CHEMISTRY 1

STUDENT WORKBOOK

A comprehensive course that teaches the fundamental ideas behind chemistry. Students will discover how to create the four states of matter, grow crystal farms, experiment with phase shifts, crosslink polymers, shake up rainbow solutions, and stew up a chemical matrix of heat and ice reactions.

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This curriculum is aligned with the National Standards and STEM for Science.

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Introduction

Greetings and welcome to the study of *Chemistry*. This unit was created by a mechanical engineer, university instructor, airplane pilot, astronomer, robot-builder and real rocket scientist… me! I have the happy opportunity to teach you everything I know about chemistry over the next set of lessons. I promise to give you my best stuff so you can take it and run with it… or fly!

To get the most out of these labs, there are really only a couple of things to keep in mind. Since we are all here to have fun and learn something new, this shouldn't be too hard.

One of the best things you can do as the student is to cultivate your curiosity about things. *Why did that move? How did that spin? What's really going on here?*

This unit on Chemistry is chock full of demonstrations and experiments for two big reasons. First, they're fun. But more importantly, the reason we do experiments in science is to hone your observational skills. Science experiments really speak for themselves much better than I can ever put into words or show you on a video. And I'm going to hit you with a lot of these science demonstrations and experiments to help you develop your observing techniques.

Scientists not only learn to observe what's going on in the experiment, but they also learn how to observe what their experiment is telling them, which is found by looking at your data. It's not enough to invent some new kind of experiment if you don't know how it will perform when the conditions change a bit, like on Mars. We're going to learn how to predict what we think will happen, design experiments that will test this idea, and look over the results we got to figure out where to go from there. Science is a process, it's a way of thinking, and we're going to get plenty of practice at it.

Good luck with this *Chemistry* unit!

For the Parent/Teacher:
Educational Goals for Chemistry 1

The study of chemistry is particularly exciting because students have the opportunity to do and see with their own eyes most of what they are expected to learn. What are those strange bubbles? A chemical reaction! Why did I get this glob of goo? I made a polymer! Concepts that would be somewhat foreign in a textbook can come to life as an experiment or demonstration. Students will gain skills at following detailed directions for labs as well as building a strong foundation of important scientific vocabulary. They will be asked to reflect on what they have learned and experimented with, then challenged to take that learning to the next level.

<u>Here are the scientific concepts:</u>

Crystals, Atoms, Molecules, Polymers, Chemical Reactions, and States of Matter

- Structure of atoms and molecules
- Crystals are organized grouping of atoms or molecules that form specific patterns
- Supersaturated solid solutions
- Physical verses chemical change
- Indicators of a chemical change
- Molecules join together to form polymers
- States of matter: solids, liquids, gases, and plasma
- Non-Newtonian fluids
- Sublimation is the process by which a solid goes directly to a gas

Temperature, the Electromagnetic Spectrum, and Density

- Evaporation and condensation of molecules
- How skin senses temperature
- Radiation
- Electromagnetic spectrum
- Density is a measure of how tightly packed the molecules are, or density = mass ÷ volume
- Factors that affect density

<u>By the end of the labs in this unit, students will be able to:</u>

- Design and build a working scale.
- Know how to demonstrate the process by which a polymer is formed; how crystals are formed; how to create a supersaturated solid solution; how to determine if a substance contains carbon dioxide.
- Understand how to determine if something is a chemical or physical reaction; what state of matter is observed; how to find density.
- Differentiate observation from inference (interpretation) and know scientists' explanations come partly from what they observe and partly from how they interpret their observations.
- Measure and estimate the weight, length and volume of objects.
- Formulate and justify predictions based on cause-and-effect relationships.

- Conduct multiple trials to test a prediction and draw conclusions about the relationships between predictions and results.
- Construct and interpret data tables from measurements and experimental data.
- Follow a set of written instructions for a scientific investigation.

Master Materials List for All Labs

This is a brief list of the materials that you will need to do *all* of the activities, experiments and projects in this unit. The set of materials listed below is just for one lab group. If you have a class of 10 lab groups, you'll need to get 10 sets of the materials listed below. Most materials allow for several times through an experiment.

aluminum foil
ammonium nitrate (single-use disposable cold pack)
baking soda
balloon
borax (laundry whitener)
calcium chloride ("Ice Melt")
chalk
cherry tomato
citric acid (spice section, used for preserving and pickling)
corn syrup
cornstarch (3 cups)
disposable cups (about 20)
distilled white vinegar
ethyl alcohol (70%)
fiber (psyllium fiber like Metamucil)
fire extinguisher
food coloring
glass jar (pickle, jam, mayo…)
glue (clear or white)
grapes (green, red or black)
guar gum (grocery store)
hard-boiled egg
honey
hydrogen peroxide
ice cubes
index card
isopropyl alcohol (91%)
kitchen scale (or other scale to measure small masses)
knife (with adult help)
lighter (with adult help)
liquid dish soap (colored)
measuring cups and spoons
microwave
molasses
old pot or saucepan
paper (black and white)
pennies (50)
pipe cleaners
plate
popsicle sticks
red cabbage
rubber gloves
ruler
salt
sand
scissors
small Ziploc bags
soap ("Ivory" brand works best)
sodium carbonate ("washing soda" in the laundry aisle)
sodium silicate*
spoon
string
sugar (9 cups)
tape
towel
vegetable oil (3 cups)
wooden skewers (3)
yellow highlighter

*Order from
www.ScienceComany.com

Lab Safety

Goggles: These should be worn when working with chemicals, heat, fire, or projectiles. These protect your eyes from chemical splatter, explosions, and tiny fast-moving objects aimed at the eyes. If you wear glasses, you can find goggles that fit over them. Don't substitute eyeglasses for goggles, because of the lack of side protection. Eyeglasses don't provide this important protection.

Clean up Messes: Your lab area should be neat, organized, and spotless before you start, during your experiment, and when you leave. Scientists waste more time hunting for lost papers, pieces of an experiment, and trying to reposition sensitive equipment … all of which could have easily been avoided had they been taught organizational skills from the start.

Dispose of Poisons: If a poisonous substance was used, created, or produced during your experiment, you must follow the proper handling procedures for disposal. You'll find details for this in the experiments as needed.

Special Notes on Batteries: Do not use alkaline batteries with your experiments. Find the super-cheap kind of batteries (usually labeled "Heavy Duty" or "Super Heavy Duty") because these types of batteries have a carbon-zinc core, which does not contain the acid that alkaline batteries have. This means when you wire up circuits incorrectly (which you should expect to do because you are learning), the circuits will not overheat or leak. If you use alkaline batteries (like Energizer and Duracell) and your students short a circuit, their wires and components will get super-hot and leak acid, which is very dangerous.

No Eating or Drinking in the Lab: All foods and drinks are banned from your classroom during science experimentation. When you eat or drink, you run the very real risk of ingesting part of your experiment. For electricity and magnetism labs, always wash your hands after the lab is over to rinse off the lead from the electrical components.

No Horse Play: When you goof around, accidents happen, which means chemicals spill, circuits short, and all kinds of hazards can occur that you weren't expecting. Never throw anything to another person and be careful where you put your hands – it could be in the middle of a sensitive experiment, especially with magnetism and electricity. You don't want to run the risk of getting shocked or electrified when it's not part of your experiment.

Fire: If you think there's a fire in the room (even if you're not sure), let your teacher know right away. If they are not around (they always should be), smother the fire with a fire blanket or use a fire extinguisher and send someone to find an adult. Stop, drop, and roll!

Questions: If you're not sure about something, stop and ask, no matter what it's about. If you don't know how to properly handle a chemical, do part of an experiment, ask! If you're not comfortable doing part of the experiment, then don't do it.

Lesson #1: Chemical Matrix of Acids and Bases

Overview: If you love the idea of mixing up chemicals and dream of having your own mad science lab, this one is for you. You are going to mix up solids and liquids in a chemical matrix, and see a lot of cool chemical reactions between acids and bases.

What to Learn: After this experiment you'll understand that an *indicator* can change color when you combine it with different materials. Today we will use a cabbage juice indicator, but there are many different kinds. You will see several *chemical reactions* take place (that means things will bubble, ooze, spit, change color and get hot or cold).

