us on social media @SchellGames. Your input will help inform future games and classroom experiences.

Sincerely,





What is HoloLAB Champions?

HoloLAB Champions is a virtual reality (VR) game about chemistry lab practice in which players complete lab challenges using virtual lab equipment.

In HoloLAB Champions, your students can work together to get through the game's challenges or practice independently. Gameplay takes place at a virtual lab desk and uses a virtual lab notebook to guide students in the lab.

Why should you use HoloLAB Champions in your classroom?

Use HoloLAB Champions to give your students a safe, fun space to practice their basic lab skills. In the HoloLAB, they can pour, scoop, spill, measure, break, weigh, and burn, all without making a mess and with the freedom to try again and again.

HoloLAB Champions has state-of-the-art simulation of liquids and solid powders, enabling your students to really feel like they are pouring into beakers or scooping powders into weigh boats.

The HoloLAB provides feedback to students on the accuracy of their measurements, their attention to detail in lab procedures, and their ability to avoid spilling and breaking in the virtual lab.

(If you're looking to connect HoloLAB to educational standards, check out [Appendix B.](#))

How does HoloLAB Champions differ from the real-world?

The HoloLAB simulation does have limits in its fidelity to the real world. In particular, the HoloLAB does not support cleaning of lab equipment or consequences of chemical exposure.

HoloLAB Champions is available in English on [Steam](#) for the [Oculus Rift](#) and [VIVE VR](#) platforms.



Quick Start Guide

First, start the game in Steam. Put on your VR headset and pick up the controllers.

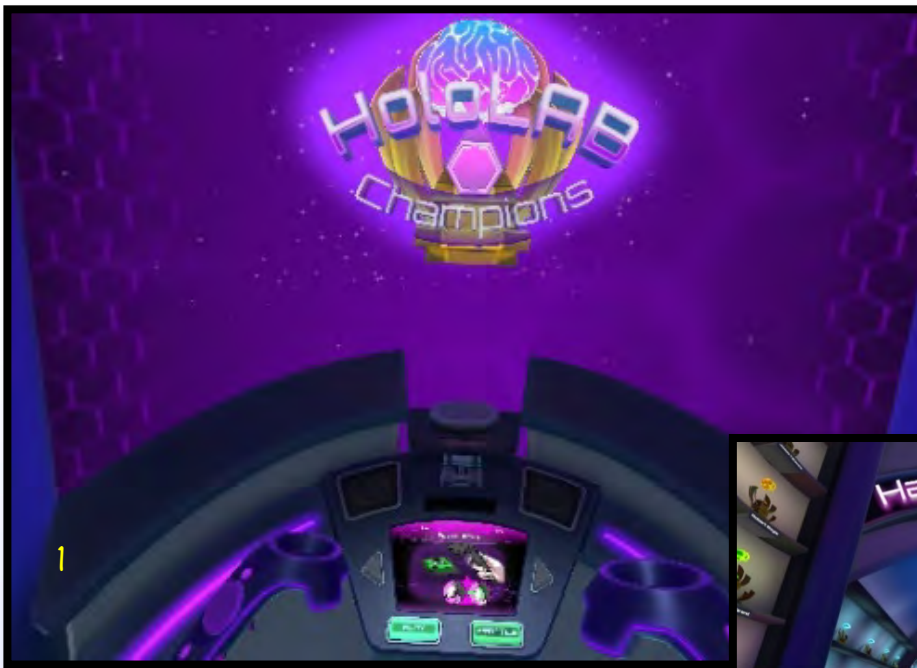
Make sure you have a clear 4'x4' area around you while playing. You will not need to walk around while playing the game, but you will need space to move your arms.

It is recommended that you have audio on while playing, either in headphones or through speakers. For more VR tips, see the [VR Usage Guide](#).

Using the Game Menu

You will start out in the “Hall of Brains” – this is the main menu of the game.

1. Make sure you are standing in the center of your play area, facing forward. You will see the HoloLAB logo (left). If you see the Hall of Brains sign (right), then turn around.





2. Use the trigger on the controllers to press the “Play” or “Practice” button to select which game mode you want to use. (See next page for brief explanation of these two options.)
3. Use the arrow buttons to move between different Play and Practice options.
4. When you have chosen your destination, pull the lever to enter the HoloLAB and play that event or practice lab.

Whenever you exit the HoloLAB, you will return to the Hall of Brains and the main menu interface. To exit the game completely, use the Steam menu at any time to quit, or take off the VR headset and close the game using the mouse and keyboard.

Playing the Game in Practice Lab Mode

HoloLAB Practice Labs are single labs. There are two types: Mini-labs and Final labs. A Practice Mini-lab typically takes 1-10 minutes to complete, while a practice Final Lab takes 10-40 minutes (depending on the player's comfort in VR.)

1. Each lab will have between 1 to 5 items to create and submit. Follow the procedure in the lab notebook to create your submissions.
2. When you have placed all the items on pedestal, pull the Submit Lever.
 - If your submission is accepted, you will receive a score for that lab and details on the contents of your submissions.
 - If your submission is rejected, you can try to fix your submission and submit again.
3. When a practice lab is complete, you may pull the Reload Equipment lever to practice again or use the Exit lever to return to the main menu.

Playing the Game in Play Mode (Events)

HoloLAB Play mode has two playable Events that feature an introduction, 10 mini-labs, one final lab, and a trophy award moment. An Event typically takes 30-45 minutes to complete.

During each lab:

1. Listen to Earl (the host's) instructions and read the lab procedure in the lab notebook.



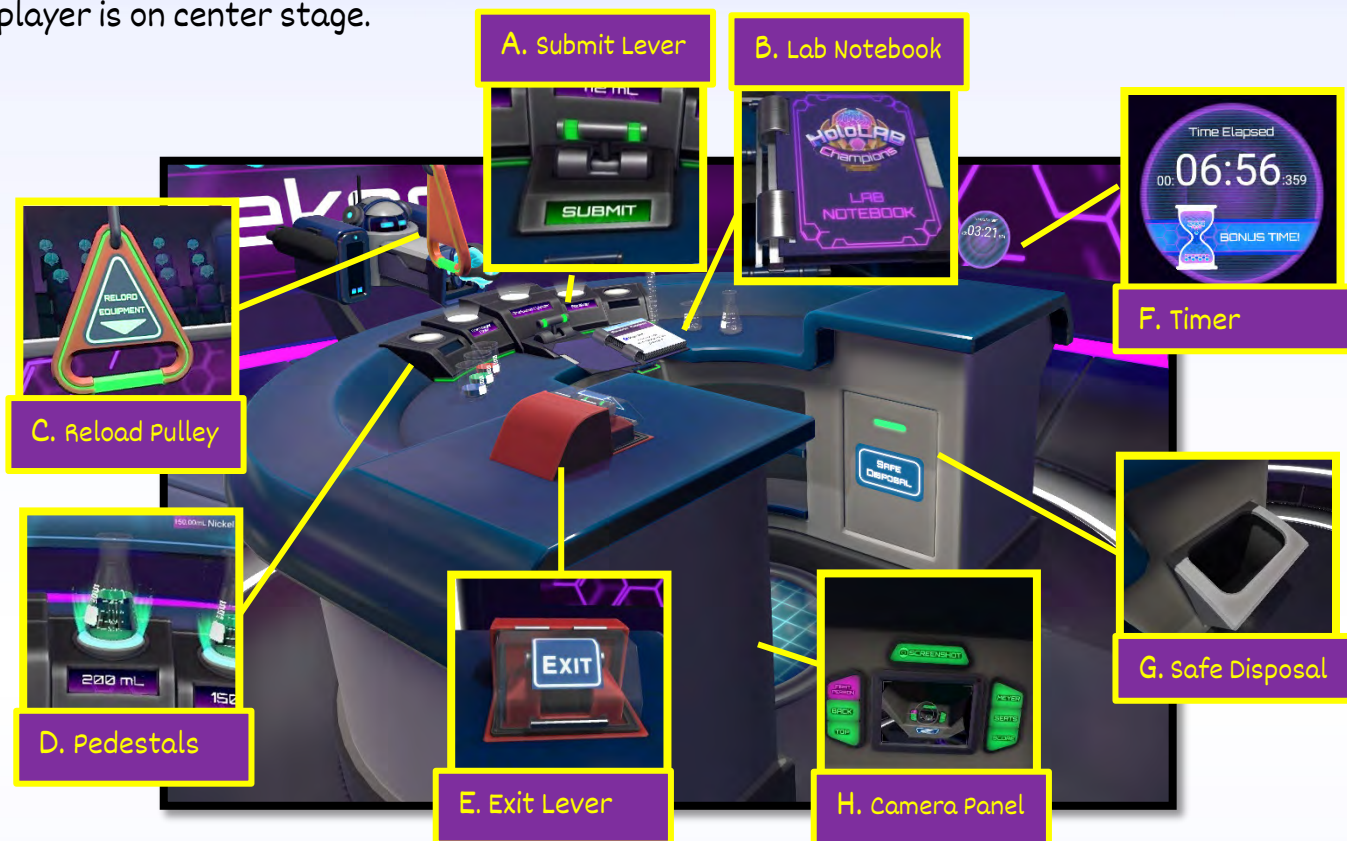
2. Following the procedure, create your submissions. Each lab will have between 1 to 5 items to create and submit.
3. When you have placed all the items on the pedestals, pull the Submit Lever.
 - If your submission is accepted, you will receive a score for that lab and then progress to the next lab.
 - If your submission is rejected, you can try to fix your submission and submit again.

4. When you have completed the entire Event, Meyer (the camera robot co-host) will "scan" your brain and present you with your trophy award.
5. When the Event is over, pull the Exit Lever (to your far left) to return to the main menu.

Note: There is no penalty for failing a submission. You can try as many times as you need. If you need to reset your materials, you can use the Reload Equipment pulley hanging to your left to start the lab again.

Tour of the HoloLAB

Both Events and Practice Labs take place in the HoloLAB, a virtual lab arena where the player is on center stage.



The HoloLAB features a large lab desk that includes:

- A. **Submission Lever:** Pull to check the items on the submission pedestals
- B. **Lab Notebook:** A virtual notebook with all the important procedure and reference materials you need to complete the current lab.
- C. **Reload Equipment Pulley:** Pull to reset all the materials for current lab to their starting state
- D. **Submission Pedestals:** Special locations where you place the materials you've prepared as required by the current lab. Each pedestal has a label indicating what should go in that location. Additional detail about each submission requirement is in the Lab Notebook procedure.
- E. **Exit Lever:** Lift the cover and pull the lever to exit back to the main menu at any time
- F. **Timer:** Displays time elapsed so far during current lab. If "Bonus Time" is visible, bonus points for timely lab completion will be awarded upon successful submission.
- G. **Safe Disposal:** Substances and equipment can be disposed of in here without penalty
- H. **Camera Panel:** These buttons change the camera view shown on the HoloLAB's big screens and the view displayed on the computer monitor to any observers

Other features of the HoloLAB include:



- A. **Earl:** A voiced host (present only in Events, not Practice labs)
- B. **Meyer:** A camera robot who reacts to the player's actions in the game
- C. **Marquee:** A large sign in front of the desk sign that displays the name of the lab and any penalties that the player has received
- D. **Big Screens:** These two large screens display the current camera view. This view represents what is being seen on the secondary monitor outside the game.
- E. **Audience:** An animated audience of holographic brains appears here (in Events only, not Practice labs)
- F. **Scoring Area:** This is where your score appears at the end of a lab or event

Game Content Overview

There are two modes in HoloLAB Champions. Here is a summary of the game content in each.

Practice Labs

This mode allows players to train and develop their skills on a particular individual mini-lab or final lab. In this mode, players can try labs in any order and can also retry an individual lab as much as they want. In practice mode, there is no music or audience in the HoloLAB. There are also no voiced instructions. Players must use the written instructions in the Lab Notebook to complete the submission or collaborate with classmates outside VR (see the classroom suggestions for each lab in [Lab Guides](#).)

After successful submission in a Practice Lab, the player will be scored based on their accuracy, speed, and any safety penalties. They will also see the exact contents of each container they submitted displayed. This extra information, not available during the Play Event labs, is to aid the player in practicing a lab for a higher accuracy score.

Practice Mini-labs usually take 1-5 minutes to complete for a player who is experienced in VR and 5-10 minutes for a player who is naive to VR.

Practice Final Labs usually take 10-20 minutes to complete for a player who is experienced in VR and take 20-40 minutes for a player who is naive to VR.

There are 16 different Practice labs available in the HoloLAB:

<u>1. Acceptable Error</u> (mini-lab) Practice pouring where exact volume must be estimated	<u>2. Precision Panic</u> (mini-lab) Practice reading a meniscus	<u>3. Chemical Barista</u> (mini-lab) Practice pouring out specific volumes using various glassware	<u>4. Tiny Transfer</u> (mini-lab) Practice transferring small amounts of liquid by pipette
<u>5. Glow, Dye, Glow</u> (mini-lab) Complete three different glowing solutions using difference fluorescent dyes	<u>6. Mass Hysteria</u> (mini-lab) Practice using a balance to measure out specified amounts of a solid	<u>7. RatiOh-No</u> (mini-lab) Practice scaling measurements up and down	<u>8. Glowing Flask Challenge</u> (final lab) Create a glowing flask by combining substances to complete a chemiluminescent reaction
<u>9. Chroma Key</u> (mini-lab) Use observation and references to identify between two substances	<u>10. A Matter of Color</u> (mini-lab) Use observation and references to identify between 5 substances	<u>11. Dissolve to Solve</u> (mini-lab) Identify which substance is soluble and which is insoluble	<u>12. Read to Succeed</u> (mini-lab) Identify between four substances based on visual observation and solubility
<u>13. Dense Party</u> (mini-lab) Observe the difference in mass of several substances by weighing identical volume amounts	<u>14. Density Intensity</u> (mini-lab) Weigh out identical amounts of different substances and observe the differences in volume based on their density	<u>15. Identiflame</u> (mini-lab) Identify between five different solids using the flame test	<u>16. Fireworks Challenge</u> (final lab) Identify between eight different unknowns using visual observation, solubility, density, and flame color

Play Events

In HoloLAB Play Events, players are challenged to complete a set sequence of 10 mini-labs that introduce a set of lab skills, culminating in a larger Final Lab that relies on those skills. Events also feature music, a host character who provides voiced instructions, and award the player a trophy at the end.

A full Play Event usually takes 25-45 minutes to complete for a player who is experienced in VR and 45-75 minutes for a player who is naive to VR.

There are two Play Events in HoloLAB Champions:

Chemiluminescence



Skills Featured: measuring volume, weighing mass, basic lab glassware, Mohr pipette, chemiluminescence reaction

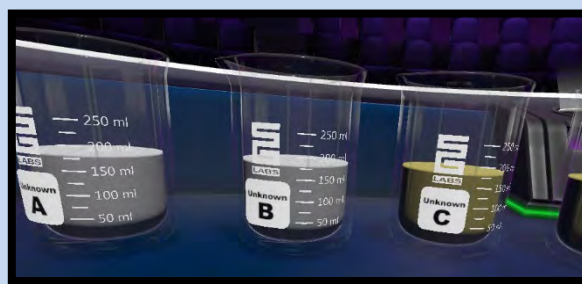
Mini-Labs Included:

1. Beaker Seeker (glassware identification)
2. Acceptable Error (volume measurement)
3. Precision Panic (reading meniscus)
4. Chemical Barista (volume measurement)
5. Tiny Transfer (Mohr pipette)
6. Glow, Dye, Glow (chemiluminescence)
7. Weigh of the World (using balance)
8. Tare Test (using tare)
9. Mass Hysteria (measuring mass)
10. RatiOh-No (scaling measurements)

Final Lab: Glowing Flask Challenge

Create a brightly glowing flask.

Identify Unknowns



Skills Featured: safety data sheets, visual observation, solubility, density, flame test

Mini-Labs Included:

1. Chroma Key (SDS; visual observation)
2. A Matter of Color (visual observation)
3. Dissolve to Solve (solubility)
4. Read to Succeed (solubility)
5. Beaker Seeker (glassware identification)
6. Tare Test (using balance)
7. Dense Party (density)
8. Density Intensity (density)
9. Turn Up the Heat (flame test)
10. Identiflame (flame test)

Final Lab: Fireworks Challenge

Identify the correct components to successfully generate a fireworks display.

Scoring Overview

Performance in HoloLAB Champions is scored along 3 domains: accuracy, safety, and speed. The player earns an accuracy score, loses points based on safety, and then earns a speed bonus.

- **Accuracy Score:** This is determined by averaging the accuracy of each of the player's submissions for a lab.
 - **In Mini-labs,** the maximum accuracy score is 50,000pts
 - **In Final Labs,** the maximum accuracy score is 500,000pts
 - **The acceptable error varies per lab:** At the end of each lab, the player is asked to submit something they prepared during the lab. This submission often includes measuring out some amount of liquid or solid substance. The acceptable error of these measurements varies based on the lab. (additional details available in the [Lab Guides](#).)
- **Safety Penalties:** The player gets penalized for lab safety issues like breaking glassware or spilling materials:
 - **Spilling substances: -1,000pts**
You can spill liquids and solids if you're not careful! These spills will be counted against you in your safety score. There is no need to clean anything up; the spill will disappear. If the player spills enough substances so that they cannot proceed, they must pull the "Reload Equipment" pulley to start the lab over again.
 - **Breaking equipment: -3,000pts**
Glassware breaks when handled incorrectly, just like in real life. If the player breaks enough glassware that they cannot proceed, they must pull the "Reload Equipment" handle to start the lab over again.
 - **Throwing equipment Out-of-bounds: -3,000 pts**
Equipment thrown out of bounds of the lab desk will disappear. If the player throws away a necessary piece of equipment so that they cannot proceed, they must pull the "Reload Equipment" lever to start the lab over again.
- **Speed Bonus:** Each lab (both mini and final) have an expected maximum completion time. If the player completes the lab before this time, they earn a speed bonus.
 - In Minilabs, the maximum accuracy score is 1,000pts
 - In Final Labs, the maximum accuracy score is 10,000pts

A Note about Steam Achievements

There are also a number of STEAM achievements that can be earned in HoloLAB Champions. These are milestone achievements in the game that are linked to your STEAM account. Players may see an achievement pop-up appear in the game while playing. These do not affect gameplay and can be ignored in the classroom.

Lab Equipment Overview

This is the lab equipment available in HoloLAB Champions.

You can find detailed notes on each piece of equipment in [Appendix A](#).



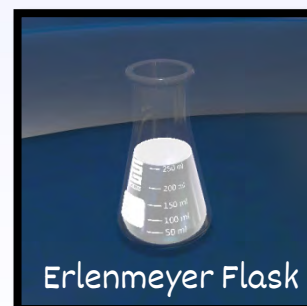
Analytical Balance



Beaker



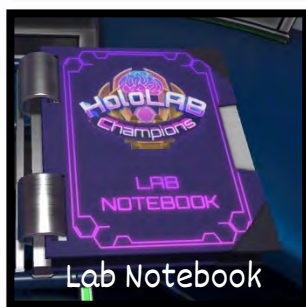
Bunsen Burner



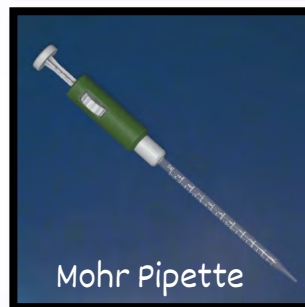
Erlenmeyer Flask



Graduated Cylinder



Lab Notebook



Mohr Pipette



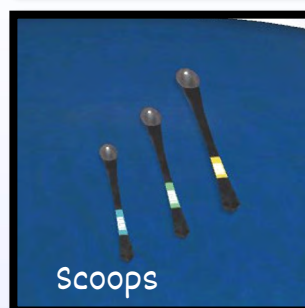
Platinum Loop



Safety Data Sheets



Safety Goggles



Scoops



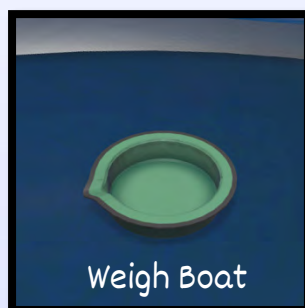
Stopper



Striker/Ignitor



Waste Disposal



Weigh Boat

Lab Guides

A Note About Students Performing in VR While Being Observed

Some of the classroom suggestions included here involve one student in VR demonstrating in front of the class. We recommend that, in the situations where one student is demonstrating in front of observing students, the student in VR is not responsible for figuring out how to solve the lab. Instead, it is the observing students who are asked to problem solve on how to complete the lab.