Materials

- muffin tin or disposable cups
- popsicle sticks for stirring and mixing
- tablecloths (one for the table, another for the floor)
- isopropyl rubbing alcohol
- hydrogen peroxide
- water
- acetic acid (distilled white vinegar)
- liquid dish soap (add to water)
- head of red cabbage (indicator)
- calcium chloride (AKA "DriEz" or "Ice Melt")
- citric acid (spice section, used for preserving and pickling)
- sodium tetraborate (borax, laundry aisle)
- sodium carbonate (washing soda, laundry aisle)
- sodium bicarbonate (baking soda, baking aisle)
- ammonium nitrate (single-use disposable cold pack)

Experiment

1. Wear your gloves and put your goggles on. No exceptions!
2. After receiving all of your chemicals, start mixing it up! Use the grid provided in the student worksheet to organize chemicals and make notes about your observations.
3. Note: Periodically hold your hand under the muffin cups to test the temperature. If it feels hot, it's an exothermic reaction which is giving off energy in the form of heat, light, explosions, etc. The chemical-bond energy is converted to thermal energy, or heat, in these experiments. If it feels cold, you've made an endothermic reaction, in which energy was absorbed. Heat from the mixture converts to bond energy. Sometimes you'll find that your mixture is so cold that it condenses the water outside the container, like water drops on the outside of an ice-cold glass of water on a hot day.

Chemical Matrix of Acids and Bases
Data Table

Describe the chemical reaction observed for each mixture

						Hydrogen Peroxide + Indicator
						Alcohol + Indicator
						Vinegar + Indicator
						Water + Indicator
Sodium Bicarbonate (Baking Soda)	**Citric Acid**	**Ammonium Nitrate (Single-use Cold Pack)**	**Calcium Chloride ("DriEz" or "Ice Melt")**	**Sodium Carbonate (Washing Soda)**	**Sodium Tetraborate (Borax)**	

Reading

In a chemistry class, one of the first things you learn in chemistry is the difference between physical and chemical changes. An example of a physical change is when you change the shape of an object, like wadding up a piece of paper. If you light the paper on fire, you now have a chemical change. You are rearranging the atoms that used to be the molecules that made up the paper into other molecules, such as carbon monoxide, carbon dioxide, ash, and so forth.

How can you tell if you have a chemical change? If something changes color; gives off light, such as chemiluminescent light sticks; absorbs heat (gets cold); or produces heat (gets warm), it's a chemical change.

What about physical changes? Some examples of physical changes include tearing cloth, rolling dough, stretching rubber bands, eating a banana, or blowing bubbles.

About this experiment: Your solutions will turn red, orange, yellow, green, blue, purple, hot, cold, bubbling, foaming, rock hard, oozy, and slimy, and they'll crystallize and gel — depending on what you put in and how much!

What's happening with the indicator? An indicator is a compound that changes color when you dip it in different substances, such as vinegar, alcohol, milk, or baking soda mixed with water. Different indicators are affected differently by acids and bases. Some change color only with an acid, or only with a base. Turmeric, for example, is good only for bases. You can prepare a turmeric indicator by mixing 1 teaspoon turmeric with 1 cup rubbing alcohol.

Why does red cabbage work? Red cabbage juice has anthocyanin, which makes it an excellent indicator for these experiments. Anthocyanin is what gives leaves, stems, fruits, and flowers their colors. Did you know that certain flowers, such as hydrangeas, are blue in acidic soil but turn pink when transplanted to a basic soil? In this experiment, you get the anthocyanin out of the cabbage and into a more useful form so you can use it as a liquid indicator.

Exercises

1. What is an indicator?

2. What examples of chemical changes did you observe?

3. What types of physical changes did you observe?

4. Why did some mixtures get hot? What type of reaction was this?

5. Why did other mixtures get cold? What type of reaction was this?

Lesson #2: Laundry Soap Crystals

Overview: Can you really make crystals out of soap? You bet! These crystals grow really fast, provided your solution is properly saturated. In only 12 hours, you should have sizable crystals sprouting up.

What to Learn: Today's focus is on crystals and supersaturated solutions. You'll use heat to dissolve more borax (sodium tetraborate) than usual in a pot of water and love the result when it cools!

Materials

- pipe cleaners
- cleaned out jar or bottle (pickle, jam, or mayo jar)
- water
- borax

Experiment

1. Wear your gloves and put your goggles on. No exceptions!
2. Use pipe cleaners to create a shape for crystals to cling to (suggestion: cut into 3 lengths and wrap around one another). Curl top pipe cleaner around a pencil, making sure the shape will hang nicely in the container without touching the sides.
3. Add 2 cups of water and 2 cups of borax (sodium tetraborate) into a pot. Heat, stirring continuously for about 5-10 minutes. Do not boil, but only heat until steam rises from the pan.
4. When the Borax has dissolved, add more, and continue to do so until there are bits of Borax settling on the bottom of the pan that cannot be stirred in (It may be necessary to stop heating and let the solution settle if it gets too cloudy). You'll be adding in a lot of borax! You have now made a supersaturated solution. Make sure your solution is saturated, or your crystals will not grow.
5. Wait until your solution has cooled to about 130^{o}F (hot to the touch, but not so hot that you yank your hand away). Pour this solution (just the liquid, not the solid bits) into the jar, and add pipe cleaner shape. Make sure the pipe cleaner is submerged in the solution. Put the jar in a place where the crystals can grow undisturbed overnight, or even for a few days. Warmer locations (such as upstairs or on top shelves) are best.
6. NOTE: These crystals are NOT edible! Please keep them away from small children and pets!

Reading

Crystals may be observed in the patterns of snowflakes, the ice in your freezer or rocks in your back yard. Quartz crystals are used in electronics like radios and in the inner workings of watches. Some crystals take thousands of years to form, but they may also quickly form with a little water and Borax.

As minerals form in the Earth's crust, they sometimes grow into a regular repeating pattern, also called a crystal. Each geometric shape is the result of the way the atoms come together as the mineral forms. Factors like pressure, temperature, available space and chemical conditions present in the minerals affect the formation of crystals. Crystals are in metals like gold, copper, silver, mercury and iron and in precious stones like diamonds, rubies, sapphires, emeralds and topaz. You'll also see crystals in ice, sugar, snow, sulfur and salt. The outward three-dimensional properties of crystals reflect the internal atomic structure of the molecules that create them.

Crystals form when liquids inside the Earth cool and harden, or when liquids underground flow into cracks and slowly form minerals. As long as the temperature is consistent and the molecules outnumber the liquid, crystals will form. If the molecules cannot join the group, they are reabsorbed back into the liquid. Examples of natural crystal formations are the stalactites and stalagmites in underground caves.

A hot solution of borax and water can hold more borax than a cool solution. As the borax solution cools, crystals of borax "fall out" of solution and deposit on the shape you have placed in the container. This is not a chemical change, however. In a chemical change, bonds are broken and new bonds are formed between different atoms resulting in different substances. A physical change does not involve a change in the substance's chemical identity. The crystals "grow" because the cooled solution cannot continue to hold all the borax that had been placed in it any longer. The pipe cleaner shape you put in the solution provides a home to the borax crystals that are falling out of solution.

Exercises

1. Why did the sodium tetraborate solution need to be supersaturated in order to form crystals?

2. The concentration of a solution is the amount of dissolved substance (borax) in a given volume of solvent (in this case, water!). Was the borate solution more concentrated when it was cool or hot? Why?

3. Why was it necessary to put a pipe cleaner into the sodium tetraborate solution?

Lesson #3: Non-Messy Squishy Slime

Overview: Sugar, water, and cornstarch by themselves are not very exciting, but combine them together and you'll find a gooey, goopy slime! This chemical reaction creates a polymer that's really fun to play with.

What to Learn: You should understand you are working with a chemical reaction, where you add two or more compounds together to get something completely different. You are making something called a polymer, which is an incredibly long chain of molecules.

Materials

Part I: Squishy Slime	Part II: Messy Squishy Slime II	Part III: Messy Squishy Slime III
• 1 cup sugar • 3 cups cornstarch • 12 cups water • measuring cup • pan • heat source • spoon for stirring • food coloring • plastic baggie	• 1 tsp fiber (psyllium fiber like Metamucil) • 1 cup water • spoon • heat source • food coloring	• 1 cup cornstarch • 2 2/3 cups vegetable oil • spoon • balloon

Experiment

1. **Squishy Slime:** Mix 1 cup sugar, 12 cups water, and 3 cups cornstarch in a saucepan. Stir constantly over medium heat until thickened, about 5 minutes. Place a glop in each of several bowls along with drops of food coloring. Place a dollop of each color into a plastic sandwich bag and zip it shut. Squish and squeeze without getting your hands slimy!