Some players (even adults!) can feel overwhelmed if asked to perform in VR in front of a large group of people. By asking the observing students to provide problem solving, the student in VR can concentrate on performing the actions suggested by their peers.

Always make sure students feel comfortable being the VR demonstrator before asking them to step into the headset. Whenever possible, avoid using first-time VR players as demonstrators in front of a large class as those new to VR may feel extra self-conscious when performing tasks in VR in front of peers.

The following guides give a summary of each lab as well as some suggestions on incorporating that lab as part of a classroom experience.

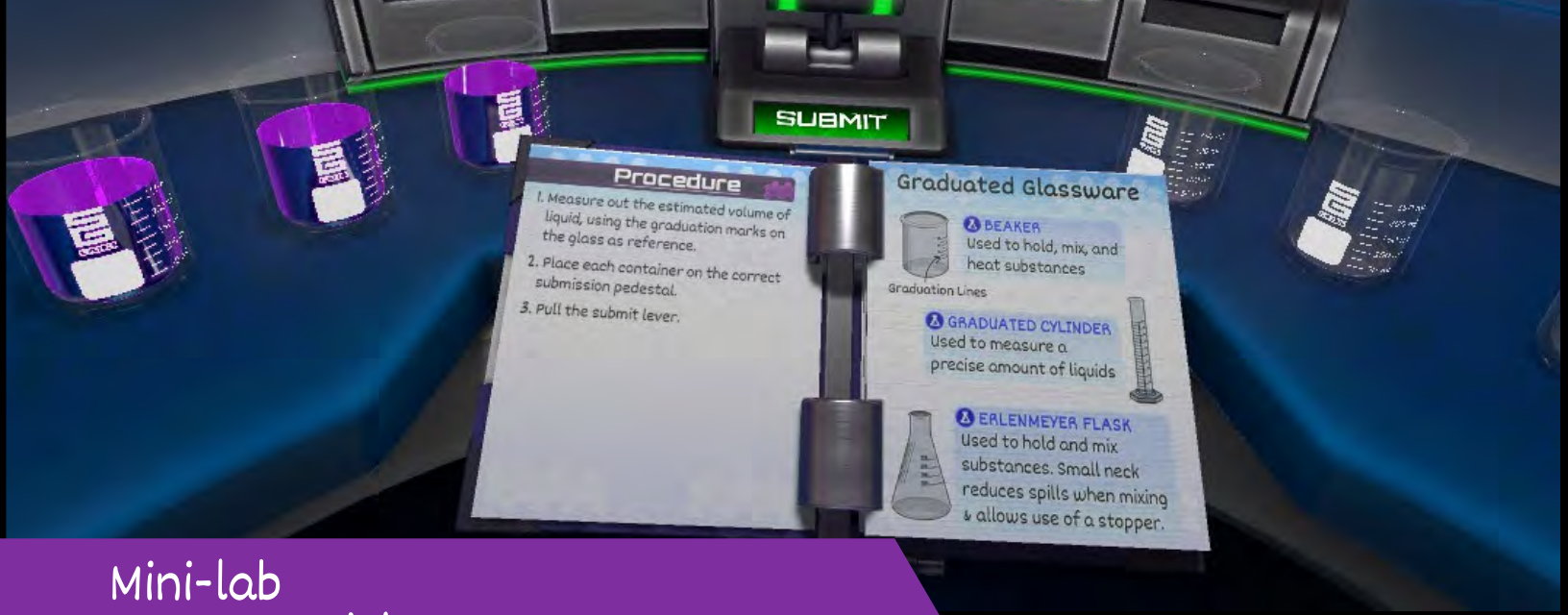
Mini-labs (typically 2-5 minutes)

1. [Acceptable Error](#)
2. [Precision Panic](#)
3. [Chemical Barista](#)
4. [Tiny Transfer](#)
5. [Glow, Dye, Glow](#)
6. [Mass Hysteria](#)
7. [RatiOh-No](#)
8. [Chroma Key](#)
9. [A Matter of Color](#)
10. [Dissolve to Solve](#)
11. [Read to Succeed](#)
12. [Dense Party](#)
13. [Density Intensity](#)
14. [Identiflame](#)

Final (big) Labs (typically 10-30 minutes)

These curriculum materials for these labs are designed to be used to facilitate a collaborative whole-class experience.

1. [Glowing Flask Challenge](#)
2. [Fireworks Challenge](#)



Mini-lab Acceptable Error

Key Skills: Estimating volume

Key Equipment: Beaker

Estimated Time: 2-5 minutes

Submission Goals:

- 43mL
- 112mL
- 238mL

What's the Purpose?

This lab asks students to approximate several volumes of liquid. The goal is to give students practice thinking about what the graduated lines of a beaker represent and to help them gain comfort with pouring liquids before focusing on being perfect with their measurements. As described by the lab title, there is a greater-than-normal acceptable amount of error permitted for submissions of this lab.

Accuracy Scoring Notes:

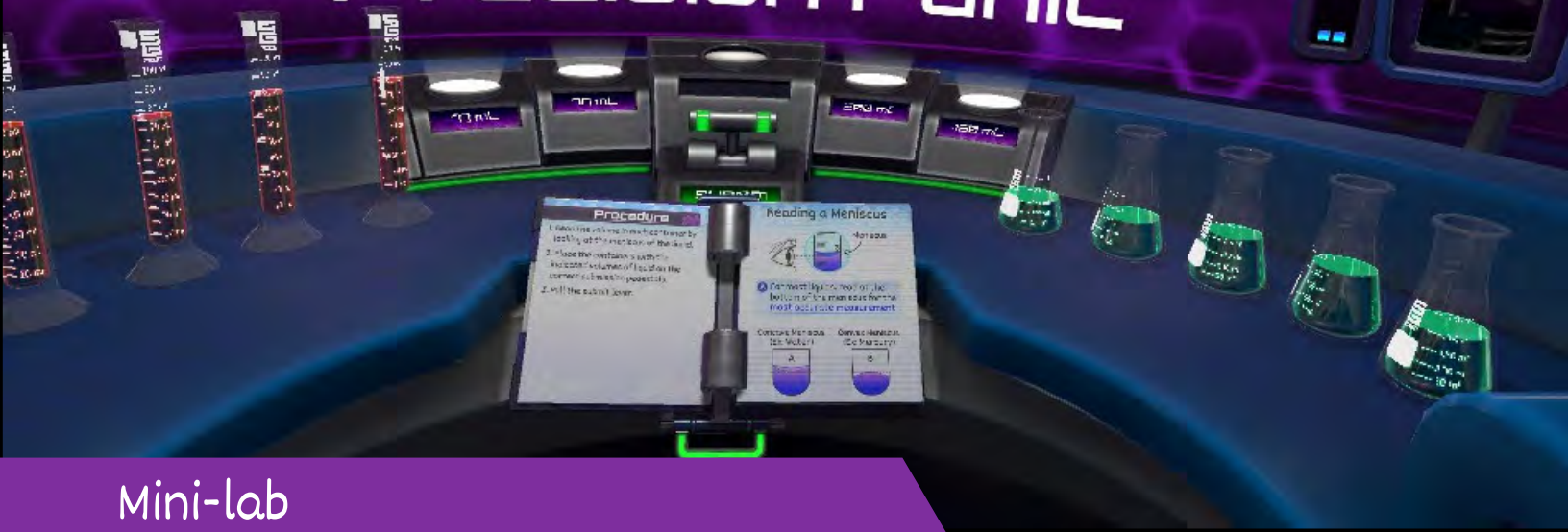
- Each pedestal submission is worth 1/3 total accuracy
- Up to 10% error counts as perfect for each submission
- Up to 50% error is accepted for each submission

Classroom Suggestion:

Demonstration using HoloLAB (20 minutes)

- Select one student to serve as the demonstrator. Have that student play the Acceptable Error mini-lab in VR in front of the class.
- Ask remaining students to suggest the acceptable level of error for each measurement and prompt the student in VR to try some of the suggestions to see which ones are accepted and which ones aren't.
- Talk about the consequences of measuring to varying levels of accuracy on the outcomes of a particular experiment.

Precision Panic



Mini-lab Precision Panic

Key Skills: Reading a meniscus and glassware graduation marks

Key Equipment: Erlenmeyer flask, graduated cylinder

Estimated Time: 2 minutes

Submission Goals:

- 77mL
- 78mL
- 200mL
- 150mL

What's the Purpose?

This lab gives students practice carefully reading volumes in containers based on glassware graduation marks and taking into account the meniscus effect.

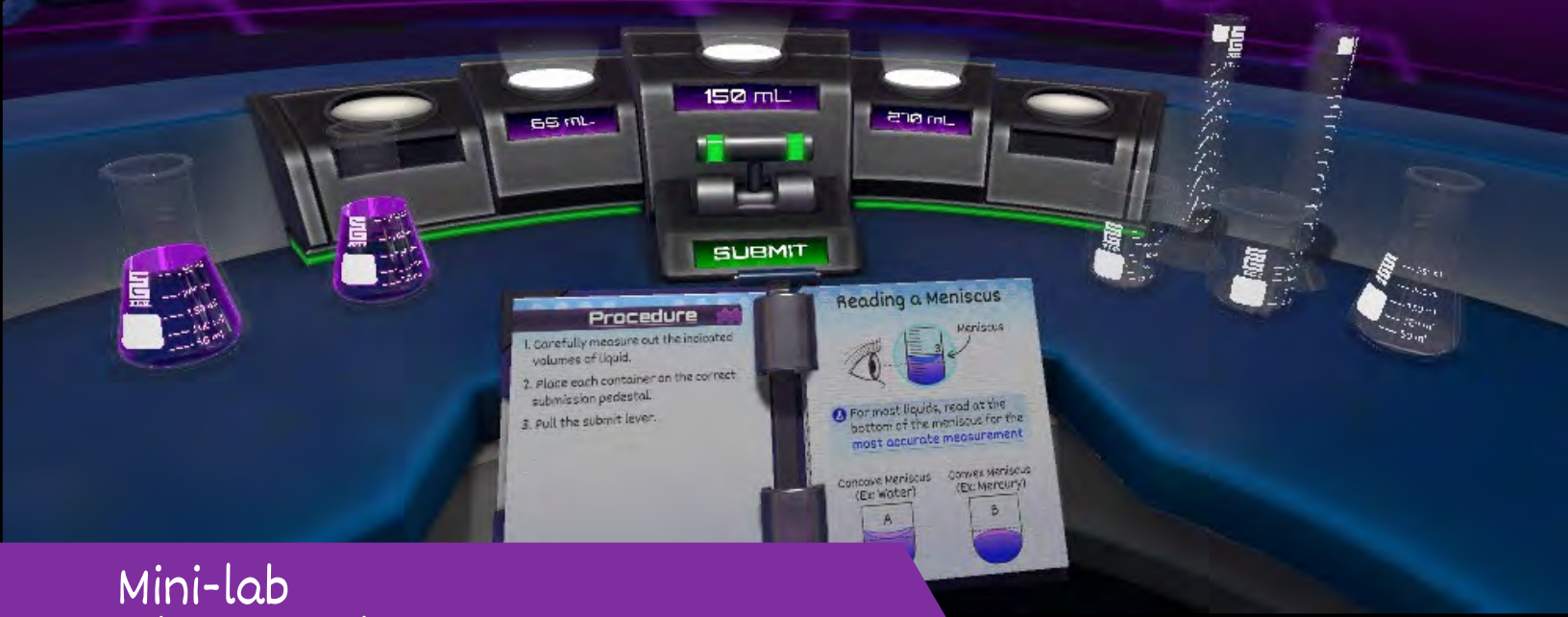
Accuracy Scoring Notes:

- Students must correctly place all four requested volumes on the pedestals to pass this lab
- As long as the student does not spill any of the liquid from the containers during the lab, they will receive a perfect accuracy score.
- The actual volumes (from left to right): 76mL, 83mL, 75mL, 77mL, 78mL, 140mL, 150mL, 200mL, 190mL, 210mL

Classroom Suggestion:

Stations (Groups of 3-4, 10 minutes at each station)

- **Station 1:** Work together to complete the Precision Panic mini-lab, with one student in VR and the others observing and offering input. How many submission attempts did it take for your group?
- **Station 2:** Measure with 2 paper rulers, each marked with different levels of precision (e.g., tenths, hundredths)
- **Station 3:** Measure using real-life meniscus
- **Station 4:** Draw a diagram of a meniscus, and explain why it has its shape
- **Station 5:** Identify real-world applications of precision - where does it matter most, and where is it less important?
- **Station 6:** Demonstration of accuracy vs precision by dropping pen onto paper dartboard and looking at clustering of marks
- **Station 7:** Compare meniscus of various liquids (water, baby oil, another very viscous liquid) poured into various containers with different diameters or made of different materials (glass vs plastic)



Mini-lab Chemical Barista

Key Skills: Measuring liquids

Key Equipment: Beaker, Erlenmeyer flask, graduated cylinder

Estimated Time: 2-5 minutes

Pedestal Goals:

- 65mL
- 150mL
- 270mL

What's the Purpose?

This lab asks students to measure out 3 different volumes of liquid with limited glassware and limited liquid. Students must choose the appropriate glassware to measure the volumes. Students should ideally measure 65 mL into a graduated cylinder, 150mL into a beaker, and 250 mL into a beaker or flask with an added 20mL from a graduated cylinder.

Accuracy Scoring Notes:

- Each pedestal submission is worth 1/3 total accuracy (max. 50k)
- Up to 2% error counts as perfect for each submission
- Up to 50% error is accepted for each submission

Classroom Suggestion:

Stations (Groups of 3-4, 10 minutes at each station)

- **Station 1:** Take turns completing the Chemical Barista mini-lab in VR
- **Station 2:** Match measurement scenario to correct equipment based on the amount of precision needed
- **Station 3:** Write out detailed instructions for someone measuring volume
- **Station 4:** Discuss situational appropriateness of significant digits when measuring volume

Tiny Transfer



Mini-lab Tiny Transfer

Key Skills: Mohr Pipette

Key Equipment: Beaker, graduated cylinder, Mohr Pipette

Estimated Time: 2-5 minutes

Submission Goals:

- 101mL
- 106mL
- 103mL

What's the Purpose?

This lab introduces students to the Mohr pipette and gives them practice using this pipette to transfer small amounts of liquid. The lab asks players to measure out 3 different volumes of liquid with limited glassware and limited liquid. Savvy students may realize that they only need to fill the pipette once all the way to be able to complete all three transfers.

Accuracy Scoring Notes:

- For each submission, less than 0.1mL error is perfect and up to 0.5mL error is accepted.
- To achieve perfect accuracy, students must understand that they should not empty the pipette tip when transferring liquid.

Classroom Suggestion:

Demonstration using HoloLAB (15 minutes)

- Select one student to serve as the demonstrator.
- Ask the student in VR to measure a small and a large amount of liquid using first the Mohr pipette and then the beaker.
- Talk through the increased precision of the Mohr pipette over that of a beaker. Identify conditions under which it is most appropriate to use a Mohr pipette vs other glassware. Discuss the consequences of varying degrees of precision in measurement.

Glow, Dye, Glow



Mini-lab Glow, Dye, Glow

Key Skills: Mohr pipette, visual observation

Key Equipment: Beaker, Erlenmeyer flask, Mohr pipette, scoops

Estimated Time: 2-5 minutes

Submission Goals:

- Rubrene
- DHA
- Rhodamine

What's the Purpose?

This lab gives students practice using the Mohr pipette while demonstrating several different chemiluminescent reactions. This lab features three pre-prepared flasks, each containing 15mL diethyl Phthalate, 75mg of TCPO, and 150mg of sodium acetate, to which the student is asked to add a single scoop of fluorescent dye and 5mL of hydrogen peroxide. The hydrogen peroxide reacts with the TCPO, and in the process provides energy to the fluorescent dye which results in its chemiluminescent glow. (Students are not expected to understand this glow reaction in detail from performing the lab.)

Accuracy Scoring Notes:

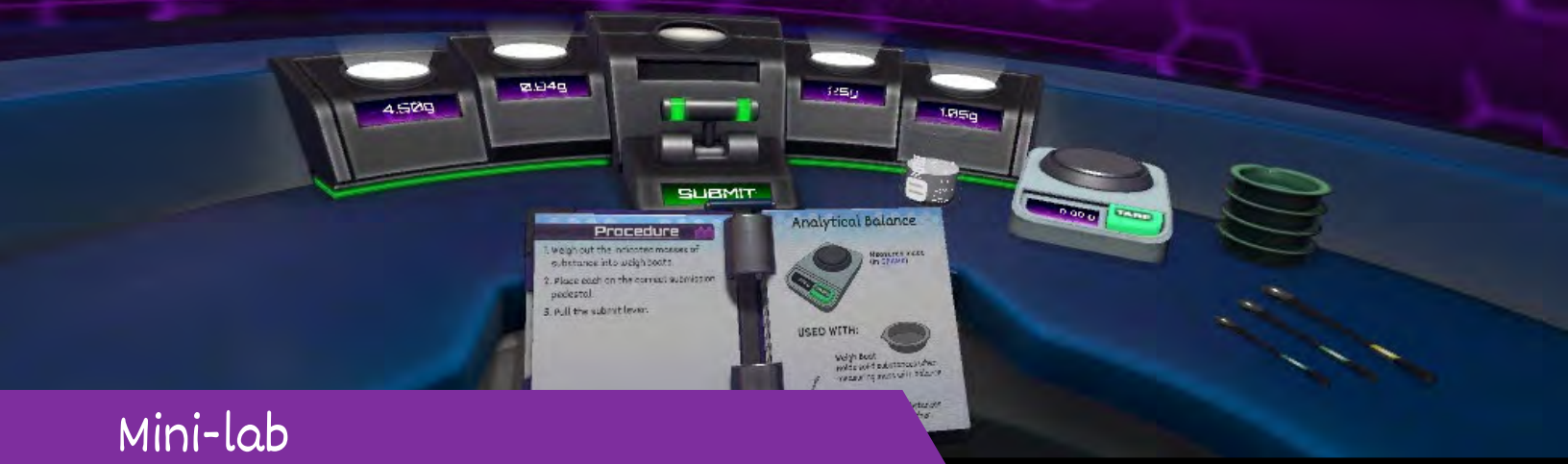
- Each pedestal submission is worth 1/3 total accuracy
- As long as the flask submitted on each pedestal contains the correct dye in an excited state, the submission will pass
- The accuracy score will be scaled according to how close the submissions' chemical contents match the expected amount

Classroom Suggestion:

Demonstration using HoloLAB (15 minutes)

- Select one student to serve as the demonstrator.
- Provide observing students with printed copies of the Chemiluminescence lab notes page. ([See Appendix E](#))
- Have the student in VR follow the procedure for the lab but stop short of identifying the dye in each flask.
- Ask the observing students to identify the three dyes. Ask the student in VR to submit the flasks based on their classmate's analysis.
- Discuss the general mechanism behind chemiluminescent reactions. Ask students to hypothesize as to the role of the hydrogen peroxide in the reaction.

Mass Hysteria



Mini-lab Mass Hysteria

Key Skills: Measuring solids

Key Equipment: analytical balance, scoops, weigh boats

Estimated Time: 3-8 minutes

Submission Goals:

- 4.5g
- 0.84g
- 25g
- 1.05g

What's the Purpose?

This lab gives students practice using an analytical balance to measure out specific amounts of solid powder. Students must measure out four different amounts, each with different levels of precision.

Accuracy Scoring Notes:

- Each pedestal submission is worth 1/4 total accuracy
- Must have exact mass to get 100%
- Up to 50% error is accepted for each submission

Classroom Suggestion:

Stations (Groups of 3-4, 10 minutes at each station)

- **Station 1:** Take turns completing the Mass Hysteria mini-lab in VR
- **Station 2:** Match measurement scenario to correct equipment based on precision needed
- **Station 3:** Write out detailed instructions for someone measuring mass
- **Station 4:** Discuss situational appropriateness of significant digits when measuring mass

RatiOh-No



Mini-lab RatiOh-No

Key Skills: scaling measurements

Key Equipment: analytical balance, beaker, Erlenmeyer flask, graduated cylinder, scoop, weigh boat

Estimated Time: 3-8 minutes

Submission Goals:

- 1/10x (2mL)
- 10x (200mL)
- 1/2x (15g)
- 2x (60g)

What's the Purpose?

This lab gives students practice scaling up and down measurements, as well as measuring solids and liquids. First students must measure the provided liquid and solid samples, then they must apply the appropriate scale to those measurements, using this scaling factor to measure out their own submissions.

Accuracy Scoring Notes:

- Each pedestal submission is worth 1/4 total accuracy
- Up to 2% error counts as perfect for each submission
- Up to 50% error is accepted for each submission

Classroom Suggestion:

Group Co-Op (20 minutes)

- Select one student to serve as the demonstrator. Have that student play the RatiOh-No mini-lab in VR in front of the class.
- Split the remaining students into four teams and assign each team to one pedestal submission.
- Each team takes a turn guiding the student in VR on how to measure or weigh out the submission for their pedestal, including applying the specific scale required.



Mini-lab Chroma Key

Key Skills: visual observation, using references

Key Equipment: beaker, safety data sheet

Estimated Time: 1-3 minutes

Submission Goals:

- Manganese Dioxide
- Barium Chlorate

What's the Purpose?

The goal of this lab is to introduce students to the practice of using observation and reference material to identify chemicals. This lab asks students to observe the color of two different substances and reference the HoloLAB's simplified version of safety data sheets to determine which substance is which.

Accuracy Scoring Notes:

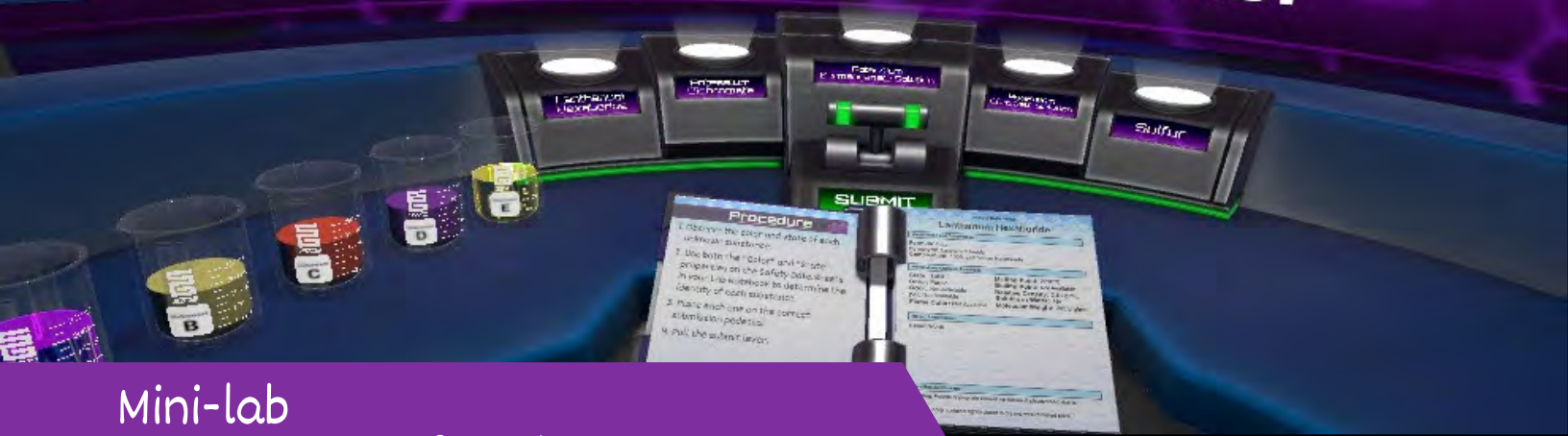
- The player will get 100% accuracy as long as they correctly match substance to the correct pedestal

Classroom Suggestion:

Demonstration using HoloLAB, then Large Group Activity

- Select one student to serve as the demonstrator. Have that student play the Chroma Key mini-lab in VR in front of the class.
- Then split the class into two groups
 - Group 1: Identify additional properties and characteristics of barium chlorate using a sample of the substance and/or reference materials
 - Group 2: Identify additional properties and characteristics of manganese dioxide using a sample of the substance and/or reference materials
- Class discussion to discuss findings. What other ways could be used to identify between these two substances?

A Matter of Color



Mini-lab A Matter of Color

Key Skills: visual observation, using references

Key Equipment: beaker, safety data sheet

Estimated Time: 2-5 minutes

Submission Goals:

- Lanthanum Hexaboride
- Potassium Chromate Solution
- Potassium Dichromate
- Potassium Permanganate Solution
- Sulfur

What's the Purpose?

This lab gives students practice with observation and references. It asks students to use color, physical state, and careful reading to identify five different unknown substances. One of the goals of this lab is to demonstrate the need to read carefully and double-check their work as several of the substances have similar names or overlap in color or state.

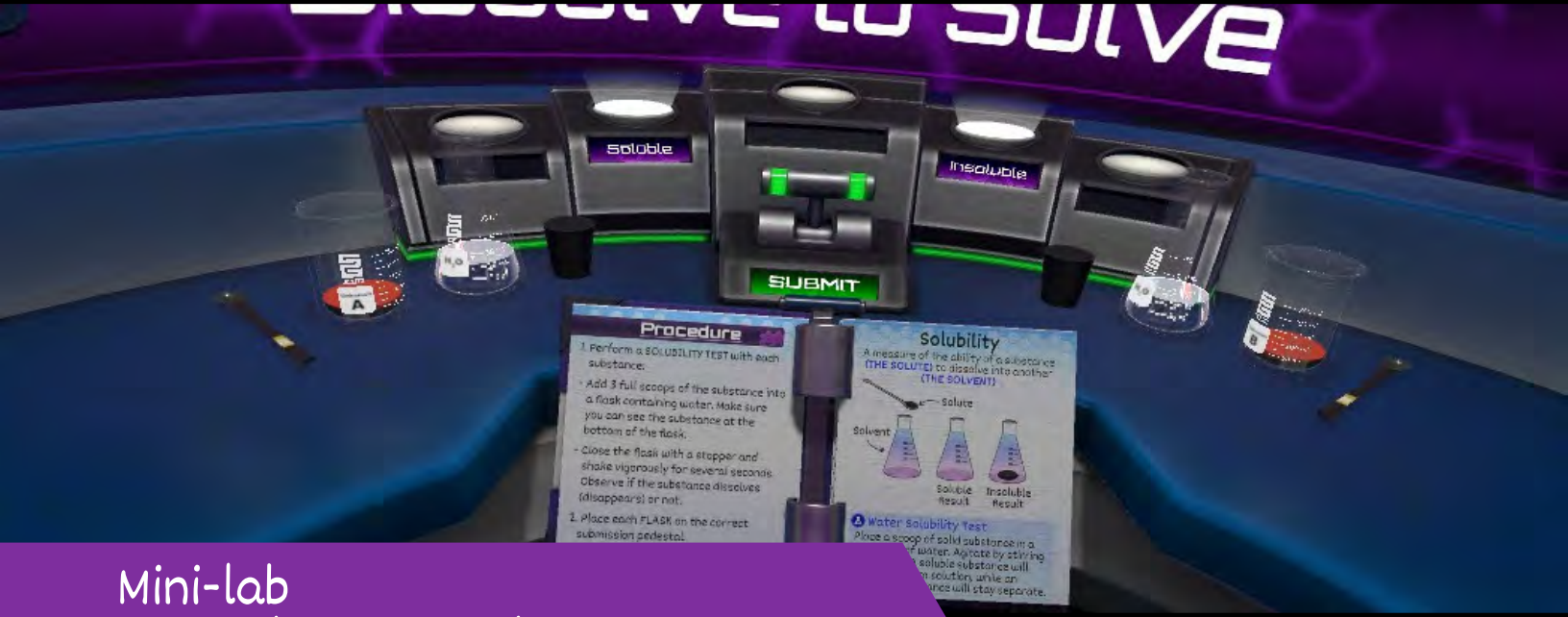
Accuracy Scoring Notes:

- The player will get 100% accuracy as long as they correctly match substance to the correct pedestal
- The correct answers, from left to right: D, E, C, A, B

Classroom Suggestion:

Team Competition (20 minutes)

- Select one student to serve as the demonstrator. Have that student start the Chroma Key mini-lab in VR in front of the class. Ask them to look at the 5 unknown substances but not place them on the pedestal.
- Split the class into teams of 4 students and provide each team with a copy of the Lab Notebook for this lab (See [Appendix E](#))
- Have teams race to identify each substance. Teams must write down their guess for each substance. Have teams raise their hands when they have their answer.
- Ask the first team to read their guess out loud and direct the student in VR to test their answer. If their answer is incorrect, proceed to the second team and so on.
- For any teams that got the substances mixed up, what was the source of their error?



Mini-lab Dissolve to Solve

Key Skills: visual observation, solubility test

Key Equipment: beaker, Erlenmeyer flask, safety data sheet, scoop

Estimated Time: 2-5 minutes

Submission Goals:

- Soluble
- Insoluble

What's the Purpose?

This lab introduces the concept of solubility and gives students a chance to practice performing a simple solubility test. This lab does not require students to identify the two substances, but they can do so using the safety data sheets in the lab notebook.

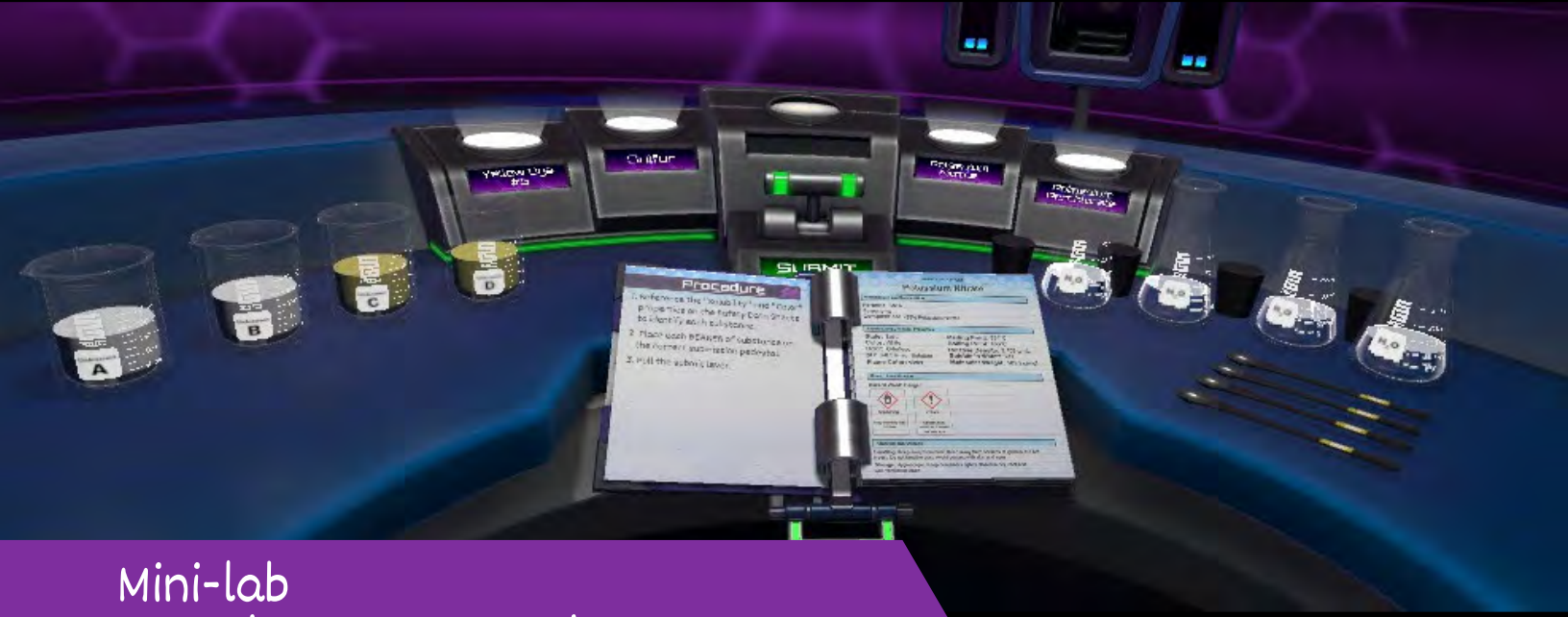
Accuracy Scoring Notes:

- Each pedestal submission is worth 1/3 total accuracy (max. 50k)
- Partial credit will be given if players submit the dry beaker instead of the mixture in the flask, as instructed by the lab procedure.
- The correct answers, from left to right: B (sodium acetate), A (silicon dioxide)

Classroom Suggestion:

Demonstration using HoloLAB, then Partner Activity

- Select one student to serve as the demonstrator. Have that student play the Dissolve to Solve mini-lab in VR in front of the class.
- Pair up students and have them conduct additional solubility tests in real life using a number of different chemicals. Challenge students to look up real-world Safety Data Sheets to determine expected results of the solubility test, as well as observations of color and state of matter.



Mini-lab Read to Succeed

Key Skills: visual observation, solubility test, using references

Key Equipment: beaker, Erlenmeyer flask, safety data sheet, scoop

Estimated Time: 2-5 minutes

Submission Goals:

- Yellow Dye #5
- Sulfur
- Potassium Nitrate
- Potassium Perchlorate

What's the Purpose?

This lab asks students to identify four chemicals based on both visual observation and solubility properties. Students are presented with four unknown substances (two white, two yellow), 4 flasks of water, and 4 scoops.

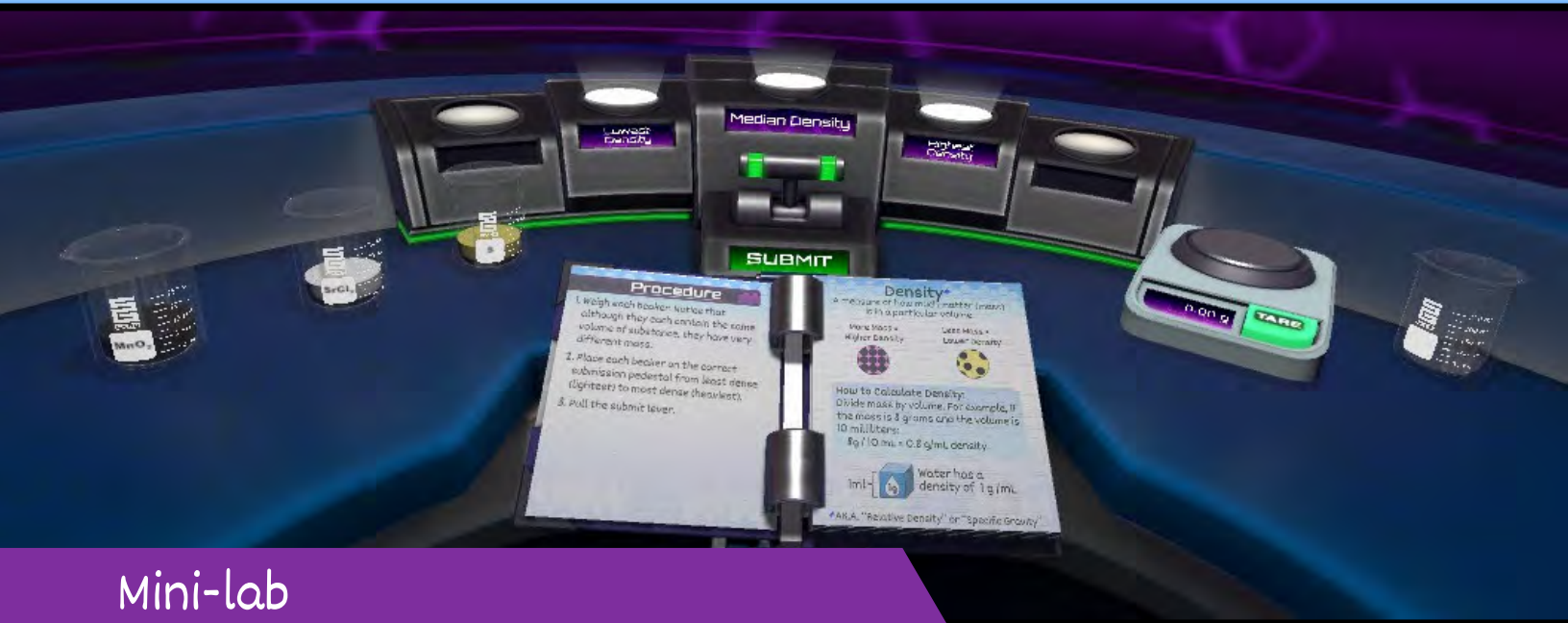
Accuracy Scoring Notes:

- Each pedestal submission is worth 25% of total accuracy, based on:
 - 1/3 – student submitted the beaker, as instructed
 - 1/3 – the submission is not contaminated with any other substances
 - 1/3 – the amount of substance submitted matches expectations based on the procedure, which asks the student to use 3 full scoops
- There is no penalty for re-using a scoop, unless it results in contamination.
- The correct answers, from left to right: C, D, B, A

Classroom Suggestion:

Stations (Groups of 3-4, 10 minutes at each station)

- **Station 1:** Take turns completing the Read to Succeed mini-lab in VR
- **Station 2:** Activity about predicting solubility by the polarity of an ionic compound
- **Station 3:** Write out ionic equations
- **Station 4:** Conduct a real-world solubility test
- **Station 5:** Create a concentration solution (using molar math)
- **Station 6:** Create a diluted solution



Mini-lab Dense Party

Key Skills: measuring mass, understanding density

Key Equipment: analytical balance, beaker

Estimated Time: 2-5 minutes

Submission Goals:

- Lowest Density
- Median Density
- Highest Density

What's the Purpose?

This lab introduces the concept of density as related to mass by asking students to weigh three identical volumes of three different chemicals and observe the different masses. Students are then asked to relate the relationship of mass to volume by ordering the three substances from least dense to most dense.