2. **Messy Squishy Slime II:** Mix one teaspoon fiber (psyllium fiber like Metamucil) with one cup cold water. (You can add food dye to of water if you'd like.) Heat mixture (use a stove with adult help, or use a microwave for a few minutes) until it looks slimy. Stir once or twice while heating.

3. **Messy Squishy Slime III:** Mix 1 cup cornstarch and 2-2/3 cups cheap vegetable oil together, stirring to combine. Let sit for an hour (if it's a hot day, stick it in the fridge while you wait). Get a friend to rub a balloon on their head (to charge it up) as you slowly tip the slime to pour it into a second container. Bring the balloon close (but not touching) to the slime, and watch the slime react to the balloon! You'll either see the slime wiggle closer, gel up, or break off a piece, depending on the consistency of your slime!

Non-Messy Squishy Slime Observations

Experiment	Observations (Tell about EVERYTHING you see, feel, and hear!)
Squishy Slime	
Messy Squishy Slime II	
Messy Squishy Slime III	

Reading

Chemical reactions happen when two or more molecules interact and change to form a new substance with different properties. There are several clues that a chemical change has occurred, including the following:

1. There is a formation of gas which is seen by a fizzing or bubbling.
2. Heat, light, or odor are produced.
3. A color change is produced.
4. A solid is formed.

A physical change, on the other hand, happens when a substance changes physical forms but still retains its original properties. Ice may be melted to water or heated until it steams, but it's still H_2O.

Sugar, water, and cornstarch are common household items that have very useful purposes. But when combined together, they create something completely different. The product of this chemical reaction is a gooey, slimy mess called a polymer. A polymer is a long chain of molecules that can be slippery, stretchy, and in this case very slimy. Some other polymers are Silly Putty, Jell-O, rubber bands, plastic, rubber, and even gum.

Exercises

1. How could you make the polymer stretchier?

2. Does the amount of cornstarch added change the slime?

3. Why should the squishy slime polymer be stored in a Ziploc bag?

4. Does the amount of water added to the polymer affect the gooeyness of the slime?

Lesson #4: Moon Sand

Overview: Moon sand is basically clay with a beach twist. If you've ever tried making a sand castle, you know the disappointment of having the structure crumble after hours of work. Moon sand adds the best properties of clay to the sand for a moldable, sandy texture that's easy to work with, and shows you firsthand what a non-Newtonian fluid looks and feels like!

What to Learn: After today's lesson, you'll know a bit about non-Newtonian fluids and viscosity and how to play with an experiment to get different results.

Materials

- cornstarch
- water
- sand
- measuring cups/spoons, depending on how much moon sand is desired
- Popsicle stick or other stirring apparatus
- food dye (optional)

Experiment

1. Wear your gloves and put your goggles on. No exceptions!
2. In a cup or bowl, mix together one scoop of corn starch and one scoop of sand.
3. In another cup, add ½ scoop of water and a few drops of food coloring
4. Add the liquids into the solids and stir with a stick or your hands. It may be necessary to add a few drops of water. Mix thoroughly until the mixture feels like clay.
5. Experiment with different amounts of corn starch, clay, or water to make moon sand with different properties!

Troubleshooting: The smaller the grain of sand, the easier it is to form intricate shapes. White sand will make better colors when food dye is added to the mixture. Use a large enough bowl and try to keep one hand clean so you can add more (of whatever you need) as you go along. The ideal mixture is approximately 2 cups sand, 2 cups cornstarch, and 1 cup water, give or take a bit. Notice how adding just a small amount of water turns it into a liquid, and adding a tiny bit more cornstarch (or sand) makes it crumble as if it were solid? Take your time to get this mixture *just* right.

Moon Sand Data Table

Once you have made your moon sand, experiment with adding more of each substance. Record your results on the following chart.

Added Material	Observations	More or Less Viscous?
Cornstarch		
Water		
Sand		

Reading

A non-Newtonian fluid is a substance that changes viscosity, such as ketchup. Ever notice how ketchup sticks to the bottom of the bottle one minute and comes sliding out the next?

Think of *viscosity* as the resistance stuff has to being smeared around. Water is “thin” (low viscosity); honey is “thick” (high viscosity). You are about to make a substance that is both low and high viscosity, depending on what ratio you mix up. Feel free to mix up a larger batch than indicated in the video – we’ve heard from families who have mixed up an entire kiddie pool of this stuff!

Moon sand is basically clay with a beach twist. If you’ve ever tried making a sand castle, you know the disappointment of having the structure crumble after hours of work. Moon sand adds the best properties of clay to the sand for a moldable, sandy texture that’s easy to work with — and it’s dirt cheap to mix up your weight in moon sand.

The students’ task is to find the perfect ratio of the three ingredients to make this weird substance. If they have too much water, they’ll get a substance that is both a liquid and a solid. If there is too much solid, it crumbles.

Exercises

1. Name a substance that is very viscous.

2. Why is moon sand called a non-Newtonian fluid?

3. What can you add to corn starch to make it more viscous?

4. If you were going to make gravy and needed it to be thicker, what could you add to it?

Lesson #5: Rubber Eggs

Overview: Did you ever think it would be OK to bounce an egg? In science class, anything is possible! Learn how in today's experiment.

What to Learn: After this bouncy experiment, you'll know one way to spot a chemical reaction. You'll also see how solid calcium carbonate and stinky liquid vinegar can combine to produce carbon dioxide gas.

Materials

- hard-boiled egg
- glass or clean jar
- distilled white vinegar
- Optional: regular egg
- Optional: chicken bones

Experiment

1. Wear your gloves and put your goggles on. No exceptions!
2. Place a hard-boiled egg into a glass or jar. Fill with enough vinegar to cover the egg and leave alone for 24 hours.
3. If doing this experiment with regular eggs or chicken bones, put each in a separate container and cover with vinegar. Let sit for 24 hours. Check again after 48 hours.

Rubber Egg Data Table

Item/Object	**Detailed Description of Results after 24 hours** *(for hard-boiled egg ONLY, include approximately how high it bounced)*	**Detailed Description of Results after 48 hours** *(for hard-boiled egg ONLY, include approximately how high it bounced)*
Hard Boiled Egg		
Regular Egg (optional)		
Chicken bones (optional)		

Reading

If you soak chicken bones in acetic acid, or distilled vinegar, you'll get rubbery bones that are soft and pliable because the vinegar reacts with the calcium in the bones. This happens with older folks when they lose more calcium than they can replace in their bones, making the bones brittle and easier to break. Scientists have discovered calcium is replaced more quickly in bodies that exercise and eat calcium-rich foods, like green vegetables.

Egg shells are also made up of calcium in the form of calcium carbonate ($CaCO_3$). This organic compound is also found in limestone, chalk, marble, and coral. It is classified as a base, with a pH below 7.

Vinegar contains acetic acid. Acetic acid is what gives vinegar its awful taste. It's classified as an acid, with a pH above 7.

As calcium carbonate reacts with the vinegar, and the egg shell dissolves, a chemical change occurs and carbon dioxide gas is released in the form of bubbles. These can be clearly seen as the egg shell dissolves. You will also smell vinegar when the bubbles occur, but vinegar is not being given off by the chemical reaction. Vinegar has a very low surface tension, which makes that stink go everywhere.

Exercises

1. Describe what the eggshell looked like before the reaction.

2. Describe the acetic acid

3. The product you witnessed in this chemical reaction was carbon dioxide, a colorless, odorless gas. How can you tell there really was a chemical reaction?

4. Why did the egg turn to "rubber?"

Lesson #6: Microwaving Soap

Overview: When you warm up leftovers, have you ever wondered why the microwave heats the food and not the plate? (Well, some plates, anyway.) It has to do with the way microwaves work. Microwaves generate high-energy electromagnetic waves that, when aimed at water molecules, make these molecules get super-excited and start bouncing around a lot. Which is why it's dangerous to heat anything not containing water in your microwave, as there's nowhere for that energy to go, since the electromagnetic radiation is tuned to excite water molecules.