Accuracy Scoring Notes:

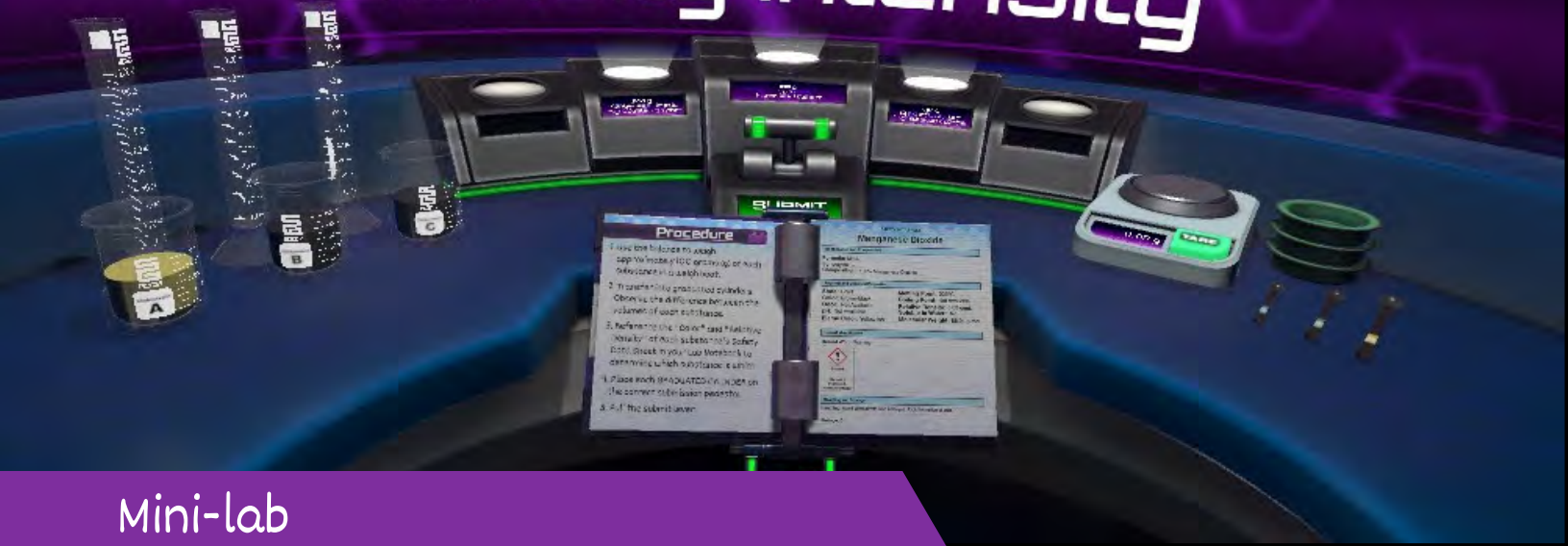
- Each pedestal submission is worth 1/3 total accuracy
- Accuracy will be lower if the player spills any of the substances
- The correct answers, from left to right: S (sulfur), SrCl₂ (strontium Chloride), MnO₂ (manganese dioxide)

Classroom Suggestion:

Stations (Groups of 3-4, 10 minutes at each station)

- **Station 1:** Take turns completing the Dense Party mini-lab in VR
- **Station 2:** Match measurement scenario to correct equipment based on the amount of precision needed
- **Station 3:** Write out detailed instructions for someone measuring volume
- **Station 4:** Discuss situational appropriateness of significant digits

Density Intensity



Mini-lab Density Intensity

Key Skills: measuring mass, understanding density

Key Equipment: Beaker, Erlenmeyer flask, graduated cylinder, safety data sheets

Estimated Time: 4-8 minutes

Submission Goals:

- Manganese Dioxide
- Sulfur
- Synthetic Rubber

What's the Purpose?

This lab gives students a hands-on demonstration of the relationship between density and volume, then asks students to identify between substances based on observed density. First, students must measure out 100g of each substance into the provided graduated cylinders. Then, students must use the safety data sheets to identify all three substances. Using visual observations, students can identify the yellow substance. In order to differentiate between the two black substances, the student should observe the extreme difference between the density of the two substances and reference the density property on the safety data sheets.

Accuracy Scoring Notes:

- Each pedestal submission is worth 1/3 of total accuracy, based on:
 - the submission is in a graduated cylinder as directed
 - the submission is not contaminated with any other substances
 - the amount of substance submitted matches expectations based on the procedure
- The correct answers, from left to right: B, A, C

Classroom Suggestion:

Stations (Groups of 3-4, 10 minutes at each station)

- **Station 1:** Take turns completing the Density Intensity mini-lab in VR
- **Station 2:** Match measurement scenario to correct equipment based on the amount of precision needed
- **Station 3:** Write out detailed instructions for someone measuring volume
- **Station 4:** Discuss situational appropriateness of significant digits

Identiflame



Mini-lab Identiflame

Key Skills: Performing flame test

Key Equipment: beaker, Bunsen burner, platinum loop, striker, safety data sheets*

Estimated Time: 2-5 minutes

Submission Goals:

- Barium Chlorate
- Copper Chloride
- Potassium Nitrate
- Calcium Carbonate
- Strontium Chloride

What's the Purpose?

This lab asks students to perform the flame test with 6 unknown substances in order to identify each. Several colors are similar to one another, so students must use careful observation to compare the colors and make a correct identification.

Accuracy Scoring Notes:

- Each pedestal submission is worth 20% total accuracy, based on:
 - the submission is not contaminated with any other substances
 - the amount of substance submitted matches expectations
- The correct answers, from left to right: E, F, A, B, C (D is not used)

*Note

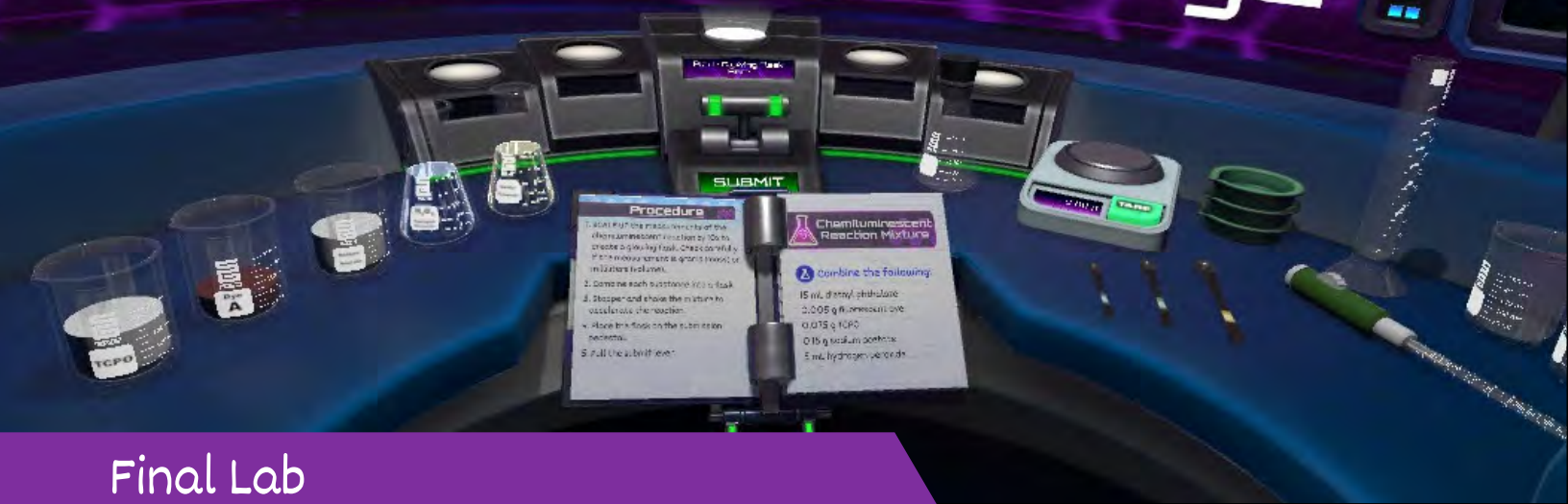
Real-world SDS documentation does not include the flame color produced by the substance.

Classroom Suggestion:

Stations (Groups of 3-4, 10 minutes at each station)

- **Station 1:** Take turns completing the Identiflame mini-lab in VR
- **Station 2:** Perform a real-world flame test
- **Station 3:** Read about spectroscopy
- **Station 4:** Practice calculations of wavelength, frequency, and energy
- **Station 5:** Explain flame color mechanism by drawing a diagram and writing out an explanation
- **Station 6:** Watch video of fireworks and identify likely substance used to create color observed

Glowing Flask Challenge



Final Lab Glowing Flask Challenge

Key Skills: Follow a multi-step procedure

Key Equipment: analytical balance, beaker, Erlenmeyer flask, graduated cylinder, scoop, weigh boat

Estimated Time: 5-15 minutes

Submission Goals:

- Glowing Flask

What's the Purpose?

This lab asks students to create a glowing flask filled with at 200 mL of chemiluminescent liquid. To complete this lab, students must multiply the provided measurements by a factor of 10. They must then measure out that calculated amount of the various chemicals required for the reaction.

Accuracy Scoring Notes:

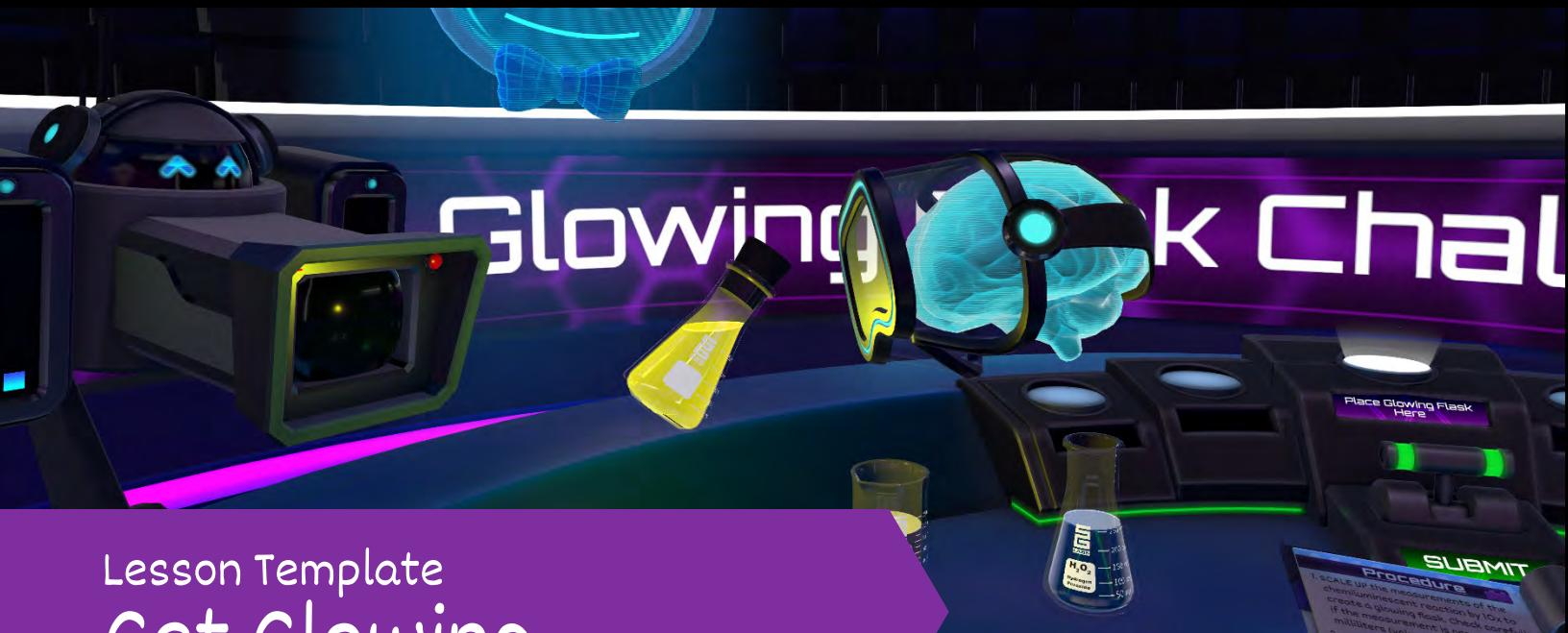
- The correct scaled measurements are: 150ml diethyl phthalate, 0.05g rubrene, 0.750g TCPO, 1.5g sodium acetate, 50ml hydrogen peroxide
- As long as at least some amount of each of the required chemicals is present in the submitted container and the player shakes it a little, the reaction will occur and the submission will pass.
- The accuracy score is based on the average percentage error of all five required chemical measurements.

Common Mistakes

- Students may overlook the procedure's instructions to scale the measurements by a factor of 10. They can still pass the lab without scaling but will receive a lower accuracy score. *If this mistake occurs, discuss why it happened and what lab practice could have prevented it.*
- Students may lose track of what step they are on or what a particular container holds. They can always use the Reload Equipment pulley to reset the lab. In a real-world lab, they could label containers. *If this mistake occurs, discuss what lab practices could be used to prevent this issue in the real-world lab.*

Comparing to the Real-World

- The simulated reaction in this lab is a simplified approximation of the real-world reaction. Therefore, the products yielded by the reaction will not match the precise products produced in the game. **For advanced students:** *As a follow-up exercise, use stoichiometry to calculate the actual expected products in the real-world.*
- In the real-world, the chemiluminescent reaction will occur (although more slowly) even without some of the chemicals or shaking of the flask. **For advanced students:** *Of the chemicals in this lab, which are required to create a glow? What is the purpose of the shaking and additional chemicals?*



Lesson Template Get Glowing

How do you measure up?

Summary

This lesson is designed to have students collaborate to complete a lab that demonstrates a chemiluminescence reaction. The class is split into 6 teams, which range in size from 1 to 5 students. One team runs the lab in VR, while the other teams are each in charge of planning and guiding one step of the lab procedure.

Estimated Time
45 minutes

Accommodates
6 teams of 1-5
students

Learning Objectives

The purpose of this lesson is to have students collaboratively practice following and completing a lab procedure using basic lab equipment.

After this lesson, students will be able to:

- A. **Name and use simple lab equipment:** To complete the procedure, students will use a graduated cylinder, beaker, Erlenmeyer flask, analytical balance, weigh boat, and scoops. There is also a Mohr pipette available, though students can complete the lab without using it.
- B. **Follow written lab instructions:**
 - Read and complete all steps in correct order.
 - Infer implied details on appropriate equipment and process.
 - Select correct chemical compounds identified in the instructions.
- C. **Describe and perform basic lab steps:**
 - Measure volume and mass of chemical substances
 - Select appropriate measuring tools and use them correctly
 - Achieve appropriate accuracy level for measurements
 - Scale substance amounts by the indicated factor

Lesson Materials

- VR equipment and computer w/ classroom-facing monitor or projector
- Lesson Printouts: Lab Procedure, Pre-Lab Procedure Worksheet, Lab Report Template, Lab Notes from [Appendix E](#) (optional)

Lesson Steps

- 1. Before the Lesson:**
 - Tell the class they will be working together to create a glowing flask in a VR lab
 - While one student will be in VR, this student will **NOT** be responsible for leading the lab. It is the observing students who will need to provide clear instructions to the student in the headset.
 - (optional) Provide background information on chemiluminescent reactions
- 2. Identify 2 students to operate as the VR team.**
 - One student will spend the class time in VR. Get them set in the equipment (head mount, hand controls), making sure that they can hear both the software and their classmates' instructions. This can be accomplished via speakers at an appropriate level (such that the class can hear the audio, too) or headphones for the player (with one side of the headphones placed askew so that they can hear their classmates).
 - One student will be the VR student's spotter. This student will make sure the student in VR does not get tangled in their VR cables. It is also their job to ensure that anything said by the student in VR is heard by the class and teacher.
- 3. Split the remaining class into 5 equal-sized teams.**
 - Give each team a copy of the full lab procedure and pre-lab procedure worksheet.
 - Assign each team one substance used in the procedure for which they will be responsible for guiding the player in VR.
 - Instruct each team to read the full procedure and discuss as a group answer the worksheet questions for their assigned substance. (5 minutes. Use this time to get the VR students set up in VR.)
 - Give each student a copy of the Lab Report. During the lab, students are individually responsible for recording their observations of what takes place in each step.
- 4. Start the game and direct the student in VR to the Practice Lab "Glowing Flask Challenge"**
- 5. Instruct the student in VR to look around the lab desk and identify all the available equipment and materials before starting the lab.**
- 6. Begin the lab. During each step of the lab:**
 - The team responsible for the step coaches the VR player on how to complete the step correctly, including what equipment to use and how and what to measure. The team can also provide background to the rest of the class on why the step is necessary, what chemical reaction takes place, etc.
 - The correct scaled measurements are: 150ml diethyl phthalate, 0.05g rubrene, 0.750g TCPO, 1.5g sodium acetate, 50ml hydrogen peroxide
- 7. After the lab is completed:**
 - After-activity Discussion
 - Ask questions that probe students' understanding of the lab's procedure
 - On occasions when the glowing reaction does not occur or the accuracy achieved is less than 100%, the observing students could be asked to identify what sources of error and to make suggestions on how to correct the issue to make it work
 - Have students turn in their lab notes after class for grading.

Extended Discussion Points

- **Origin of the fluorescence:** Discuss *why* the reaction occurs and the role each substance plays in the reaction. Talk about how commercially available glowsticks produce on-demand glow. Discuss why the glow eventually fades.
- **Percent Error:** If the solution did not glow as expected or if the accuracy score was not perfect, discuss possible sources of error and how to quantify that error.

Glowing Flask Challenge

Procedure

1. Scale the measurements of the chemiluminescent reaction by 10x to create a glowing flask. Check carefully if the measurement is grams (mass) or milliliters (volume).
2. Combine each substance into a flask.
3. Stopper and shake the mixture to accelerate the reaction.
4. Place the flask on the submission pedestal.
5. Pull the submit lever.

Chemiluminescent Reaction

15 mL diethyl phthalate

5 mg fluorescent dye

75 mg TCPO

0.15 g sodium acetate

5 mL hydrogen peroxide

Glowing Flask Challenge

Pre-Lab Procedure Worksheet

- **Diethyl phthalate**
 - What volume does the player need to measure according to the lab procedure?

 - What equipment should the player use to measure this volume?

- **Fluorescent dye**
 - What volume does the player need to measure according to the lab procedure?

 - What equipment should the player use to measure this volume?

- **TCPO**
 - What volume does the player need to measure according to the lab procedure?

 - What equipment should the player use to measure this volume?

- **Sodium acetate**
 - What volume does the player need to measure according to the lab procedure?

 - What equipment should the player use to measure this volume?

- **Hydrogen peroxide**
 - What volume does the player need to measure according to the lab procedure?

 - What equipment should the player use to measure this volume?

Glowing Flask Challenge Lab Report

Name:

Date:

Purpose: *Briefly state the goal of this lab*

Materials: *List the equipment and chemicals used in the lab*

Method: *Record each action taken during the lab*

Results: *Describe the final results of the lab.*

Final Score: *Record the final score achieved in the lab*

Accuracy Score:

Accuracy %:

Safety Penalties:
(if any)

Time Bonus:

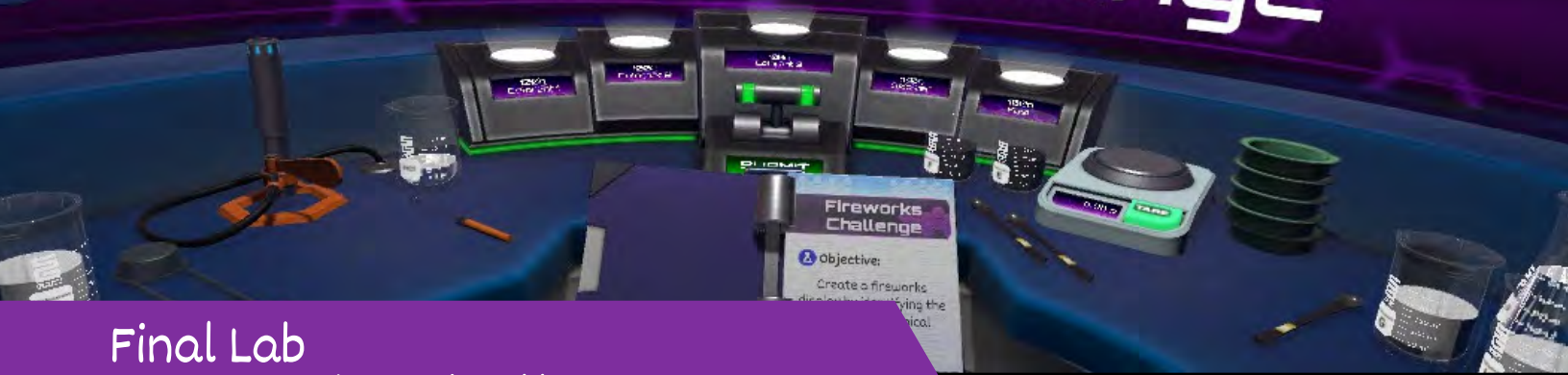
Discussion: *Answer the following questions after group discussion upon lab completion*

If your group did not get a perfect accuracy score, theorize about possible sources of error during the lab.

How was completing this lab in the HoloLAB different from doing so in a real-world lab?
Suggest at least 3 differences.

E.g., In a real-world lab, students would wear gloves when working with the chemicals in this lab

Fireworks Challenge



Final Lab Fireworks Challenge

Key Skills: Identifying unknowns through observation and testing

Key Equipment: analytical balance, beaker, Bunsen burner, Erlenmeyer flask, graduated cylinder, platinum loop, safety data sheets

Estimated Time: 15-30 minutes

Submission Goals:

- 100g Colorant 1
- 100g Colorant 2
- 100g Colorant 3
- 100g Oxidizer
- 100g Fuel

What's the Purpose?