What to Learn: Light you can see (visible light like a rainbow) makes up only a tiny bit of the entire electromagnetic spectrum. Microwaves emit "microwaves" that are lower frequency, lower energy waves than visible light, but are higher energy, higher frequency than radio waves. The soap in this experiment will show you how a bar of Ivory soap contains air, and that air contains water vapor which will get heated by the microwave radiation and expand.

Materials

- 3 Ivory soap bars
- microwave (not a new or expensive one)
- plate

Experiment

1. Open the microwave.
2. Unwrap the bar of Ivory soap and place it on the plate (be sure it's glass or ceramic).
3. Set the time for 2-3 minutes.
4. Watch it very closely and remove it when it reaches its maximum volume (when it stops expanding).
5. NOTE: the soap may be hot after the experiment, so please be careful! Allow it to cool for a few minutes prior to touching it.
6. You can even use the soap after you're done.
7. After you have done your experiment once, design an experiment to test a question you have about Ivory soap. This experiment should be designed to answer a specific question, and you'll make a guess (called a hypothesis) as to how things will turn out. After making a guess, perform the experiment and write down what you observed happen. In the last column of your data table, you'll write what you conclude. The first one has been done as an example for you. The question that the sample is answering is: *How does soap bar volume affect how much it puffs up?* You can test all sorts of questions, from what happens if you put more than one bar of soap in, or what if you use lower power for longer, or what if you chill the bar in the freezer overnight first? The questions are endless. Have fun!

Microwaving Soap Data Table

Hypothesis	Experiment	Observation	Conclusion
Half a bar of soap will only puff just as big as a whole bar.	*Put half a bar of soap in microwave for 2.5 minutes and a whole bar in for 2.5 minutes and compare.*	*When compared, the half bar puffed up <u>more</u> than the whole bar!*	*There might be less mass to move out of the way, so the bar puffs up more easily. Needs more testing. Maybe test a quarter of a bar next?*

Reading

Microwaves generate high-energy electromagnetic waves that, when aimed at water molecules, make these molecules get super-excited and start bouncing around a lot.

We see this happen when we heat water in a pot on the stove. When you add energy to the pot (by turning on the stove), the water molecules start vibrating and moving around faster and faster the more heat you add. Eventually, when the pot of water boils, the top layer of molecules are so excited they vibrate free and float up as steam.

When you add more energy to the water molecule, either by using your stove top or your nearest microwave, you cause those water molecules to vibrate faster. We detect these faster vibrations by measuring an increase in the temperature of the water molecules (or in the food containing water). Which is why it's dangerous to heat anything not containing water in your microwave, as there's nowhere for that energy to go, since the electromagnetic radiation is tuned to excite water molecules.

This following experiment is a quick example of this principle using a naked bar of Ivory soap. The trick is to use Ivory, which contains an unusually high amount of air. Since air contains water moisture, Ivory also has water hidden inside the bar of soap. The microwave will excite the water molecules and your kids will never look at the soap the same way again.

Note: Scientists refer to 'light' as the visible part of the electromagnetic spectrum, where radio and microwaves are lower energy and frequency than light (and the height of the wave can be the size of a football field). Gamma rays and X-rays are higher energy and frequency than light (these tend to pass through mirrors rather than bounce off them).

Exercises

1. What is it in your food (and the soap) that is actually heated by the microwave?

2. How does a microwave heat things?

Lesson #7: Salty Eggs

Overview: Have you ever noticed how much easier it is to float in the ocean than a swimming pool? Why is this? You will discover the answer using an egg, a glass of water, and some salt.

What to Learn: After today you'll know how salt changes the density of water, which affects your ability (and your egg's ability!) to swim in it.

Materials

- hard-boiled egg
- glass
- water
- salt

Experiment

1. Place a hard-boiled egg in a glass of water (it should sink!)
2. Add a spoonful of salt and stir.
3. Repeat until the egg rises up from the bottom. You may need to wait for the cloudy saltwater to settle in order to see clearly.
4. Complete the data table.
5. Experiment further by adding a little water until the egg sinks again. It is possible to make the egg hover in the middle of the cup. This is called the equilibrium point!

Salty Eggs Data Table

Amount of Salt	Amount of Water	Observation	Conclusion

Reading

Did you know that most people can't crack an egg with only one hand without whacking it on something? The shell of an egg is quite strong! Challenge your students to try this at home over a sink and see if they can figure out the secret to cracking an egg in the palm of their hand.

How can you tell if an egg is cooked or raw? Simply spin it on the counter and you'll get a quick physics lesson in inertia…although you might not know it. A raw egg is slushy inside, and will spin slow and wobbly. A cooked egg is all one solid chunk, so it spins quickly.

This experiment is all about density. Density is basically how tightly packed atoms are. Mathematically, density is mass divided by volume. In other words, it is how heavy something is, divided by how much space it takes up. If you think about atoms as marbles, then something is denser if its marbles are jammed close together.

For example, take a golf ball and a ping pong ball. Both are about the same size or, in other words, take up the same volume. However, one is much heavier, has more mass, than the other. The golf ball has its atoms much more closely packed together than the ping pong ball and as such the golf ball is denser.

Here's a riddle: Which is heavier, a pound of bricks or a pound of feathers? Well, they both weigh a pound so neither one is heavier! Now, take a look at it this way: Which is denser, a pound of bricks or a pound of feathers? Aha! The pound of bricks is much denser since it takes up much less space. The bricks and the feathers weigh the same but the bricks take up a much smaller volume. The atoms in a brick are much more squished together than the atoms in the feathers.

Have you ever noticed how it is easier to float in the ocean than the lake? If so, then you already know how salt can affect the density of the water. Saltwater is more dense that regular water, and body tissues contains plenty of water, among other things.

Did you know that thinner people are denser than heavier people? For example, championship swimmers will sink and have to work harder to stay afloat, but the couch potato next door will float more easily in the water.

Exercises

1. Density measures how tightly packed atoms and molecules are. If you add two substances together, will the denser substance stay on top or sink to the bottom?

2. When the egg was placed in the fresh water, what happened? What was denser, the water or the egg? What was less dense?

3. When the water got salty enough, what did you observe? What was denser, the salty water or the egg? What was less dense?

4. Based on your observations, which is denser: salt water or regular water? How do you know?

Lesson #8: Quick and Easy Density

Overview: Today you'll get to make a layered, colorful density jar and watch some fun effects of hot and cold water. Both will allow you to play while learning about density!

What to Learn: You should know that density means how tightly atoms are packed together in a substance.

Materials

- large glass jar
- water
- vegetable oil
- liquid dish soap (colored if possible)
- honey
- corn syrup
- molasses
- rubbing alcohol
- two identical glasses or jars
- hot water
- cold water
- red and blue food coloring
- index card or other thick, heavy paper

Experiment

Part I

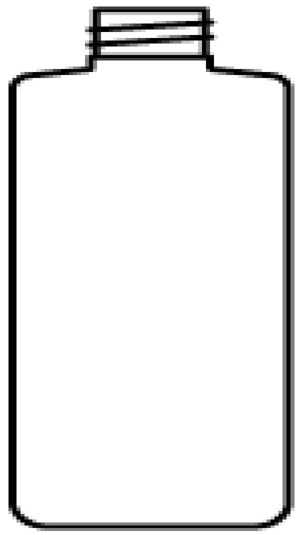
1. Wear your gloves and put your goggles on. No exceptions!
2. Add a layer of honey to the bottom of a glass jar.
3. Gently add a layer of molasses.
4. Add a layer of soap.
5. Use food coloring to color the water, then add it to the jar.
6. Add a layer of oil.
7. Add a layer of alcohol.

Part II

9. Get out two identical water bottles. Fill one to the brim with warm-hot water. Add 1-2 drops red food coloring.
10. Fill the second bottle with cold water. Add 1-2 drops blue food coloring. Notice how the food coloring flows in the two different temperatures.
11. Place a thick sheet of heavy paper (such as an index card) and use it to cap the blue bottle. Very quickly invert the bottle and stack it mouth-to-mouth with the red bottle. This is the tricky part: When the bottles are carefully lined up, remove the card. Is it different if you invert the red bottle over the blue?