This lab asks students to use a variety of identification methods to differentiate between 8 different substances to create a series of yellow, blue, and pink fireworks. The methods students can use for identification include visual observation, solubility, density, and flame color. Upon their submission, a simulated trio of fireworks will be displayed based on what the student submitted.

Accuracy Scoring Notes:

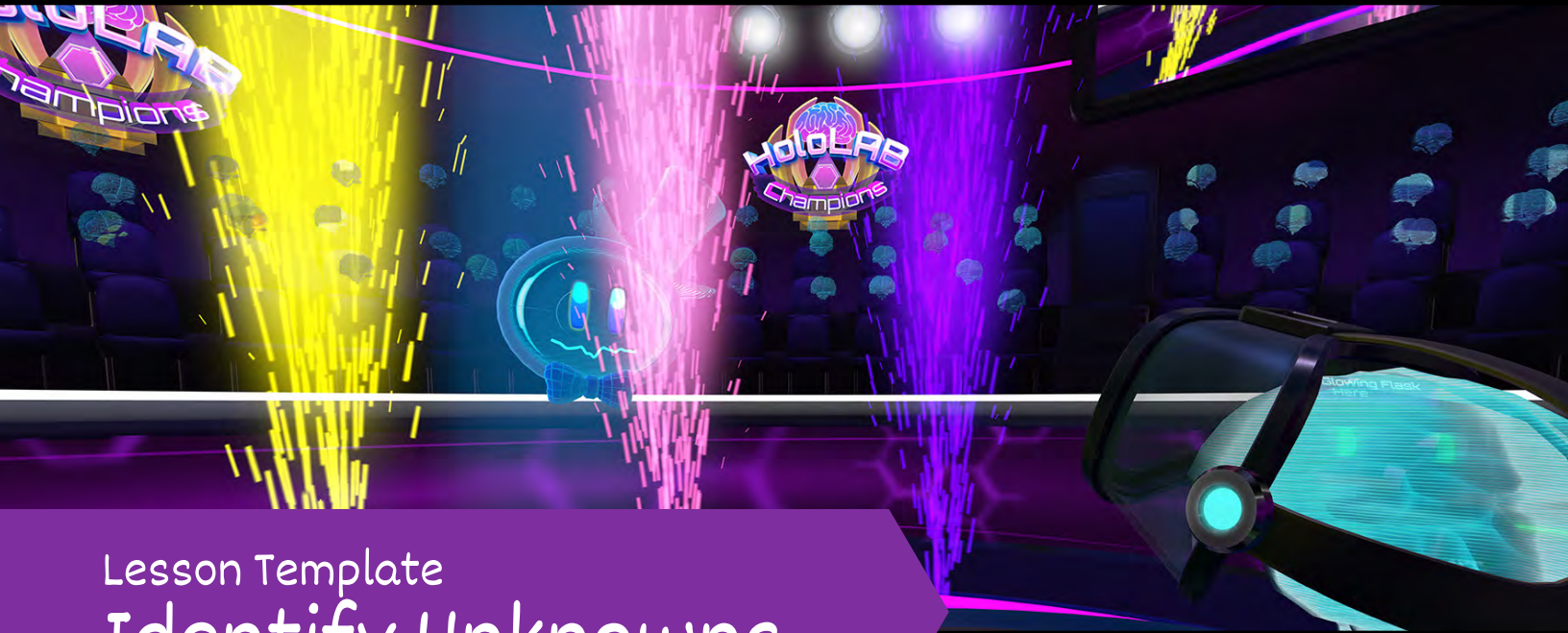
- The player will pass the lab as long as they submit at least a small amount of substance on each pedestal (at least 30mL)
- The success and color of the three fireworks displayed is dependent on what the player submits: If the player does not submit the correct substance for the oxidizer or fuel, the fireworks will be duds (puffs of smoke). If the player submits an incorrect substance for any of the colorants, the color of that firework will be incorrect.

Common Mistakes

- This lab involves managing a lot of lab materials. As a result, students may lose track of what unknowns they've already tested and the corresponding results. *If this mistake occurs, ask observing students to check their lab notes. Did they record enough detail to recover from the confusion? What strategies could be used with the lab equipment to prevent these mix-ups?*
- Students may overlook the procedure's instructions that indicate which tests to use for which unknowns. This can result in students feeling overwhelmed on how to approach the identification process. *If this mistake occurs, discuss why it happened and what lab practice could have prevented it.*

Comparing to the Real-World

- There are many other tests that could be used to differentiate between substances. **For advanced students:** *Discuss other methods of identification.*
- In the real-world, many of these chemicals are not safe for casual handling. **For advanced students:** *Reference SDSs for a quick reference on the hazards of each substance. Discuss the safe real-world handling of each substance.*



Lesson Template

Identify Unknowns

Identify, Measure, Explode!

Summary

This lesson is designed to have students collaborate to complete a lab that demonstrates methods of identifying unknowns. The class is split into 9 teams, which range in size from 1 to 5 students. One team runs the lab in VR, while the other teams are each in charge of planning and guiding one step of the lab procedure.

Estimated Time

45 minutes

Accommodates

9 teams of 1-3 students

Learning Objectives

The purpose of this lesson is to have students collaboratively practice following and completing a lab procedure using basic lab equipment.

After this lesson, students will be able to:

- A. **Name and use simple lab equipment:** To complete the procedure, students will use a beaker, striker, metal loop, Bunsen burner, graduated cylinder, analytical balance, weight boat, Material References (based on Safety Data Sheets) and scoops.
- B. **Practice methodical processes for identification:**
 - Perform intentional tests and observe the results
 - Reference details about the substance to confirm properties.
 - Track their observations and present an identified unknown.
- C. **Describe and perform basic lab steps:**
 - Measure mass and volume to determine density
 - Select appropriate measuring tools and use them correctly
 - Achieve appropriate accuracy level for measurements
 - Perform flame tests with an open flame
 - Mix solid powders into liquids to observe solubility

Lesson Materials

- VR equipment and computer w/ classroom-facing monitor or projector
- Lesson Printouts: Lab Procedure, Pre-Lab Procedure Worksheet, Lab Report Template, Lab Notes from [Appendix E](#) (optional)

Lesson Steps

1. Before the Lesson:

- Tell the class they will be collaborating together to complete a lab in which they will identify 8 unknowns and create a firework display in VR
 - While one student will be in VR, this student will **NOT** be responsible for leading the lab. It is the observing students who will need to provide clear instructions to the student in the headset.
- (optional) Provide background solubility, safety data sheets, density, and/or flame test

2. Identify 2 students to operate as the VR team.

- One student will spend the class time in VR. Get them set in the equipment (head mount, hand controls), making sure that they can hear both the software and their classmates' instructions. This can be accomplished via speakers at an appropriate level (such that the class can hear the audio, too) or headphones for the player (with one side of the headphones placed askew so that they can hear their classmates).
- One student will be the VR student's spotter. This student will make sure the student in VR does not get tangled in their VR cables. It is also their job to ensure that anything said by the student in VR is heard by the class and teacher.

3. Split the remaining class into 8 teams.

- Each team will be in charge of one unknown compound in the lab. Note that for the purposes of completing the lab, only 5 substances must be identified and measured. However, for purposes of class demonstration and learning opportunities, this activity will result in all 8 unknowns being identified.
- Give each team a copy of the full lab procedure and lab notes. Instruct them to read the complete procedure.
- Give each team one of the eight [Safety Data Sheets](#) of the unknowns in this lab:
 - Ammonium Perchlorate
 - Barium Chlorate
 - Calcium Carbonate
 - Copper Chloride
 - Gunpowder
 - Iron Powder
 - Silicon Dioxide
 - Sodium Nitrate
- Each team is responsible for recognizing their chemical(s) based on the tests performed by the player in VR.

4. Start the game and direct the student in VR to the Practice Lab "Fireworks Challenge"

5. Instruct the student in VR to look around the lab desk and identify all the available equipment and materials *before* starting the lab.

6. Begin the lab:

- The observing teams take turns directing the student in VR on how to perform a specific test on a specific unknown. They can choose any test (e.g., flame test, density calculation, solubility test) though the lab procedure does suggest particular order and particular tests for unknowns.
 - Note that each unknown will not require each test in order to identify it.
- The other students are individually responsible for recording their observations of what takes place in each step.
- When the class feels that they have identified a substance definitively as one of the required chemicals, the student in VR measures out 100g of that substance and places it on the correct pedestal.
- The substances that must be submitted on the pedestals are (from left to right):
 - Colorant A: B (100g)
 - Colorant B: C (100g)
 - Colorant C: A (100g)
 - Oxidizer: G (100g)
 - Fuel: E (100g)

7. After the lab is completed:

- After-activity Discussion
 - Ask questions that probe students' understanding of the various identification methods demonstrated in the lab
 - On occasions when the student in VR does not complete the procedure correctly and the fireworks reaction does not occur, or the resulting fireworks are not the correct colors, or the accuracy score is less than 100%, the students could be asked to theorize what error(s) they made and how to correct those errors.
- Students turn in their lab notes after class for grading.

Extended Discussion Points

- **Concept of Identifying Unknowns:** Why is it important to know what you are handling? Discuss how methods to determine what something is differ from what something is not. What are other methods of differentiating substances?
- **Anatomy of a Firework:** What are each of the parts that enable a firework to work correctly? What would happen if each part were missing? Talk about the role of the oxidizer and why pure carbon doesn't burn as well as gunpowder.
- **Safe Handling of Fireworks:** Fireworks are explosive devices. What happens if a firework fuse is lit but the firework doesn't fire? What should be done to handle duds or misfired fireworks?
- **Pollution Effects of Fireworks:** What happens to the air around a firework when it explodes? What happens to the materials that gave the firework its color? Are they totally consumed?
- **Bulk Density:** What influences the density measurements of a powdered solid? How does particle size and variability impact measured density? What are other ways to measure density when working with a powdered solid? (Water displacement test if the substance is insoluble in water)

Fireworks Challenge

Procedure

1. Use the flame test to identify the three required metal salt colorants from Unknowns A, B, C, and D.
2. Use information about color and density to identify the fuel from Unknowns E and F.
3. Use the solubility test to identify the oxidizer from Unknowns G and H.
4. Place 100 g of each substance on the correct submission pedestal.
5. Pull the submit lever.

Required Chemicals for Fireworks

Colorant 1: Sodium nitrate

Colorant 2: Copper Chloride

Colorant 3: Calcium Carbonate

Fuel: Gunpowder

Oxidizer: Ammonium Perchlorate

Fireworks Challenge Lab Report

Name:

Date:

Purpose: *Briefly state the goal of this lab*

Materials: *List the equipment and chemicals used in the lab*

Method: *Record each action taken during the lab*

Results & Conclusions: *Describe the final results of the lab.*

Unknown	Identified As	Supporting Evidence
A		
B		
C		
D		
E		
F		
G		
H		

Fireworks Observations: *Note the appearance & color of the three fireworks*

Final Score: *Record the final score achieved in the lab*

Accuracy Score:

Accuracy %:

Safety Penalties:
(if any)

Time Bonus:

Discussion: *Answer the following questions after group discussion upon lab completion*

If your group did not get a perfect accuracy score, theorize about possible sources of error during the lab.

How was completing this lab in the HoloLAB different from doing so in a real-world lab? Suggest at least 3 differences.

E.g., In a real-world lab, each empty container would probably weigh different amounts, even if the same type and size of container, requiring a tare of the scale when switching containers

Appendix A: Details on Lab Equipment

This list gives additional information about each piece of lab equipment in HoloLAB Champions and how its virtual incarnation differs from the real-world.

Analytical Balance



In the game

- Used to measure mass to 0.01 grams (scale of 2) Can only measure one container at a time

Compare to the real world

- Most high school classroom laboratories have balances which measure to 0.1 or 0.01 grams while some high-end balances can measure mass down to 1 μg .
- A real-world balance can measure solid substance placed directly on the scale (although this is generally not good lab practice!)
- Real-world analytical balances usually have a transparent enclosure with doors over the measuring pan to prevent dust and air currents from impacting the measurement.

Beaker



In the game

- Used to measure volume up to 250mL
- Shows grading divisions of 50mL

Compare to the real world

- There are many different size beakers (e.g., 50 mL, 100mL, 150mL, 400mL). Matching glassware size to the amount being measured (e.g., measuring smaller amounts in smaller beakers and larger amounts in larger beakers) makes the quantity easier to see and helps improve accuracy.

Bunsen Burner



In the game

- Gas flow is turned on by turning the orange lever (a sound will be heard indicating the gas is flowing)
- The flame is ignited using the in-game striker
- There is no consequence to leaving the gas on without a flame or leaving the flame on unattended.

Compare to the real world

- Real-world Bunsen burners also have an air mixture adjustment knob.
- In the real-world leaving on the gas when the burner is unlit or unattended is dangerous.

Erlenmeyer Flask



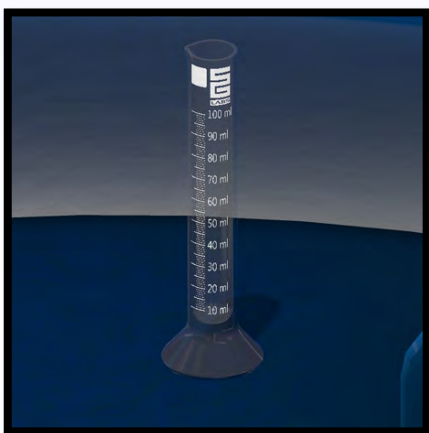
In the game

- Used to measure volume up to 250mL
- Shows grading divisions of 50mL

Compare to the real world

- There are many different size Erlenmeyer flasks (e.g., 100mL, 150mL, 400mL, etc.). Matching glassware size to the amount being measured (e.g., measuring smaller amounts in smaller beakers and larger amounts in larger beakers) makes the quantity easier to see and helps improve accuracy.

Graduated Cylinder



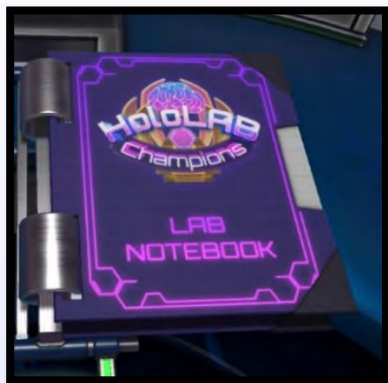
In the game

- Used to measure volume up to 100mL
- Shows grading divisions of 1mL and 10mL

Compare to the real world

- There are many different sizes of graduated cylinders (e.g., 10 mL, 50mL, etc.) Matching glassware size to the amount being measured (e.g., measuring smaller amounts in smaller beakers and larger amounts in larger beakers) makes the quantity easier to see and helps improve accuracy.

Lab Notebook



In the game

- Provides key instructions and references to the player on how to complete each lab

Compare to the real world

- In a real-world lab, the lab notebook is where notes and observations about procedures done in the lab would be recorded, as the student or scientist performs them.

Mohr Pipette



In the game

- Measures up to 10 mL; grading divisions of 1mL and 0.1 mL
- Grading divisions count up and down to assist with transfer, depending on which side of the pipette you look at
- Features a pump mechanism attached to the pipette.
- The HoloLAB pipette pump will draw up liquid when the tip is immersed in liquid (and the controller touch pad or thumbstick is pressed) and will expel liquid when the tip not immersed in

Compare to the real world

- A Mohr pipette might be a higher-precision tool than most high school chemistry labs have. Students can learn about it and practice using it in the HoloLAB but it might be more common to complete these types of small measurements using a 10mL graduated cylinder or small, disposable plastic pipettes.
- There are different types of pumps that can be used with a glass pipette. The pump is usually separate from the pipette.
- A real-world Mohr pipette pump requires the user to manually turn the wheel up or down to draw up or expel liquid. Additionally, a real-world pipette pump of this type may also include a release valve to release liquid from the pipette.

Platinum Loop



In the game

- Will pick up a little substance from any filled container. The loop itself does not contribute to the flame color during the flame test in the game, but it does start with some dirt on it, requiring the player to clean the loop (according to the instructions provided in the lab notebook) in order to get an accurate flame color for identification.

Compare to the real world

- Also called an inoculating loop, most high school labs will use less expensive materials such as nichrome wire. Nichrome contributes a trace of orange to the flame, so platinum is preferable. Wooden splints may also be used, but they burn if exposed to the flame too long.

Safety Data Sheets



In the game

- Include: Nicknames, Formula, Composition, Color, State, Odor, pH, Melting Point, Boiling Point, Relative Density, Flame Color, Solubility, Molecular Weight, Handling, Storage, Hazard Word, GHS icons & warning statements

Compare to the real world

- Safety Data Sheets are extremely detailed. For the purposes of HoloLAB, we have streamlined the SDS to only include the most relevant information and be a single page. Typically, a full SDS includes many more pages of information, particularly about hazards, handling, and safety information.

Safety Goggles



In the game

- At the beginning of each gameplay period, the player is prompted to put on safety goggles before working in the lab.

Compare to the real world

- Safety first! It is essential to wear appropriate protective gear while working in the lab, so students must remember to use their safety goggles in real life, too.
- In the real-world, gloves and a lab coat would also be used as part of good safety practice for most procedures in the lab.

Scoops



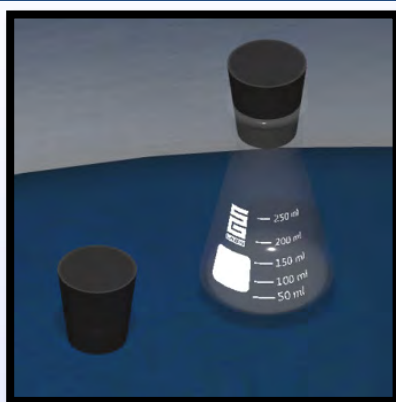
In the game

- There are three sizes of scoops in the game which hold (from largest to smallest) 0.3mL, 0.1mL, and 0.05mL.

Compare to the real world

- A standard lab will typically have a chemical spoon, a scoopula (i.e., a metal scoop that is a half cylinder that comes to a rounded edge to “scoop” up objects), or spatula.

Stopper



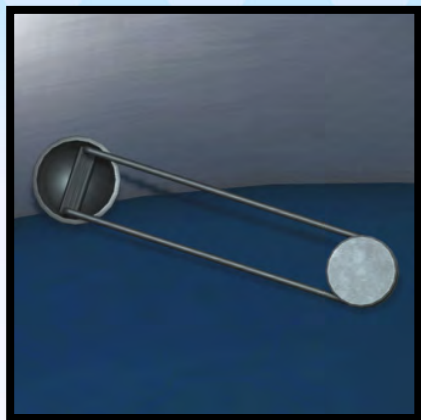
In the game

- Used to stopper up Erlenmeyer flasks in the game to allow for shaking without spilling

Compare to the real world

- Flask stoppers are made of rubber, silicone, glass, or cork and come in a wide variety of sizes to fit the sizes of the glass cylinders or flasks.
- Sometimes a glass watch is used to cover a beaker.

Striker/Ignitor



In the game

- Used to light the HoloLAB Bunsen burner. The striker's spark is generated by pushing the large round trackpad on the front of the **VIVE** controller or press the thumbstick on the **Rift** controller.

Compare to the real world

- Also called a flint spark lighter, these are typically made of steel and vary in size. In the real-world, the striker is operated by squeezing the metal arm to generate a spark.

Waste Disposal



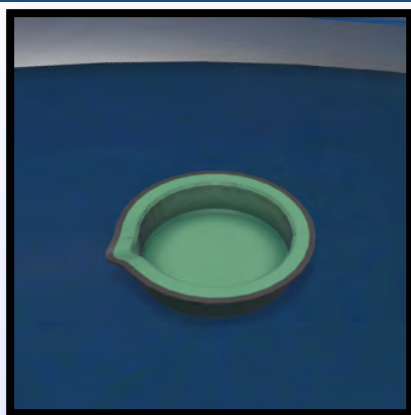
In the game

- There is a single waste disposal which the player can use to dispose of extra substances and dirty equipment. Substances and equipment disposed of in the waste disposal will not trigger spill warnings. Use of the waste disposal is not required by the game, but can be used to manage the lab desk space as well as avoid spill penalties.