Quick and Easy Density Illustration

Draw, color, and label the layers in your density jar. Label the material with the lowest density and the one with the highest density.



Reading

Density is basically how tightly packed atoms are. Mathematically, density is mass divided by volume. If an object has a mass of 20 grams and a volume of 10 milliliters, its density is 20÷10, or 2g/mL. For example, take a golf ball and a ping pong ball. Both are about the same size or, in other words, take up the same volume. However, one is much heavier, meaning it has more mass than the other. The golf ball has its atoms much more closely packed together than the ping pong ball and as such the golf ball is denser. This property can be used in creating a "density jar." A substance that is denser will float to the bottom of a container, while a less dense one will stay near the top.

Exercises

1. What material had the highest density? How do you know?
2. What liquid was the least dense? How do you know?
3. What did you observe in the experiment using cold water and hot water? In which one did the food coloring move faster? Why was this?
4. What did you observe when you flipped the two jars on top of each other?

Lesson #9: Lava Lamp

Overview: We're going to watch how density works by making a simple lava lamp that doesn't need electricity! If you like to watch blob-type shapes shift and ooze around, then this is something you're going to want to experiment with.

What to Learn: After today's experiment, you'll understand what density is, and know some cool facts about the differences between oil and water

Materials

- empty glass jar with straight sides or clean 2 liter soda bottle
- vegetable oil
- salt
- water
- food dye

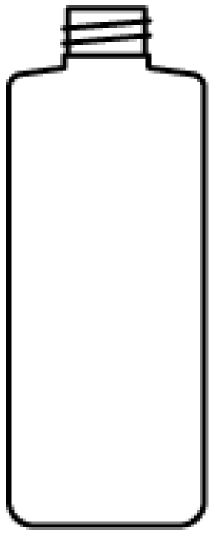
Experiment

1. Wear your gloves and put your goggles on. No exceptions!
2. Fill the container halfway with water
3. Add a layer of oil (fill about 1/3 of the way). Observe the water and oil.
4. Sprinkle salt on top and observe. Salt will combine with the oil and drop down to the bottom. Eventually the oil will break free of the salt and float back to the top.
5. Keep sprinkling salt on top.
6. Add food coloring and observe.

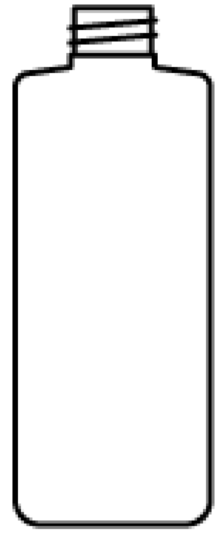
Lava Lamp Illustration

Label on the diagram:

1. Water
2. Oil



Use the following diagram to show what happens when salt is added:



Reading

Everything is made up of molecules. Density is the measure of how tightly the molecules are packed together in a solid object, liquid or gas. With some materials, such as liquids and gases, the density can be changed. With solid objects, the density can't be changed.

Oil and water are chemically very different from one another. Oil is made up of very long molecules that do not attract other molecules well. Water usually bonds well with other molecules due to its short molecules with positively and negatively charged ends that are very anxious to bond with something, almost anything. Also, oil molecules are very large and water molecules are very small. These differences are the main reasons that oil and water don't mix.

Water birds like ducks and geese are covered with feathers that soak up water like a sponge, but they can swim around in water and not drown. How is that possible? The birds have a gland on their bodies that contains oil. The birds use their beaks to transfer this oil to the feathers that will come in contact with the water. Since water and oil don't mix, the oil makes a barrier that keeps the water off the feathers.

Oil is slippery because of two main reasons. First, oil molecules are long and large. They do not bond easily with anything because they are satisfied with themselves the way they are…not looking for any company, no friends. Secondly, oil molecules have a very high surface tension. It is hard for most substances to break the surface tension of oil, so oil slides around instead of grabbing hold of anything because it….well, it just wants to be alone.

In today's experiment, students will actually be watching the salt itself fall through the oil. However, the oil sticks to the salt to form a larger object. Since the salt is heavier than water, the whole glob sinks to the bottom of the glass. At the bottom of your cup, the oil eventually breaks free of the salt and rises back up.

Exercises

1. What happened when you mixed the water and oil? Which one was on top?

2. What is denser: water or oil? How do you know?

3. Fill in the blanks to determine what happened: When I sprinkled salt on the oil and water mixture, the salt combined with the ________________and dropped to the bottom of the container. Eventually the ________________ broke free and floated to the top, while the ________________ stayed at the bottom.

4. What did the food coloring mix with? The oil or the water? Based on what you learned about the differences between oil and water, does this make sense?

Lesson #10: Penny Crystal Structure

Overview: What in the world is going on when water freezes? Something is happening to those little H_2O molecules, but what??? You'll find out today using pennies and a ruler.

What to Learn: You will learn what atoms and molecules are up to in their little microscopic world as they go from a liquid to a solid. You will also see what happens when a solid breaks. (Have you ever chipped off a piece of ice? Then you already know what cleavage is!)

Materials

- 50 pennies
- ruler

Experiment

1. Lay about 20-50 pennies on the table so that they are all sitting flat on the table. Now, use the ruler to push the pennies toward one another until there is one big glob of pennies on the table, all touching one another. Don't push so hard that they pile on top of one another.
2. Take a look at the pennies. Do you notice anything? You may notice that the pennies form patterns. How could that happen? You just shoved them together you didn't lay them out in any order. Taa daa! That's what often happens when solids form.
3. Now, place your ruler on the right hand side of your penny blob so that it's touching the bottom half of your pennies.
4. Slowly push the ruler to the left and watch the pennies.
5. You may have noticed that the penny "crystal" split in quite a straight line. This is called cleavage. Since crystals form patterns, they will tend to break in pretty much the same way you saw your pennies break

Reading

Imagine a bunch of folks all stuck to one another by big rubber bands. Each person can wiggle and jiggle but they can't really move anywhere. Atoms in a solid are the same way. Each atom can wiggle and jiggle, but they are stuck together. In science, we say that the molecules have strong bonds between them. Bonds are a way of describing how atoms and molecules are stuck together.

There's nothing physical that actually holds them together (like a tiny rope or something). Like the Earth and Moon are stuck together by gravity forces, atoms and molecules are held together by nuclear and electromagnetic forces. Since the atoms and molecules are so close together, they will often form crystals.

The molecules are pulled so close to one another that they will form patterns, also known as matrices. These patterns are very dependent on the shape of the molecule, so different molecules have a tendency to form different shaped crystals. Salt has a tendency to form a cube shape. Go take a look… and you'll find that they are like little blocks!

Water has a tendency to from triangle or hexagon shapes, which is why snowflakes have six sides. The pennies in this experiment also form a hexagon shape. Solids don't always form crystals, but they are more common than one may think. A solid that's not in a crystalline form is called amorphous.

In this experiment, the penny "crystal" will split in quite a straight line. This is called cleavage. Since crystals form similar patterns, they will tend to break in the same way the pennies break.

Break an ice cube and take a look. You may see many straight sections. This is because the ice molecules "cleave" according to how they formed. The reason you can write with a pencil is due to this concept. The pencil is formed of graphite crystal. The graphite crystal cleaves fairly easily and allows your students to write down their amazing physics discoveries!

Exercises

1. Explain what happened when you pushed the pennies together.

2. Draw a diagram of the structure your pennies formed.

3. You observed how the pennies broke into a straight line when pushed around with a ruler. What is this called? Do you think all crystals break into a perfectly straight line? Why or why not?

4. Are atoms closer together in a liquid or a solid?

5. You learned that many solids form into crystalline shapes but that some don't. What are these called?

Lesson #11: Rock Candy Crystals

Overview: Candy, anyone? That's what you'll make today, and you'll learn about crystals as you go! Yum!

What to Learn: You'll find out how to make a supersaturated solid solution by heating up water and adding more and more sugar. Once your crystals form, you'll see the regular repeating pattern that all crystals have.

Materials

- sauce pan
- spoon
- stove or other heating apparatus
- 8 cups granulated sugar
- 3 cups water
- measuring cup
- glass jar (cleaned out pickle, jam or may jars work great)
- aluminum foil
- wooden skewer (string or yarn will also work)
- tape
- food coloring is optional but fun!