Compare to the real world

- Most lab equipment is cleaned with thorough cleaning processes and then reused. Substances are disposed of according to various safety protocols, based on their hazard properties.

Weigh Boat



In the game

- The weigh boats in HoloLAB look a lot like the flexible polyethylene ones typically found in chemistry labs. The weighing boats in HoloLAB are not flexible, though they do help weigh and pour solids into containers accurately.

Compare to the real world

- Weighing dishes and weighing paper are also used to weigh chemicals in the lab. Here, too, the weight of the container in which a compound is weighed should be as small as possible to make sure the precision of the measurement is high. Disposable weighing papers are common and convenient.
- Avoiding spills is very important in the lab to minimize contamination and waste. When using flexible holders (paper or plastic boats, for example), it is best to fold the weighing holder in half like a taco shell to create a spout from which to pour.

Appendix B: Connection to Standards

HoloLAB Champions can be connected to the following standards:

Next Generation Science Standards (NGSS)

- Science and Engineering Practices
 - Asking Questions and Defining Problems
 - Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information
 - Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables
 - Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory.
 - Planning and Carrying Out Investigations
 - Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly.
 - Select appropriate tools to collect, record, analyze, and evaluate data.
 - Analyzing and Interpreting Data
 - Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
 - Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data.
 - Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.

National Science Education Standards

- Science as Inquiry
“Scientific inquiry refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results.”

English Language Arts Standards – Science & Technical Subjects

- CCSS.ELA-LITERACY.RST.9-10.3 & CCSS.ELA-LITERACY.RST.11-12.3
Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.
- CCSS.ELA-LITERACY.RST.9-10.4 & CCSS.ELA-LITERACY.RST.11-12.4
Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context
- CCSS.MATH.CONTENT.HSN.Q.A.3
Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

Appendix C: VR Usage Guide

Prepare Before You Play

- Familiarize yourself with the VR hardware you are using; read the owner's manual or check out <https://www.vive.com/us/setup/> and <https://www.oculus.com/setup/> for some useful resources
- If possible, set up a rug that delineates the 4 ft by 4 ft play area of HoloLAB.
 - Although HoloLAB does not ask the player to move around the space very much, a rug under the player's feet that helps them feel the boundaries of the play area can give the player in the headset more confidence that they won't bump into furniture or walls while in VR. It also helps those outside the VR game to know the space they should walk around to avoid interfering with the player in VR.
- To avoid injury, do not use stationary objects like walls, tables or chairs to delineate play area.
- Set up the display monitor so that observing students not in VR can see what is happening in the game. Ideally, this display is placed so that its orientation matches the player's orientation to make it easier for viewers to follow along and to communicate meaningfully with the player.
- Plan for the player in VR to use sound, if at all possible. For group play, ideally sound would be played through speakers so observing students can also hear. (If the player in VR has headphones, they can be worn with one side set askew so that (s)he can hear classmates' comments and instructions.)
- Ensure hand controllers are charged or have working batteries.
- Use sanitizing lens wipes to clean and sanitize headset and controllers.

Recommended Steps for Guiding First Time VR Players

Whenever possible, avoid using first-time VR players as demonstrators in front of a large class as those new to VR may feel extra self-conscious when performing tasks in VR in front of peers.

1. Let the individual hold the controllers briefly before they put on the headset to become familiar with the look, feel, and placement/use of buttons
2. Show them the headset straps and how they tighten before handing them the headset. Make sure to loosen the headset straps to make it easier to put on.
3. Allow the player to put on the headset. Ask the individual to move the headset up and down on their face until they find the clearest view
4. Assist the individual in tightening the 3 velcro straps on the sides and top of the headset to ensure a snug yet comfortable fit
5. If using headphones, place them on individual's head and prompt them to adjust them for comfort and usability. It can be helpful for the individual to keep one ear clear of a headphone so that they can hear individuals outside of VR. Note that headphone use is only recommended for solo or small-group play, while speaker use is recommended for large group play so that everyone can hear and respond to the game audio
6. Prompt the individual to hold out their hands, then place a controller in each hand (placing the wrist strap attached to the controller around each wrist is recommended)
7. Provide instructions for which lab to complete and how to begin the lab.

General Best Practices for A Great Player Experience in VR

- When you approach or touch the individual in VR, always vocally express what is happening (e.g., “I’m standing in front of you to take your controllers,” “I’m going to put the headphones on for you to adjust and I’m going to plug them in behind you,” “I’m moving the cord behind you,” etc.)
- Do not allow anyone in the play area unless they are the one in VR or they are providing support for the player in VR
- Keep outside conversations (unrelated to the game) to a minimum so as not to confuse the person in VR.
- Keep an eye on the cord attaching the back of the headset to the computer so that the player does not trip
- Do not touch the **VIVE** lighthouses, **Oculus** sensors, or walk directly in front of them as this can disrupt gameplay.
- Try to always keep the headset and hand controllers inside the gameplay area so the system can track them continuously.
- Remind the player that if at any time they start feeling nauseous, they should let you know.
 - If player reports feeling sick, quickly and carefully remove headset, help them sit down, and provide water and fresh air until symptoms pass. Note that this is uncommon for relatively stationary experiences like HoloLAB, but possible.
- Keep in mind that some players may feel self-conscious or overwhelmed if asked to perform in VR in front of a large group of people. Always make sure students feel comfortable being the VR demonstrator before asking them to step into the headset.

Best Practices for After Player Exits VR

- After playing, be aware that individuals may want to recombobulate (e.g., fix hair, make up, etc.) due to the headset. Be patient with this request as it is common.
- Use sanitizing lens wipes to clean and sanitize headset and controllers between users
- Turn off the **VIVE** headset and charge the hand controllers when not in use
- Check that **Rift** controller batteries have a proper charge before their next use

Appendix D: Troubleshooting

Minimum Supported Hardware

CPU: Intel i7-4790 @ 36 Ghz

Memory: 8.0 GB

OS: Windows 8 64-bit

Graphics Card: GeForce GTX 970 4.096 gb

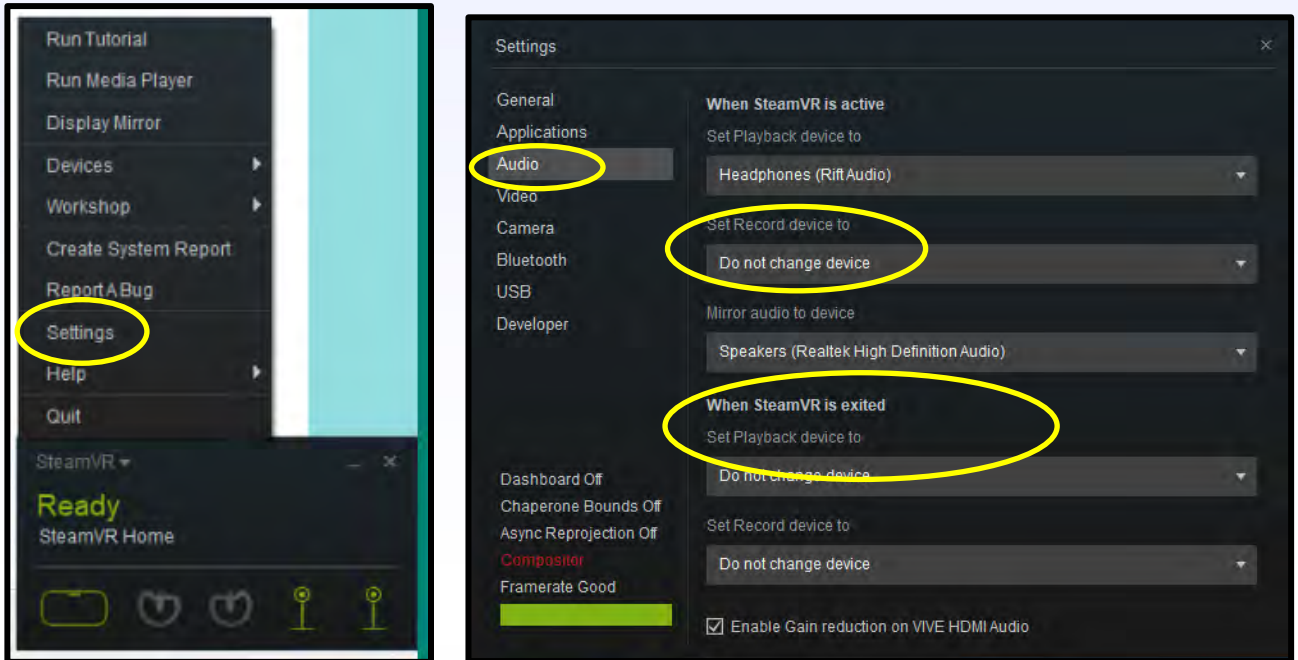
Common Problems

- **The monitor view suddenly appears pixelated or the player may describe seeing a menu over their game and the HoloLAB game as “greyed out.”**
 - **What probably happened:** The player accidentally pressed the STEAM menu button on the controller. To fix this, they should press the STEAM button again. You may need to assist them.
- **The game world appears noticeably darkened to the player.**
 - **What probably happened:** The player stepped out of bounds or is standing inside the HoloLAB desk. If the player is too far out of the expected play area in HoloLAB, the game world will visually darken. Stepping back to the center of the play area should bring things back to normal.
- **A controller is not visible or seems to be not working correctly in the game.**
 - **What probably happened:** First, check the SteamVR status window on the computer. If one of the controller icons is flashing, the player may have stepped out of the play area and lost tracking. Returning to the center of the player area should fix this issue. If one of the controller icons is greyed out, the system cannot detect the controller. Check that the power light on the **VIVE** controller is on. It is possible that the controller needs to be charged. If the power light is on, press and hold the power button on the controller to bring up a menu that the individual in the headset can see. Instruct them to select restart, and the controller should reappear. Check **Rift** controller battery charge. Controllers may need a button to be pressed to turn on.
- **When starting HoloLAB Champions from Steam, you see a message that says “You are logged in another computer already playing HoloLAB Champions. Launching HoloLAB Champions here will disconnect the other session from Steam.”**
 - **What probably happened:** If you use the same Steam account across multiple computers, you may see this message. You may see it even if it appears that no other computers are currently running the game. If you are okay with the possibility that you may not have the latest save from another computer (i.e., your game may not show the highest scores achieved on another computer), you can simply ignore this message and launch HoloLAB Champions. If you want to play the game on multiple machines at once, you will need to create additional Steam accounts, and download HoloLAB Champions on each one. If you believe you need the saved game from the other computer but this message persists even though you are no longer playing on that computer, try returning to

that computer, launching the game briefly, then closing the game. This may allow Steam to finish syncing that computer's saved game to the Steam cloud server.

- **Can't hear audio in headphones/speakers.**

- **What probably happened:** You may need to adjust your audio settings for your computer or your headset. First check that you can hear audio from your computer outside HoloLAB Champions. Next check your headset Settings under "Audio" to make sure that you are outputting audio to the headset and mirroring to the correct speakers:

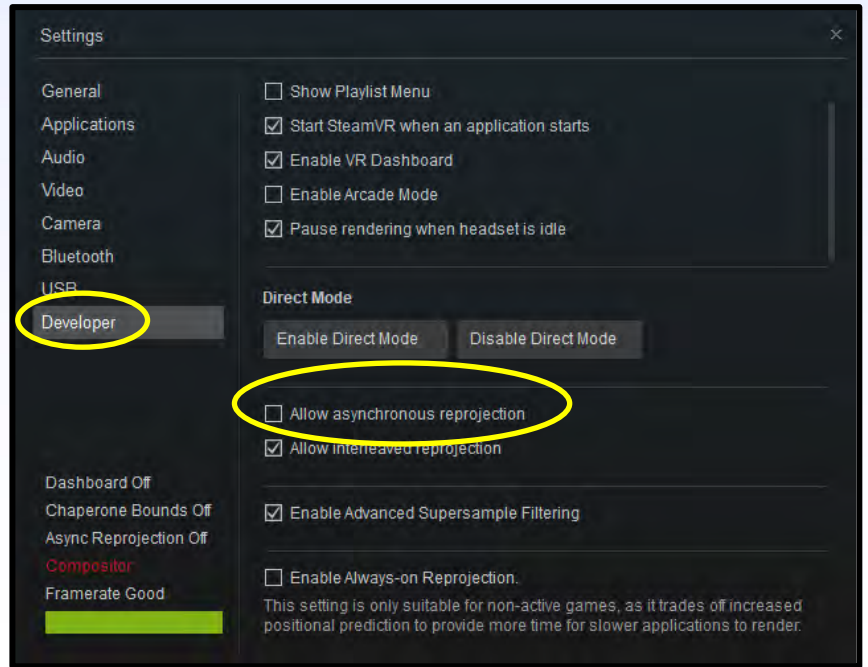
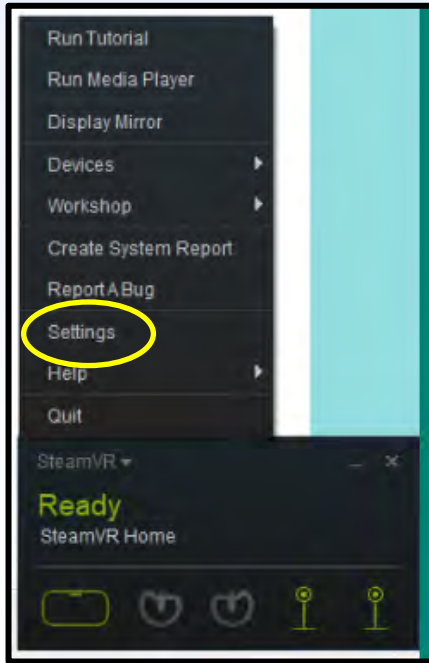


- **You change the camera view but it keeps changing back to first-person.**

- **What probably happened:** The game automatically detects if your framerate drops low for more than 6 seconds. If it does, the game switches the secondary camera to mirror the first-person view, as this reduces performance load. If you see this issue a lot, it is likely that your machine is below the recommended specification for the game.

Note: During the Play Events, the camera angle displayed will change automatically at a few key moments. The camera starts in Meyer-cam (the view from the Meyer camera robot). At the start of the first mini-lab, it switches to first-person so that observers can best follow along with the player. At the end of the Play Event, before the trophy award moment, it switches to the back camera to give a better view of the brain-scan moment. Finally, the camera switches back to Meyer-cam after the trophy is awarded to show the player hoisting their awarded trophy.

- **The camera view seems to jitter when you move your head.**
 - **What probably happened:** There is a VR setting that can change some aspects of the game's performance on some machines, sometimes resulting in a visual jitter when moving your head left and right in the game. If you observe this problem, go to your VR settings under "Developer" and make sure that "Allow asynchronous reprojection" is turned off:



Appendix E: Lab Notebook Content

The following index lists the pages (by page number in this document) that included in-game in the Lab Notebook for every Practice Lab in HoloLAB Champions.

Practice Lab Name	Notebook Pages	Procedure Instructions In-Game
Acceptable Error	59, 60, 63	<ol style="list-style-type: none"> 1. Measure out the estimated volume of liquid, using the graduation marks on the glass as reference. 2. Place each container on the correct submission pedestal.
Precision Panic	59, 60, 63	<ol style="list-style-type: none"> 1. Read the volume in each container by looking at the meniscus of the liquid. 2. Place the containers with the indicated volumes of liquid on the correct submission pedestals.
Chemical Barista	59, 63	<ol style="list-style-type: none"> 1. Carefully measure out the indicated volumes of liquid. 2. Place each container on the correct submission pedestal.
Tiny Transfer	63, 64, 65	<ol style="list-style-type: none"> 1. Use the Mohr pipette to transfer the appropriate volume of blue dye to the three provided flasks of yellow dye. 2. Place each one on the correct submission pedestal.
Glow, Dye, Glow	63, 64, 65, 66	<ol style="list-style-type: none"> 1. For each of the three prepared flasks, add one scoop of a different dye. 2. Use the Mohr pipette to add 5 mL of Hydrogen Peroxide (H_2O_2) to each flask. 3. Cork each flask with a stopper, then shake to accelerate the glow reaction. 4. Identify the dye in each flask by its glow color. 5. Place the glowing flasks on the correct submission pedestals.
Mass Hysteria	61, 62, 63	<ol style="list-style-type: none"> 1. Weigh out the indicated masses of substance into weigh boats. 2. Place each on the correct submission pedestal.
RatiOh-No	61, 62, 63, 64, 65	<ol style="list-style-type: none"> 1. Measure the volume of purple liquid in the provided graduated cylinder. 2. Scale this volume by multiplying by the amounts indicated on the submission pedestals. Measure out these amounts of the blue liquid. 3. Measure the mass of the red powder in the provided beaker. 4. Scale this mass by multiplying by the amounts indicated on the submission pedestals. Measure out these amounts of the yellow solid. 5. Place the scaled amounts on the correct submission pedestals.
Glowing Flask Challenge	59, 60, 61, 62, 63, 64, 65, 66	<ol style="list-style-type: none"> 1. SCALE UP the measurements of the chemiluminescent reaction by 10x to create a glowing flask. Check carefully if the measurement is grams (mass) or milliliters (volume). 2. Combine each substance into a flask. 3. Stopper and shake the mixture to accelerate the reaction. 4. Place the flask on the submission pedestal.

Practice Lab Name	Notebook Pages	Procedure Instructions In-Game
Chroma Key	71, 73, 80	<ol style="list-style-type: none"> 1. Observe the color of each unknown substance. 2. Use the "Color" property on the Safety Data Sheets in your Lab Notebook to determine which substance is which. 3. Place each substance on the correct submission pedestal.
A Matter of Color	71, 79, 81, 82, 85, 92	<ol style="list-style-type: none"> 1. Observe the color and state of each unknown substance. 2. Use both the "Color" and "State" properties on the Safety Data Sheets in your Lab Notebook to determine the identity of each substance. 3. Place each one on the correct submission pedestal.
Dissolve to Solve	67, 87, 82	<ol style="list-style-type: none"> 1. Perform a SOLUBILITY TEST with each substance: <ul style="list-style-type: none"> - Add 3 full scoops of the substance into a flask containing water. Make sure you can see the substance at the bottom of the flask. - Close the flask with a stopper and shake vigorously for several seconds. Observe if the substance dissolves (disappears) or not. 2. Place each FLASK on the correct submission pedestal.
Read to Succeed	67, 83, 84, 92, 93	<ol style="list-style-type: none"> 1. Reference the "Solubility" and "Color" properties on the Safety Data Sheets to identify each substance. 2. Place each BEAKER of substance on the correct submission pedestal.
Dense Party	62, 63, 68, 80, 91, 92	<ol style="list-style-type: none"> 1. Weigh each beaker. Notice that although they each contain the same volume of substance, they have very different mass. 2. Place each beaker on the correct submission pedestal from least dense (lightest) to most dense (heaviest).
Density Intensity	62, 63, 68, 80, 86, 92	<ol style="list-style-type: none"> 1. Use the balance to weigh approximately 100 grams (g) of each substance in a weigh boat. 2. Transfer into graduated cylinders. Observe the difference between the volumes of each substance. 3. Reference the "Color" and "Relative Density" of each substance's Safety Data Sheet in your Lab Notebook to determine which substance is which. 4. Place each GRADUATED CYLINDER on the correct submission pedestal
Identiflame	69, 70, 73, 74, 75, 77, 83, 90, 91	<ol style="list-style-type: none"> 1. Perform a flame test with each substance. 2. Reference the "Flame" property on the Safety Data Sheets in your Lab Notebook to determine which substance is which. 3. Place each substance on the correct submission pedestal.
Fireworks Challenge	67, 68, 69, 70, 73, 74, 75, 76, 77, 78, 88, 90	<ol style="list-style-type: none"> 1. Use the flame test to identify the three required metal salt colorants from Unknowns A, B, C, and D. 2. Use information about color and density to identify the fuel from Unknowns E and F. 3. Use the solubility test to identify the oxidizer from Unknowns G and H. 4. Place 100 g of each substance on the correct submission pedestal:

Graduated Glassware



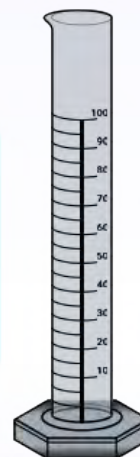
Graduation Lines

BEAKER

Used to hold, mix, and heat substances

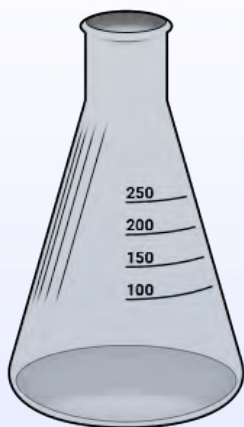
GRADUATED CYLINDER

Used to measure a precise amount of liquids

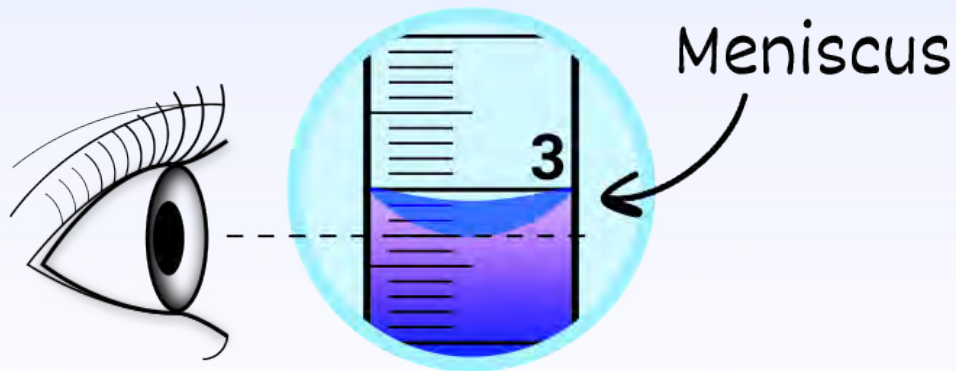



ERLENMEYER FLASK

Used to hold and mix substances. Small neck reduces spills when mixing & allows use of a stopper.