Experiment

1. Place 3 cups of water in a sauce pan. Add 8 cups of sugar, and stir over medium heat approximately 4-7 minutes. You should be able to get all the sugar to dissolve. You can add more sugar until you start to see undissolved bits at the bottom of the pan. If this happens, just add a bit of water until they disappear. This is called a supersaturated solid solution.
2. Add food coloring to the water, if desired.
3. Allow solution to cool to about 130°, and then pour into the jar.
4. Place an aluminum foil "lid" on the jar. Poke a small hole in the middle and place a wooden skewer (or piece of string) through the hole. Make sure the stick doesn't touch the sides or bottom of the jar. Attach skewer in place with a piece of tape. (OPTIONAL: Before placing skewer in jar, "seed" a wet stick by sprinkling sugar over it then inserting up through bottom of aluminum foil lid so sugared end is resting in the solution.)
5. Put the whole thing aside in a warm, quiet place for 2 days to a week to get started. Some crystals will take up to six months for form large structures (as seen in image).

Reading

Crystals are formed when atoms line up in patterns and solidify. There are crystals everywhere — in the form of salt, sugar, sand, diamonds, quartz, and many more! To make crystals, you need to make a very special kind of solution called a supersaturated solid solution. This means a solution has been made more concentrated than normally possible.

Think of it this way: If you add salt by the spoonful to a cup of water, you'll reach a point where the salt doesn't disappear (dissolve) anymore and forms a lump at the bottom of the glass. The point at which it begins to form a lump is just past the point of saturation. If you heat up the saltwater, the lump disappears. You can now add more and more salt, until it can't take any more (you'll see another lump starting to form at the bottom). This is now a supersaturated solid solution. Mix in a bit of water to make the lump disappear. Your solution is ready for making crystals. Now, if you add something for the crystals to cling to, like a rock or a stick, crystals can grow. For faster-growing crystals, it is possible to "seed" the rock, stick, string, etc. This means to coat it with the material you formed the solution with, such as salt or sugar.

Making a supersaturated solution can be very difficult. If there is too much salt (or other solid) mixed in, the solution will crystallize all at the same time and form a huge rock that can't be pulled out of the jar. If there is too little salt, then crystals grow agonizingly slowly. To find the right amount takes time and patience.

Exercises:

1. Why was it necessary to make a supersaturated solid solution to get crystals?
2. A solute is the material you dissolve. And a solvent is what you dissolve something in. What was the solute in today's experiment? What was the solvent?
3. Sometimes when this experiment is done, students end up with a huge chunk of sugar right away. What could have happened?
4. What might be the problem if crystals don't form, or take weeks and weeks to form?

Lesson #12: Bouncy Putty Slime

Overview: Time to play with polymers! Polymers are very long chains of molecules and are super fun because they act differently depending on what they are made of and how they're put together. This polymer slime will even bounce!

What to Learn: In today's experiment you will learn that polymers are long, long chains of molecules that often have very fun and useful properties. You will see that it's possible to play with polymers so they form different structures. The fishnet structure of today's polymer will cause it to bounce.

Materials

- borax (laundry whitener)
- water
- white glue
- disposable cups (2)
- popsicle sticks (2)
- tablespoon
- teaspoon
- optional: food coloring

Experiment

1. Wear your gloves and put your goggles on. No exceptions!
2. Combine 6 tablespoons water with one teaspoon borax in a cup. Stir with a popsicle stick for 10-15 seconds. (Optional: add a few drops of food coloring)
3. In another cup, mix 1 tablespoon white glue and 1 tablespoon water.
4. Pour glue solution into borax solution.
5. Stir for one second with a popsicle stick, then quickly pull the putty out of cup and play with it until it dries enough to bounce on table (3-5 minutes).
6. Pick up an imprint from a textured surface or print from a newspaper, bounce and watch it stick, snap it apart quickly and ooze apart slowly.
7. Complete the Data Table.

Bouncy Putty Slime Data Table

Compound/Object	Detailed Description (what does it look like? How does it act? Is it a solid or a liquid?)
White Glue	
Borax	
Bouncy Putty	

Reading

"Poly-" means many and "-mer" means part, or segment. Glue is a polymer, which is a long chain of molecules all hooked together like tangled noodles. When you mix the glue solution with the borax solution, the water molecules start linking the noodles together along the length of each noodle to get more like a fishnet. Scientists call this a *polymetric compound of sodium tetraborate and lactated glue*. We call it bouncy putty.

The property of a polymer will depend on what is happening at the molecular level. Things that are made of polymers look, act, and feel differently based on how the molecules are connected. Some are rubbery, some are gooey, and some are hard.

Exercises:

1. Think about a ladder. If the glue solution is one side of the ladder and the borax solution is the other side, what is holding the two sides together?

2. Is glue a solid or a liquid? How about the bouncy ball?

3. Was this a physical or chemical change? How do you know?

4. Why does the ball bounce?

Lesson #13: Glowing Slime

Overview: When you think of slime, do you imagine slugs, snails, and puppy kisses? Or does the science fiction film The Blob come to mind? Any way you picture it, slime is definitely slippery, slithery, and just plain icky — and a perfect forum for learning about polymers. This slime can also be made to glow, which is a terrific introduction to understanding UV light.

What to Learn: By the time you are finished you will understand that just as spaghetti needs sauce to stick together, polymers need a cross-linking agent. And, you'll learn to make cool luminescent slime you can view with a little help from a black light.

Materials

- water
- popsicle sticks
- disposable cups
- clear glue or white glue
- yellow highlighter
- measuring spoons
- scissors
- borax (laundry whitener)
- Optional: UV fluorescent black light

Experiment

1. Wear your gloves and put your goggles on. No exceptions!
2. Remove the end of a highlighter pen.
3. Tip pen over until the roll of felt comes out.
4. Slit along the plastic coating covering the felt. Spread the fibers out.
5. Over a large container, douse entire felt with water until it turns white. This is the glow juice.
6. Put 4 tablespoons of glow juice into a disposable cup. Add 1 tablespoon borax (sodium tetraborate). Stir 10 seconds until you dissolve as much sodium tetraborate solution as possible.
7. In a second cup, put 2 tablespoons water and 2 tablespoons clear glue. Mix 20 seconds.
8. Pour glue solution into sodium tetraborate/glow juice solution and stir 1-2 times
9. Pull out slime and play with it until it bounces on table (note: it may be squished back together if it breaks).
10. Place slime under a long wave UV light and it will fluoresce!
11. When you are finished, slime may be stored in the refrigerator or freezer and thawed in a microwave

Glowing Slime Data Table

Experiment with adding different amounts of borax or glue to see how each affects your slime. Record in the following table:

Cup #1	Cup #2	Results
4 T Glow Juice + 1 T Borax	2 T water + 2 T clear glue	
4 T Glow Juice + 2 T Borax	2 T water + 2 T clear glue	
4 T Glow Juice + 1 T Borax	2 T water + 3 T clear glue	

Reading

Imagine a plate of spaghetti. The noodles slide around and don't clump together, just like the long chains of molecules (called polymers) that make up slime. They slide around without getting tangled up. The pasta by itself (fresh from the boiling water) doesn't hold together until you put the sauce on. Slime works the same way. Long, spaghetti-like chains of molecules don't clump together until you add the sauce … until you add something to cross-link the molecule strands together.

The sodium-tetraborate-and-water mixture is the "spaghetti" (the long chain of molecules, also known as a polymer), and the "sauce" is the glue-water mixture (the cross-linking agent). You need both in order to create a slime worthy of Hollywood filmmakers.

There are a lot of everyday things that fluoresce, or glow, when placed under a black light. Note that a black light emits high-energy UV light. You can't see this part of the spectrum, just as you can't see infrared light found in the beam emitted from the remote control to the TV. This is why "black lights" were so named. Stuff glows because fluorescent objects absorb the UV light and then spit light back out almost instantaneously. Some of the energy gets lost during that process, which changes the wavelength of the light, which makes this light visible and causes the material to appear to glow

Exercises

1. What is the "spaghetti" in this experiment? What is the "sauce"?
2. What are polymers?
3. Is your slime a solid, a liquid, or a bubbly gas?
4. What causes the glow juice to glow?
5.