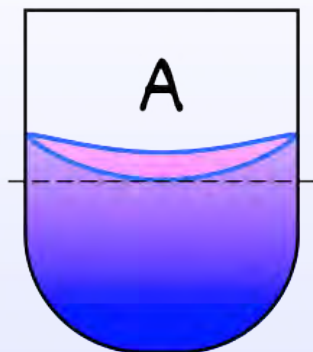


Reading a Meniscus

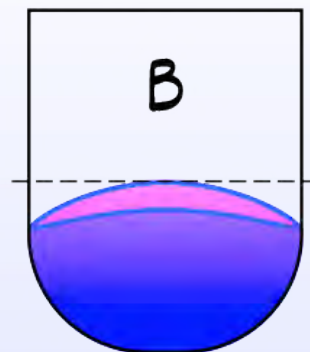


 For most liquids, read at the bottom of the meniscus for the most accurate measurement.

Concave Meniscus
(Ex: Water)



Convex Meniscus
(Ex: Mercury)

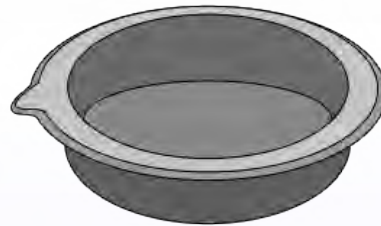


Analytical Balance



Measures mass
(in GRAMS)

USED WITH:



Weigh Boat

Holds solid substances when
measuring mass with balance



Scoop

Used to transfer solid substances
from one container to another

How To Tare



1. Put empty container on balance.



2. Press the TARE button. The balance should read 0g.



3. Now if you add a substance to the container, the balance will only show the mass of that substance, not the container.

Measuring Mass and Volume

MASS

The amount of matter in something

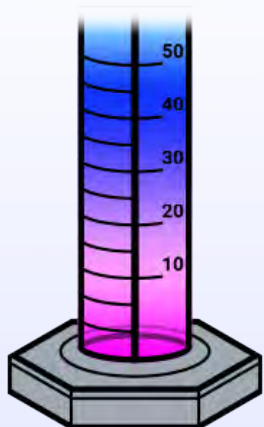
- Measured in GRAMS
- Written as "g"



VOLUME

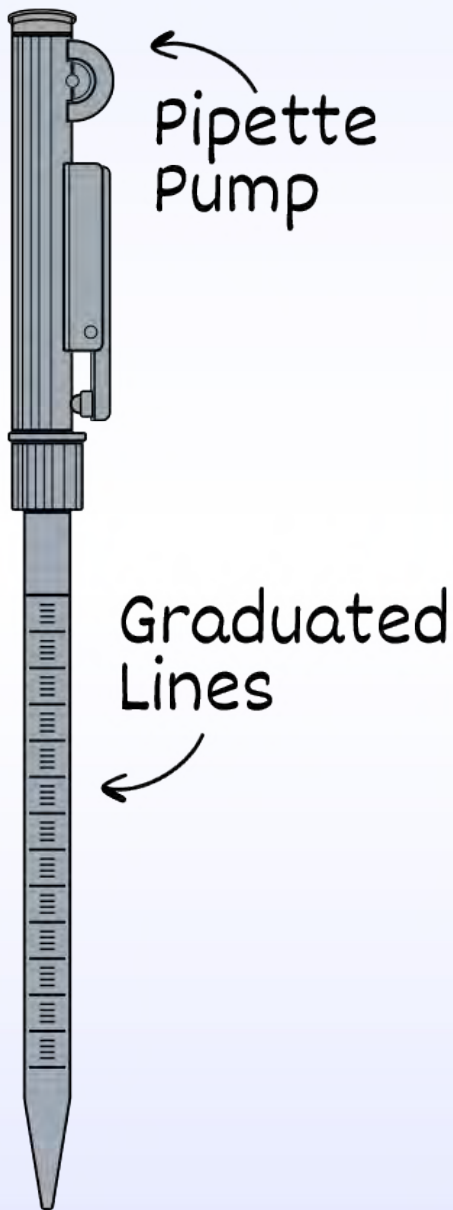
The amount of space something takes up


- Measured in MILILITERS
- Written as "mL" or "ml"

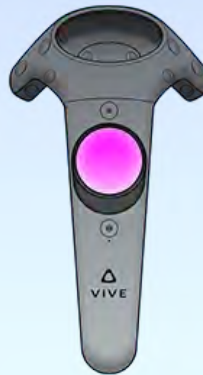



Mohr Pipette

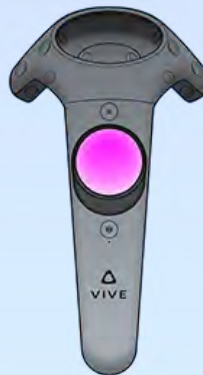
Used to TRANSFER small, precise amounts of liquid.



 Press with tip IN LIQUID to draw up

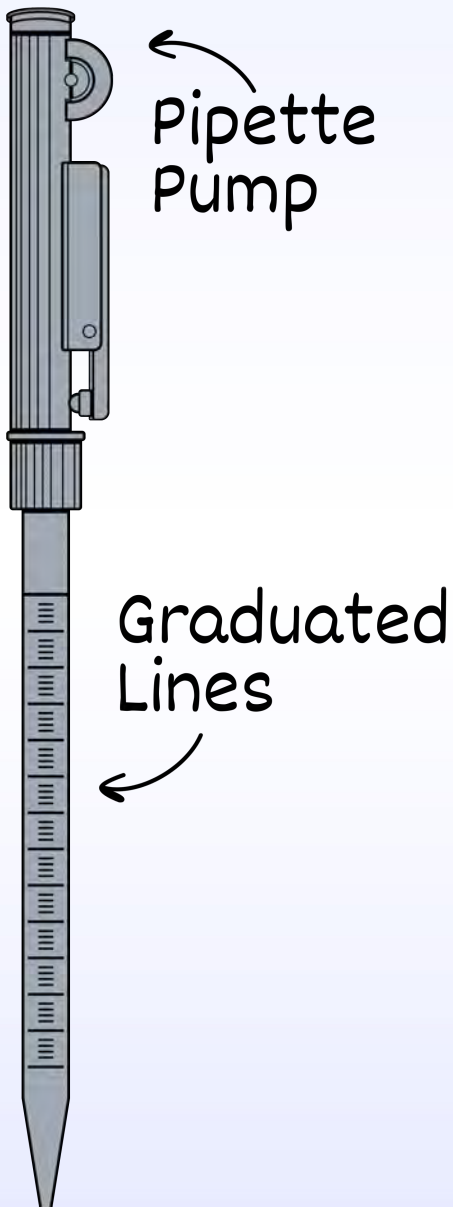



 Press with tip IN AIR to expel

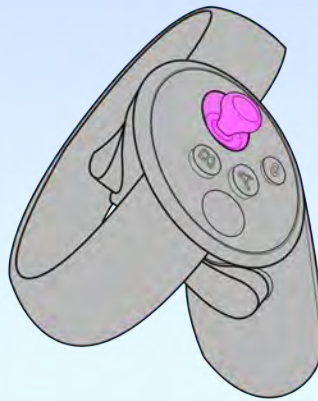



Mohr Pipette

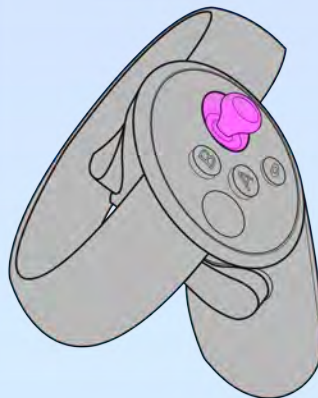
Used to TRANSFER small, precise amounts of liquid.




 Press with tip IN LIQUID to draw up



 Press with tip IN AIR to expel



Pipetting Tips for Accurate Measurements

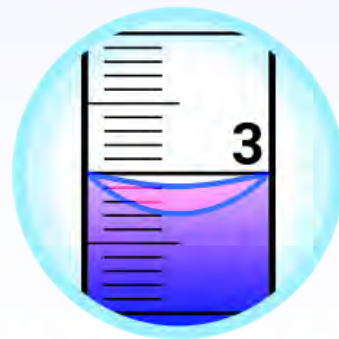
 To transfer liquid correctly, fill and then SUBTRACT to correct amount



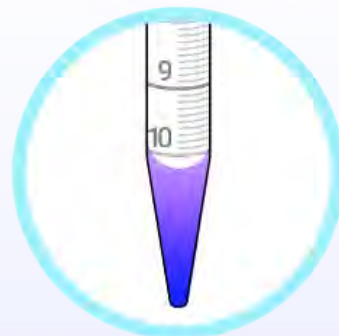
Fill to here

Transferring
3.3 mL

Empty to here



Read from BOTTOM
of meniscus




Some liquid
remains in tip


Chemiluminescence


Light Generated from a Chemical Reaction

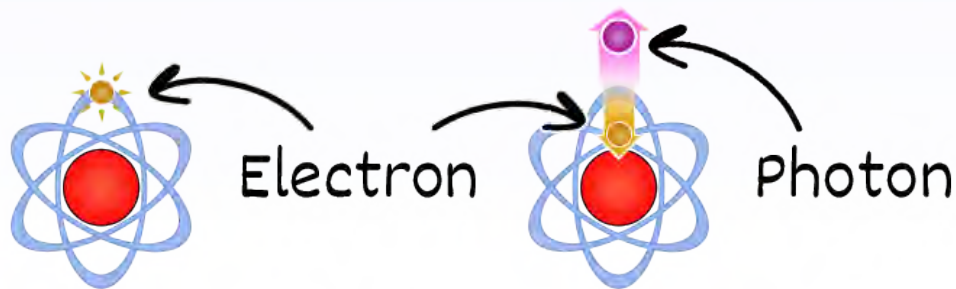
Example Chemiluminescent Dyes

BPEA 

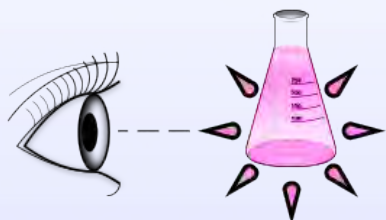
DPA 

Rhodamine B 

Rubrene 



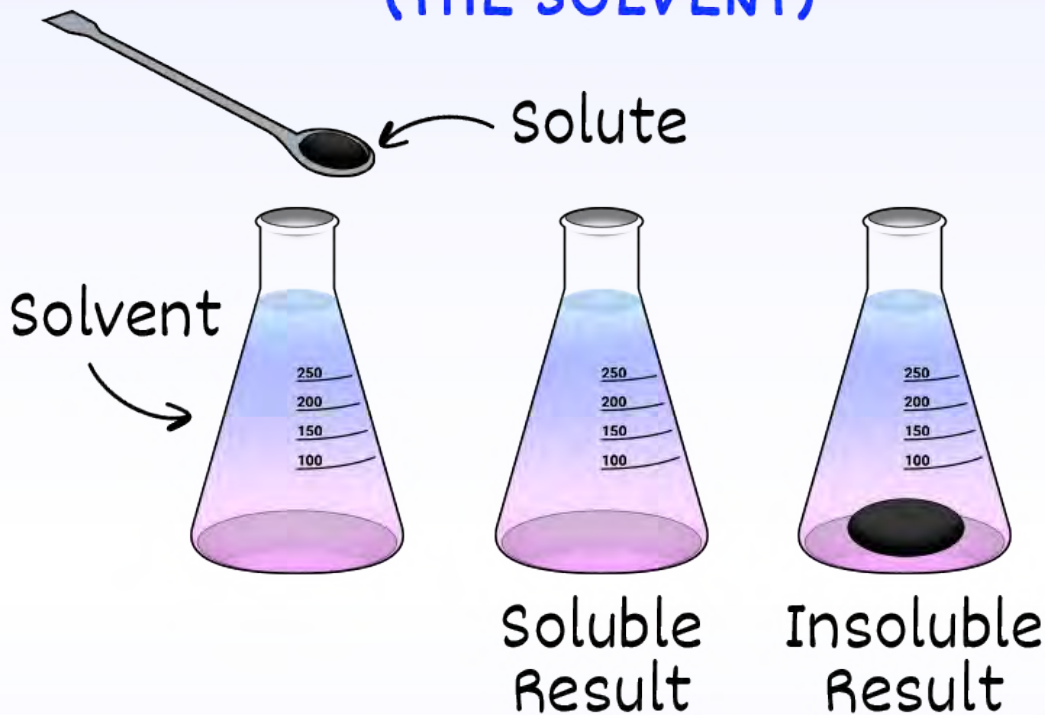
In a chemiluminescent reaction, a chemical enters an "excited" state that breaks down over time, releasing energy as photons.



Our eyes see this release of photons as visible light.

Solubility

A measure of the ability of a substance
(THE SOLUTE) to dissolve into another
(THE SOLVENT)



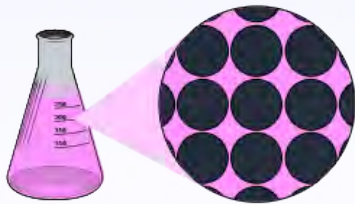
Water Solubility Test

Place a scoop of solid substance in a container of water. Agitate by stirring or shaking. A soluble substance will form a uniform solution, while an insoluble substance will stay separate.

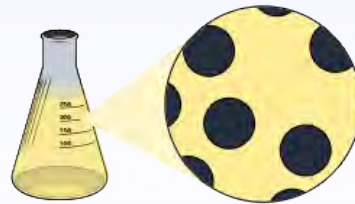
Density*

A measure of how much matter (mass) is in a particular volume.

More Mass =
Higher Density



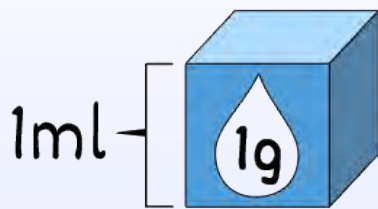
Less Mass =
Lower Density



How to Calculate Density:

Divide mass by volume. For example, if the mass is 8 grams and the volume is 10 milliliters:

$$8\text{g} / 10\text{ mL} = 0.8\text{ g/mL density}$$



Water has a density of 1 g / mL


*AK.A. “Relative Density” or “Specific Gravity”

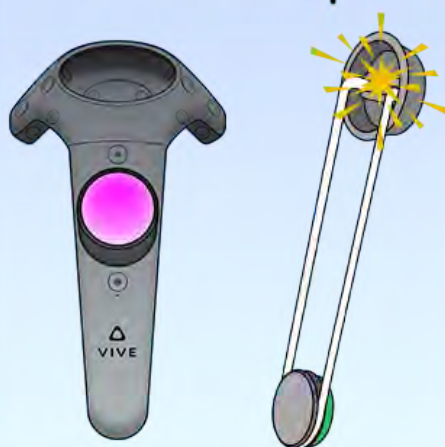
Bunsen Burner*

Used to heat substances in the lab

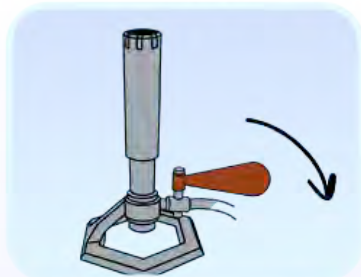


Used With:
striker (Igniter)
Used to ignite the
flame of the
bunsen burner.

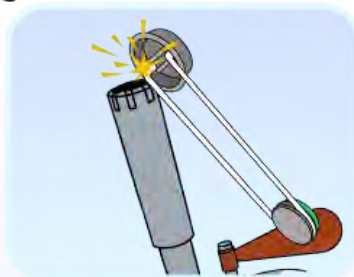
 Press to
create spark



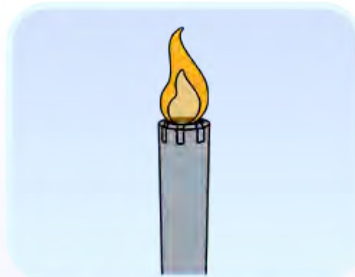
How to Ignite Bunsen Burner



1. Turn on gas
by rotating
lever.



2. Hold striker
close to top of
bunsen burner
and strike it.

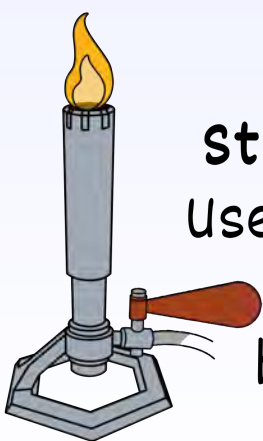


3. A flame
should
appear.


*Don't leave the gas on without a flame!

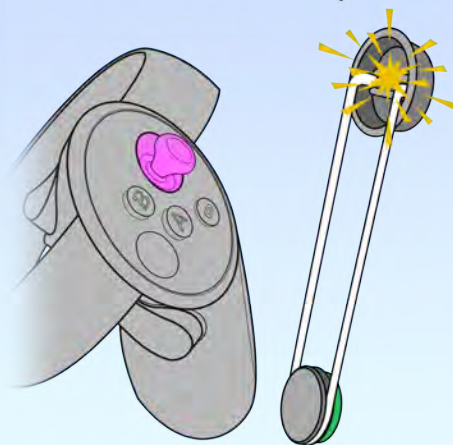
Bunsen Burner*

Used to heat substances in the lab

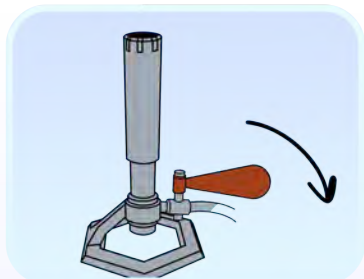


Used With:
Striker (Igniter)
Used to ignite the
flame of the
bunsen burner.