Lesson #14: Bouncy Ball

Overview: This is one of those "chemistry magic show" types of experiments to wow your friends and family. Here's the scoop: You take a cup of clear liquid, add it to another cup of clear liquid, stir for ten seconds, and you'll see a color change, a state change from liquid to solid, and you can pull a rubber-like bouncy ball right out of the cup.

What to Learn: Solids and liquids have different properties. Polymers are long chains that can be linked together to form silicones which have really cool uses.

Materials

- sodium silicate ("water glass")
- ethyl alcohol, also called ethanol (70%)
- beakers or disposable cups (2 per group)
- popsicle sticks (2 per group)
- teaspoon measures (2 per group)
- rubber gloves
- small Ziploc bags

Experiment

1. Wear your gloves and put your goggles on. No exceptions!
2. In one cup, measure four teaspoons of sodium silicate solution (it should be a liquid). Sodium silicate can be irritating to the skin for some people, so wear rubber gloves when doing this experiment!
3. Measure 1 teaspoon of ethyl alcohol into a second cup. Ethyl alcohol is extremely flammable—cap it and keep out of reach when not in use.
4. Pour the alcohol into the sodium silicate solution and stir with a popsicle stick.
5. You'll see a color change (clear to milky-white) and a state change (liquid to a solid clump.
6. Using gloves, gather up the polymer ball and firmly squeeze it in your hands.
7. Compress it into the shape you want—is it a sphere, cube, or do you prefer a dodecahedron?
8. Bounce it!
9. Be patient when squeezing the compound together. If it breaks apart and crumbles, gather up the pieces and firmly press together.
10. When finished, seal ball in plastic bag. It will eventually become a bouncy pancake which may be reformed by slowly squeezing the pieces together.
11. Fill out the Bouncy Ball Data Table

Bouncy Ball Data Table

Compound/Object	Detailed Description
Sodium silicate	
Ethyl alcohol	
Bouncy ball	

Reading

Polymers are made up of many molecules all strung together to form really long chains. The sodium silicate is a long polymer chain of alternating silicon and oxygen atoms. When ethanol (ethyl alcohol) is added, it bridges and connects the polymer chains together by cross-linking them.

Think of a rope ladder—the wooden rungs are the cross-linking agents (the ethanol) and the two ropes are the polymer chains (sodium silicate).

Silicones are water repellent, so you'll find that food dye doesn't color your bouncy ball. You'll find silicone in greases, oils, hydraulic fluids, and electrical insulators.

A solid is a kind of matter that has its own shape and does not flow at a given temperature. The molecules that make up a solid are close together and have little movement. Solids can be different colors and textures and have different degrees of malleability. Liquids take the shape of their containers. The molecules in a liquid are further apart and are able to vibrate and move more freely.

Exercises

1. Before the reaction, what was the sodium silicate like? Was it a solid, liquid, or gas? What color was it? Was it slippery, grainy, viscous, etc.?

2. What was the ethanol like before the reaction?

3. How is the product (the bouncy ball) different from the two chemicals in the beginning?

4. Is the bouncy ball a solid or a liquid? How do you know?

5. Was this reaction a physical or chemical change?

Lesson #15: Sewer Slime

Overview: Get ready to be grossed out as you make a sewer slime that closely resembles snot!

What to Learn: You should understand that the guar gum from today's experiment is a polymer, or long chain of molecules. The borax links all those polymers together in a chemical reaction, forming a gel.

Materials

- borax (sodium tetraborate)
- water
- 2 disposable cups
- measuring spoons (tablespoon, ½ teaspoon, ¼ teaspoon)
- popsicle sticks
- powdered guar gum

Experiment

1. Wear your gloves and put your goggles on. No exceptions!
2. Fill a cup with 7 tablespoons of cold water.
3. Add ¼ teaspoon of guar gum by first placing the measured amount in your hand then sprinkling into the water. This prevents clumping. Stir with a popsicle stick 10 times and stop, leaving the stick in.
4. Leave it for 2 minutes to thicken. Cautiously dip a pinkie into the cup, and then rub it in your fingers. Does it smell?
5. Meanwhile, in a second cup, mix ½ teaspoon borax (sodium tetraborate) in one tablespoon water.
6. Add ½ teaspoon of the borax Solution to the guar gum solution. Stir observe what you have made!

Sewer Slime Data Table

Experiment with adding different amounts of guar gum or Borax to see how each affects your slime. Record in the following table:

Cup #1	Cup #2	Results
7 T water + ¼ tsp guar gum	1 T water + ½ tsp borax	
7 T water + ½ tsp guar gum	1 T water + ½ tsp borax	
7 T water + ¼ tsp guar gum	1 T water + 1 tsp borax	

Reading

Guar gum comes from the guar plant (also called the guaran plant), and people have found a lot of different and interesting uses for it. It's one of the primary substitutes for fat in low-fat and fat-free foods. Some kids call this polymer "fake fat" slime, mostly because it's used in fat-free baking. Cooks like to use guar gum in foods as it has 8 times the thickening power of cornstarch, so much less is needed for the recipe. Ice cream makers use it to keep ice crystals from forming inside the carton. Doctors use it as a laxative for their patients.

Chemically, guar gum is a polysaccharide, meaning it is a carbohydrate that can be broken down into two or more small sugar molecules. Guar gum is made of the sugars galactose and mannose. Either borax or calcium can cross-link guar gum, causing the long polymer strands to stick together, forming a gel. In today's experiment we will use borax to create gooey, messy sewer slime!

Exercises

1. Describe your slime using as many details as you can.

2. The guar gum is a polymer. What does this mean?

3. Why did the borax make it look like slime?

4. Was this a physical or chemical reaction? How do you know?

Lesson #16: Hidden CO_2

Overview: If you've ever burped, you know that it's a lot easier to do after chugging an entire soda. Now why is that? Soda is loaded with gas bubbles — carbon dioxide (CO_2), to be specific. You will experiment to determine where carbon dioxide gas may be hiding in other household items. You'll also create your own scale to determine if CO_2 weighs the same as air, more, or less.

What to Learn: Focus on carbon dioxide for today's experiment. Where is it? How do you know? What does carbon dioxide look like as a solid?

Materials

Part I (Hidden CO_2)

- baking soda
- chalk
- distilled white vinegar
- washing soda
- disposable cups (3)
- popsicle sticks (3)
- Optional: Other items to experiment with: flour, baking powder, powdered sugar, or cornstarch (in place of baking soda/chalk/washing soda) and lemon juice, orange juice, or oil (in place of distilled white vinegar)

Part II (Bonus: Making a Scale to Measure CO_2)

- baking soda
- distilled white vinegar
- two disposable cups
- large container
- two water bottles or stacks of books
- two long pencils or skewers
- string

Experiment

1. Wear your gloves and put your goggles on. No exceptions!
2. Fill 3 cups with a few tablespoons of vinegar.
3. Put samples into each cup: chalk, sprinkle of baking soda, sprinkle of washing soda. Observe and fill out data sheet.

<u>To continue with Bonus experiment (Making a Scale to Measure CO_2):</u>

4. Construct a scale by following these steps:
    a. Suspend a long dowel (pencil, skewer, etc) between two water bottles and attach with tape.
    b. Use string to suspend two small disposable cups from either end of a second dowel.

c. Attach second dowel as a cross-piece across the first suspended dowel. Make sure the scale can go up and down very freely and easily and cups are balanced evenly.

5. In a large container, sprinkle baking soda to cover the bottom.
6. Add distilled vinegar just until bubbles reach the top of the container.
7. Wait a few minutes for the bubbles to completely pop. The container is now full of carbon dioxide gas
8. Pour gas into one of the cups and observe.

Hidden CO_2 Data Table

Mixture	Description of Reaction	Speed of Reaction
Vinegar + chalk		
Vinegar + baking soda		
Vinegar + washing soda		

Reading

If you've ever burped, you know that it's a lot easier to do after chugging an entire soda. Now why is that?

Soda is loaded with gas bubbles — carbon dioxide (CO_2), to be specific. And at standard temperature (68˚F) and pressure (14.7 psi), carbon dioxide is a gas. However, if you burped in Antarctica in the wintertime, it would begin to freeze as soon as it left your lips. The freezing temperature of CO_2 is -109˚F, and Antarctic winters can get down to -140˚F. You've actually seen this before, as dry ice (frozen burps!).