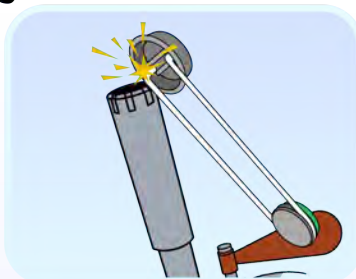
 Press to
create spark



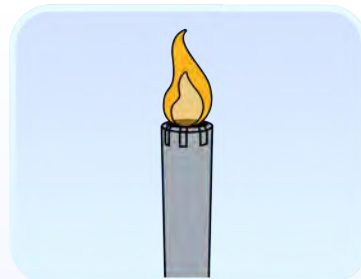
How to ignite bunsen burner



1. Turn on gas
by rotating
lever.



2. Hold striker
close to top of
bunsen burner
and strike it.



3. A flame
should
appear.

*Don't leave the gas on without a flame!

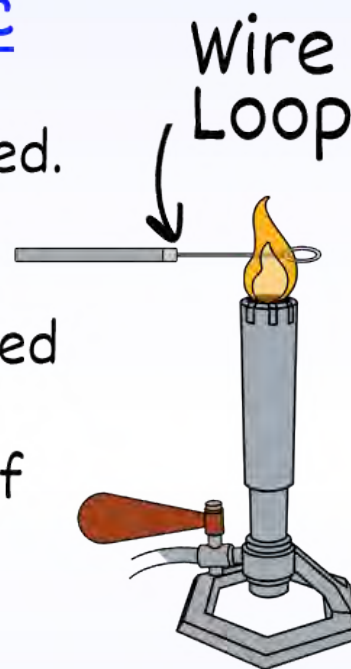
The Flame Test

The flame test identifies the presence of certain metal ions in a substance.*

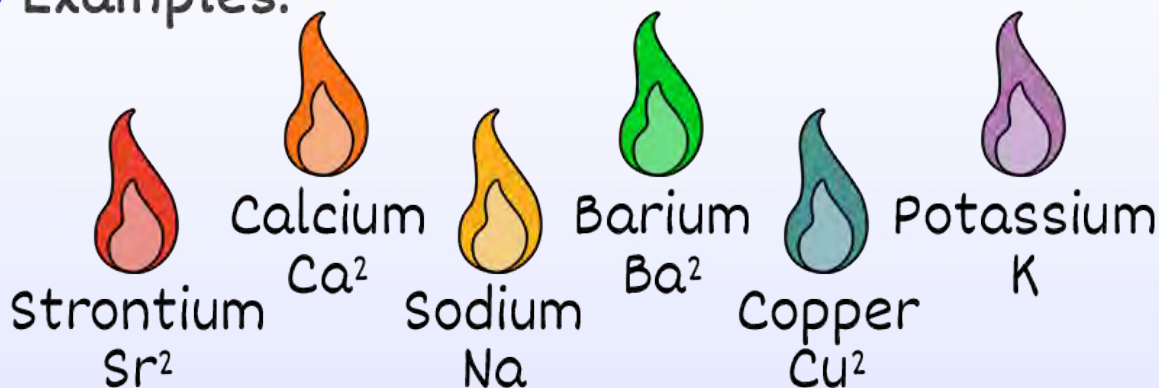
1. Clean the wire loop by DIPPING IT IN HYDROCHLORIC ACID and then INSERTING IN FLAME until no color is observed.

2. Dip the cleaned loop into the solution or solid to be tested

3. Hold the loop at the edge of the bunsen burner flame and observe the color.



*Examples:



Safety Data Sheets (SDS)*

Contains information on working safely with a chemical product. The HoloLAB uses abridged safety data sheets with the following information:

The image shows a screenshot of a Safety Data Sheet (SDS) for Potassium Dichromate. The document is organized into several sections, with callouts pointing to specific parts:

- Identification and Composition:** Points to the top section of the SDS, which includes the chemical name and identification number.
- Physical and Chemical Properties:** Points to the section containing physical data such as melting point, boiling point, and molecular weight.
- Hazard Identification:** Points to the section containing hazard pictograms and associated hazard statements.
- Handling and Storage:** Points to the section containing instructions for safe handling and storage of the chemical.

* A.K.A. Material Safety Data Sheet (MSDS)

SAFETY DATA SHEET

Ammonium Perchlorate

Identification and Composition

Formula: NH_4ClO_4

Synonym: --

Composition: 100% Ammonium Perchlorate

Physical and Chemical Properties

State: Solid

Color: White

Odor: Not Available

pH: Not Available

Flame Color: Not Available

Melting Point: 130°C

Boiling Point: Not Available

Relative Density: 1.95 g/mL

Soluble in Water: Yes

Molecular Weight: 117.49

Hazard Identification

Hazard Word: Danger



Handling and Storage

Handling: Handle with care. Avoid jolting, friction and impact. Keep containers tightly sealed.

Storage: Store in cool, dry place in tightly closed containers. Keep away from heat and direct sunlight.

SAFETY DATA SHEET

Barium Chlorate

Identification and Composition

Formula: Ba(ClO₃)₂

Synonym: --

Composition: 100% Barium Chlorate

Physical and Chemical Properties

State: Solid

Color: White

Odor: Odorless

pH: Not Available

Flame Color: Green

Melting Point: 414°C

Boiling Point: Not Available

Relative Density: 3.18 g/mL

Soluble in Water: Yes

Molecular Weight: 304.2 g/mol

Hazard Identification

Hazard Word: Danger



Oxidizing

May cause fire or explosion.



Irritant

Causes serious eye irritation.



Environmental Hazard

Toxic to aquatic life with lasting effects.

Handling and Storage

Handling: Keep away from heat. Do not ingest. Do not breathe gas/fumes/vapor/dust. Avoid contact with skin.

Storage: Keep container tightly closed in dry, cool, well-ventilated place out of direct sunlight.

SAFETY DATA SHEET

Calcium Carbonate

Identification and Composition

Formula: CaCO₃

Synonym: --

Composition: 100% Calcium Carbonate

Physical and Chemical Properties

State: Solid

Color: White

Odor: Not Available

pH: Not Available

Flame Color: Pink

Melting Point: Not Available

Boiling Point: Not Available

Relative Density: 2.71 g/mL

Soluble in Water: Moderately

Molecular Weight: 100.09

Hazard Identification

Hazard Word: Warning



Handling and Storage

Handling: Wash thoroughly after using. Avoid breathing dust. Provide appropriate exhaust ventilation.

Storage: Keep container tightly closed. Avoid source of ignition and direct sunlight.

SAFETY DATA SHEET

Copper Chloride

Identification and Composition

Formula: CuCl_2

Synonym: --

Composition: 100% Copper Chloride

Physical and Chemical Properties

State: Solid

Color: White

Odor: Not Available

pH: Not Available

Flame Color: Blue

Melting Point: Not Available

Boiling Point: Not Available

Relative Density: 3.39 g/mL

Soluble in Water: Yes

Molecular Weight: 134.45

Hazard Identification

Hazard Word: Danger



Corrosive

Harmful if
swallowed or in
contact with skin.



Irritant

Causes skin
irritation and
serious eye



**Environmental
Hazard**

Very toxic to
aquatic life with
lasting effects.

Handling and Storage

Handling: Provide appropriate exhaust ventilation at places where dust is formed.

Storage: Keep container tightly closed in a dry and well-ventilated place.

SAFETY DATA SHEET

Gunpowder

Identification and Composition

Formula: --

Synonym: Black Powder

Composition: 75% Potassium Nitrate, 15% Charcoal, 10%

Physical and Chemical Properties

State: Solid

Color: Black

Odor: Not Available

pH: Not Available

Flame Color: Not Available

Melting Point: Not Available

Boiling Point: Not Available

Relative Density: 1.8 g/mL

Soluble in Water: Moderately

Molecular Weight: Not

Hazard Identification

Hazard Word: Danger



Explosive

Explosive; mass explosion hazard.



Toxic

Toxic is swallowed or inhaled.



Irritant

Causes skin and eye irritation.



Environmental Hazard

Very toxic to aquatic life with lasting effects.

Handling and Storage

Handling: Wash thoroughly after use. Avoid dust formation. Do not expose to direct sunlight. Avoid mechanical shock, heat, or electrical discharge.

Storage: Store in cool, dry place in tightly closed containers. Keep away from sources of ignition. Avoid mechanical impact or electrical discharge.

SAFETY DATA SHEET

Hydrochloric Acid

Identification and Composition

Formula: HCl

Synonym: --

Composition: 30% Hydrochloric Acid, 70% Water

Physical and Chemical Properties

State: Liquid

Color: Clear

Odor: pungent odor

pH: < 1

Flame Color: Not Available

Melting Point: -74°C

Boiling Point: 81.5-100°C

Relative Density: 1.1 g/mL

Soluble in Water: Yes

Molecular Weight: 36.46 g/mol

Hazard Identification

Hazard Word: Danger



Corrosive

Corrosive to metals and skin.



Irritant

Specific target organ toxicity.

Handling and Storage

Handling: Never use hot water. Never add water to the acid. Prevent contact with skin, eyes, and clothing. Use only in well-ventilated areas.

Storage: Store in cool, dry place in tightly closed containers. Keep away from food and beverages.

SAFETY DATA SHEET

Iron Powder

Identification and Composition

Formula: Fe

Synonym: --

Composition: 100% Iron Powder

Physical and Chemical Properties

State: Solid

Color: Black to Gray

Odor: Odorless

pH: NA

Flame Color: Golden

Melting Point: 1535°C

Boiling Point: 2750°C

Relative Density: 7.86 g/mL

Soluble in Water: No

Molecular Weight: 55.847

Hazard Identification

Hazard Word: Danger



Handling and Storage

Handling: Minimize dust generation. Dry powders can build static electricity charges.

Storage: Provide ventilation for containers. Avoid storage near extreme heat or open flame.

SAFETY DATA SHEET

Lanthanum Hexaboride

Identification and Composition

Formula: B₆La

Synonym: Lanthanum boride

Composition: 100% Lanthanum Hexaboride

Physical and Chemical Properties

State: Solid

Color: Purple

Odor: Not Available

pH: Not Available

Flame Color: Not Available

Melting Point: 2210°C

Boiling Point: Not Available

Relative Density: 2.61 g/mL

Soluble in Water: No

Molecular Weight: 203.8 g/mol

Hazard Identification

Hazard Word: --

Handling and Storage

Handling: Provide appropriate exhaust ventilation at places where dust is formed.

Storage: Keep container tightly closed in dry and well-ventilated place.

SAFETY DATA SHEET

Manganese Dioxide

Identification and Composition

Formula: MnO₂

Synonym: --

Composition: 100% Manganese Dioxide

Physical and Chemical Properties

State: Solid

Color: Brown-black

Odor: Not Available

pH: Not Available

Flame Color: Yellow-ish

Melting Point: 535°C

Boiling Point: Not Available

Relative Density: 5.03 g/mL

Soluble in Water: No

Molecular Weight: 86.94 g/mol

Hazard Identification

Hazard Word: Warning



Handling and Storage

Handling: Avoid contact with skin and eyes. Avoid formation of dust.

Storage: 0

SAFETY DATA SHEET

Potassium Chromate Solution

Identification and Composition

Formula: K_2CrO_4

Synonym: --

Composition: 95% Water, 5% Potassium Chromate

Physical and Chemical Properties

State: Liquid

Color: Yellow

Odor: Not Available

pH: Neutral

Flame Color: Not Available

Melting Point: Not Available

Boiling Point: 100°C

Relative Density: 1.03 g/mL

Soluble in Water: Yes

Molecular Weight: 194.19

Hazard Identification

Hazard Word: Danger



Handling and Storage

Handling: Keep container dry. Keep away from heat. Do not ingest. Do not breathe gas/fumes/vapor/dust. Avoid contact with skin.

Storage: Oxidizing materials should be stored in a separate safety storage cabinet or room.

SAFETY DATA SHEET

Potassium Dichromate

Identification and Composition

Formula: $\text{Cr}_2\text{K}_2\text{O}_7$

Synonym: --

Composition: 100% Potassium Dichromate

Physical and Chemical Properties

State: Solid

Color: Orange-red

Odor: Odorless

pH: Not Available

Flame Color: Not Available

Melting Point: Not Available

Boiling Point: Not Available

Relative Density: 2.676 g/mL

Soluble in Water: Yes

Molecular Weight: 294.19

Hazard Identification

Hazard Word: Danger



Toxic

Fatal if inhaled.



Corrosive

Causes severe skin burns and eye damage.



Oxidizing

May intensify fire.

Handling and Storage

Handling: Do not breathe gas/fumes/vapor/spray. Wear protective clothing. Avoid contact with skin and eyes.

Storage: Keep container tightly closed in dry and well-ventilated place.

SAFETY DATA SHEET

Potassium Nitrate

Identification and Composition

Formula: KNO_3

Synonym: --

Composition: >95% Potassium Nitrate

Physical and Chemical Properties

State: Solid

Color: White

Odor: Odorless

pH: 6-8.5 in aq. Solution

Flame Color: Violet

Melting Point: 334°C

Boiling Point: 400°C

Relative Density: 2.109 g/mL

Soluble in Water: Yes

Molecular Weight: 101.1 g/mol

Hazard Identification

Hazard Word: Danger



Oxidizing

May intensify fire;
oxidizer.



Irritant

Causes skin
irritation. Causes
serious eye

Handling and Storage

Handling: Keep away from heat. Keep away from sources of ignition. Do not ingest. Do not breath dust. Avoid contact with skin and eyes.

Storage: Hygroscopic. Keep containers tightly closed in dry, cool and well-ventilated place.

SAFETY DATA SHEET

Potassium Perchlorate

Identification and Composition

Formula: ClKO_4

Synonym: --

Composition: 100% Potassium Perchlorate

Physical and Chemical Properties

State: Solid

Color: White

Odor: Not Available

pH: 5.0-7.0

Flame Color: Purple,

Melting Point: 400°C

Boiling Point: Not Available

Relative Density: 2.52 g/mL

Soluble in Water: No

Molecular Weight: 138.6 g/mol

Hazard Identification

Hazard Word: Danger



Oxidizing

May cause fire or explosion; strong oxidizer.



Irritant

Harmful if swallowed

Handling and Storage

Handling: Avoid contact with skin and eyes. Do not breathe dust. Keep away from clothing and other combustible materials.

Storage: Keep container tightly closed in dry, cool, well-ventilated place.

SAFETY DATA SHEET

Potassium Permanganate

Identification and Composition

Formula: KMnO_4

Synonym: --

Composition: 96% Water, 4% Potassium Permanganate

Physical and Chemical Properties

State: Liquid

Color: Violet

Odor: Odorless

pH: Neutral

Flame Color: Violet

Melting Point: 0°C

Boiling Point: 100°C

Relative Density: 1.01 g/mL

Soluble in Water: Yes

Molecular Weight: 158.03

Hazard Identification

Hazard Word: Danger



Corrosive

Causes skin irritation.



Irritant

Causes serious eye damage.



Environmental Hazard

Toxic to aquatic life with lasting effects.

Handling and Storage

Handling: Do not breathe gas/fumes/vapor/spray. Wear protective clothing. Avoid contact with skin and eyes.

Storage: Keep container tightly closed in dry, cool, well-ventilated place.

SAFETY DATA SHEET

Powdered Synthetic Rubber

Identification and Composition

Formula: --

Synonym: reprocessed rubber

Composition: 100% Synthetic Rubber

Physical and Chemical Properties

State: Solid

Color: Black

Odor: mild rubber

pH: Not Available

Flame Color: Lots of Smoke

Melting Point: NA

Boiling Point: NA

Relative Density: 0.85 g/mL

Soluble in Water: No

Molecular Weight: Not

Hazard Identification

Hazard Word: --

Handling and Storage

Handling: Mimimize dust formation; Keep away from sources of heat, flame, or ignition.

Storage: Store in a cool dry place away from sources of heat or ignition.

SAFETY DATA SHEET

Red Lead

Identification and Composition

Formula: Pb_3O_4

Synonym: Minium, triplumbic tetroxide

Composition: 100% Red Lead

Physical and Chemical Properties

State: Solid

Color: Orange-red

Odor: Not Available

pH: Not Available

Flame Color: Not Available

Melting Point: Not Available

Boiling Point: Not Available

Relative Density: 8.3 g/mL

Soluble in Water: Yes

Molecular Weight: 685.6 g/mol

Hazard Identification

Hazard Word: Danger

Handling and Storage

Handling: --

Storage: --

SAFETY DATA SHEET

Silicon Dioxide

Identification and Composition

Formula: O₂Si

Synonym: --

Composition: 100% Silicon Dioxide

Physical and Chemical Properties

State: Solid

Color: White

Odor: Not Available

pH: Not Available

Flame Color: Not Available

Melting Point: 1610°C

Boiling Point: Not Available

Relative Density: 2.64 g/mL

Soluble in Water: No

Molecular Weight: 60.08 g/mol

Hazard Identification

Hazard Word: Warning



Handling and Storage

Handling: Avoid contact with skin and eyes. Avoid formation of dust.

Storage: Keep container tightly closed in a dry and well-ventilated place.

SAFETY DATA SHEET

Sodium Acetate

Identification and Composition

Formula: $C_2H_3NaO_2$

Synonym: --

Composition: 100% Sodium Acetate

Physical and Chemical Properties

State: Solid

Color: White

Odor: Slight

pH: 11

Flame Color: Yellow

Melting Point: 324°C

Boiling Point: Not Available

Relative Density: 1.52 g/mL

Soluble in Water: Yes

Molecular Weight: 82.03 g/mol

Hazard Identification

Hazard Word: --

Handling and Storage

Handling: Avoid formation of dust and aerosols.

Storage: Keep container tightly closed in a dry and well-ventilated place.

SAFETY DATA SHEET

Sodium Nitrate

Identification and Composition

Formula: NaNO_3

Synonym: --

Composition: 100% Sodium Nitrate

Physical and Chemical Properties

State: Solid

Color: White

Odor: Odorless

pH: 8-10

Flame Color: Yellow

Melting Point: Not Available

Boiling Point: Not Available

Relative Density: 2.26 g/mL

Soluble in Water: Yes

Molecular Weight: 84.99 g/mol

Hazard Identification

Hazard Word: Warning



Handling and Storage

Handling: Use with adequate ventilation. Wash thoroughly after using. Avoid formation of dusts.

Storage: Keep container tightly closed in a well-ventilated place.

SAFETY DATA SHEET

Strontium Chloride

Identification and Composition

Formula: SrCl₂

Synonym: --

Composition: 100% Strontium Chloride

Physical and Chemical Properties

State: Solid

Color: White

Odor: Odorless

pH: Not Available

Flame Color: Red

Melting Point: Not Available

Boiling Point: Not Available

Relative Density: 3.05 g/mL

Soluble in Water: Yes

Molecular Weight: 158.53

Hazard Identification

Hazard Word: Danger



Irritant

Causes serious eye irritation.



Corrosive

May cause respiratory irritation.

Handling and Storage

Handling: Avoid contact with skin and eyes. Avoid formation of dust.

Storage: Keep container tightly closed in a dry and well-ventilated place.

SAFETY DATA SHEET

Sulfur

Identification and Composition

Formula: S

Synonym: --

Composition: 100% Sulfur

Physical and Chemical Properties

State: Solid

Color: Light Yellow

Odor: Slight

pH: Not Available

Flame Color: Blue

Melting Point: Not Available

Boiling Point: Not Available

Relative Density: 2.07 g/mL

Soluble in Water: No

Molecular Weight: 32.07 g/mol

Hazard Identification

Hazard Word: Warning



Handling and Storage

Handling: Avoid contact with skin and eyes. Avoid formation of dust.

Storage: Keep container tightly closed in dry and well-ventilated place.

SAFETY DATA SHEET

Yellow 5 Dye

Identification and Composition

Formula: $C_{16}H_9N_4Na_3O_9S_2$

Synonym: Tartrazine

Composition: 100% Yellow Dye #5

Physical and Chemical Properties

State: Solid

Color: Yellow

Odor: Not Available

pH: Not Available

Flame Color: Not Available

Melting Point: Decomposes

Boiling Point: Not Available

Relative Density: Not Available

Soluble in Water: Yes

Molecular Weight: 534.36

Hazard Identification

Hazard Word: Danger



Handling and Storage

Handling: Use with adequate ventilation. Wash thoroughly after using. Avoid formation of dusts.

Storage: Keep container tightly closed in a dry and well-ventilated place.