Carbon dioxide has no liquid state at low pressures (75 psi or lower), so it goes directly from a block of dry ice to a smoky gas (called sublimation). It's also acidic and will turn cabbage juice indicator from blue to pink. CO_2 is colorless and odorless, just like water, but it can make your mouth taste sour and cause your nose to feel as if it's swarming with wasps if you breathe in too much of it (though we won't get anywhere near that concentration with our experiments).

The triple point of CO_2 (the point at which CO_2 would be a solid, a liquid, and a gas all at the same time) is around five times the pressure of the atmosphere (75 psi) and around -70°F. (What would happen if you burped then?)

What sound does a fresh bottle of soda make when you first crack it open? PSSST! What is that sound? It's the CO_2 (carbon dioxide) bubbles escaping. What is the gas you exhale with every breath? Carbon dioxide. Hmmm … it seems as if the soda is already pre-burped. Interesting.

Exercises

1. How do you know carbon dioxide was inside the chalk, baking soda, and washing soda?

2. When the carbon dioxide bubbles popped, where did the carbon dioxide go?

3. What would happen to the chalk if you left it in the vinegar?

4. What is sublimation?

5. If you completed the bonus experiment, did carbon dioxide weigh more or less than air? How do you know?

Lesson #17: Plasma Grape

Overview: You've heard about solids, liquids, and gases, but is there anything else out there? It's time to learn about plasma! Plasma makes up most of the matter in the universe, since most of it is inside of stars, and stars make up most of the matter we can detect with our eyes.

What to Learn: Clouds of gas are made up of wiggly, jiggly atoms that dance all over the place. When gases are heated, more energy is added and this makes those molecules dance around even harder. When this happens, they collide with each other more often, knocking electrons off here and there. Those naked electrons and charged ions give the gas different properties than the original gas. so scientists call this new highly energetic gas *plasma.*

Materials

- microwave (not a new or expensive one)
- green grape
- red grape
- cherry tomato
- a knife with adult help

Experiment

1. Carefully cut the grape lengthwise almost in half. Make sure to leave a bit of skin connecting the two halves.
2. Open the grape like a book, so that the two halves are next to one another still attached by the skin.
3. Put the grape into the microwave with the outside part of the grape facing down and the inside part facing up.
4. Close the door and set the microwave for ten seconds. You may want to dim the lights in the room.
5. Repeat with other items.

Note: This experiment creates a momentary, high-amp short-circuit in the oven, a lot like shorting your stereo with low-resistance speakers. It's not good to operate a microwave for long periods with little to nothing in them. This is why we only do it for a few seconds. While this normally isn't a problem in most microwaves, don't do this experiment with an expensive microwave or one that's had consistent problems, as this might push it over the edge.

Plasma Grape Data Table

Item	Results
Green grape	
Red grape	
Cherry tomato	

Reading

There are three well-known states of matter, which are solids, liquids, and gases. Plasma is the fourth state of matter. Note – this is NOT the kind of plasma doctors talk about that is associated with blood. Other places you can find plasma include neon signs, fluorescent lights, plasma globes, and small traces of it are found in a flame.

The textbook definition says plasma is an ionized gas. What does that mean? Plasma is formed when enough energy is added (often in the form of raising the temperature) to a gas so that the electrons break free and start zinging around on their own. Since electrons have a negative charge, having a bunch of free-riding electrons causes the gas to become electrically charged. This gives some cool properties to the gas. Anytime there are charged particles like electrons off on their own, they are referred to by scientists as *ions*.

Plasma is HOT HOT gas, and in this case, HOT HOT air, with a bit of water vapor. Grapes work well for this experiment because grapes contain high quantities of juice that conducts electricity. The grape halves are like little cups full of this conductive juice connected by a tiny bridge (the part that isn't cut all the way through). When you hit the ON button on the microwave, the energy being shot at the grape moves the electrons across the bridge very quickly, which heats up the bridge until it bursts into flame… and when this happens, the electrons that are traveling through the flame arc across and ionize the air around the grape and a burst of bright plasma shoots up. If you watch carefully, you will see two flames shoot up, not one.

Exercises

1. Describe in detail what you observed in the plasma grape experiment. Was there a flame? What color was it? About how high did it go? How long did it last?

2. What are the four types of matter?

3. The textbook definition of plasma is "an ionized gas." What does this mean in plain English?

4. Why do you think it was necessary to make sure there was a bit of skin connecting the two halves of the grape? What do you think happens to the electrons traveling across this "bridge?"

Lesson #18: Sensing Temperature

Overview: Have you ever wondered how an ice-cold glass of water gets water drops on the *outside* of the cup? It's all about temperature change! You will see how a temperature difference can fool your fingers in today's hot and cold experiment.

What to Learn: You will understand why condensation occurs and feel how skin can detect a temperature difference, but not an exact temperature.

Materials

- cup of hot water
- cup of cold water
- cup of room-temperature water

Experiment

1. Place one finger from one hand in the hot (not scalding) water. Place a finger from your other hand in the ice-cold water. Leave them there for a moment.
2. At the same time, take both fingers and place them in the room-temperature water. What do you feel?
3. Complete the data table.

Sensing Temperature Data Table

What do your fingers feel? Write your observations here!

Right Hand Finger	Left Hand Finger	Observations

Reading

Have you ever wondered how an ice-cold glass of water gets water drops on the *outside* of the cup? Where does that water come from? Does it ease its way through the glass? Did someone come by and squirt the glass with water? No, of course not. Some of the gaseous water molecules in the air came close enough to the cold glass to lose some molecular speed. Since they lost speed, they formed bonds between each other and liquefied. They condensed on the cold surface of the glass.

Imagine, though, if you will, that you live several hundred years ago and the process of condensation wasn't understood. You happen to be an inquisitive, highly perceptive, person (which of course you are) and you notice this film of water showing up on cold things. Water appearing out of apparently nowhere! You'd be pretty amazed, wouldn't you?!?

Isn't it amazing that every time you pick up a cold can of soda there are molecular interactions happening right in front of your eyes! This is why science is so wonderful. It provides the skills to see these amazing things and the skills to investigate and perhaps understand them.

The skin contains temperature sensors that work by detecting the direction heat flows in or out of the body, but not temperature directly. These sensors change temperature depending on their surroundings. When one finger is heated up then placed in water at room temperature, the heat flows out of the body. The brain gets a message saying the finger is cooler. A finger placed in ice water followed by room temperature water tells the brain it was detecting a heat flow into your body… and presto! You have one confused brain.

In order for heat to flow, there must be a temperature difference. But why then do the metal legs of a table feel colder than the wood tabletop when both are at the same room temperature? The metal will feel colder because heat flows away from your skin faster into the metal than the wood. We'll talk about heat capacity in a later experiment, but this is why scientists had to invent the thermometer: The human body isn't designed to detect temperature, only heat flow.

Exercises

1. How did the hot finger feel when it was placed into the room-temperature water?

2. How did the cold finger feel when it was placed into the room-temperature water?

3. Based on your observations, what can you infer about how a skin detects temperature?

4. After taking a hot shower, a student noticed something interesting. When she put on her glasses and went into the hallway, her glasses fogged up with tiny droplets of water. What was happening?

Lesson #19: Indoor Rain Clouds

Overview: If you've ever wondered why water forms on the *outside* of a glass of ice water, this is your big chance to discover the real reason through chemistry and state changes.

What to Learn: This lab demonstrates evaporation and condensation of molecules in the air. Today you'll get to make it rain indoors!

Materials

- glass of ice water
- glass of hot water
- towel
- ruler

Experiment

1. Take two clear glasses that fit snugly together when stacked. (Cylindrical glasses with straight sides work well.)
2. Fill one glass half-full with ice water and the other half-full with very hot water (definitely an adult job – and take care not to shatter the glass with the hot water!). Be sure to leave enough air space for the clouds to form in the hot glass.
3. Place the cold glass directly on top of the hot glass and wait several minutes. If the seal holds between the glasses, a rain cloud will form just the bottom of the cold glass, and it actually rains inside the glass! (You can use a damp towel around the rim to help make a better seal if needed.)
4. Complete the table. Measure the water height carefully with your ruler. If you have 2" of water in the hot water glass, then write 2". Please be careful when measuring hot water!

Indoor Rain Clouds Data Table

Hot Water Height	Ice Water Height	How well did it rain?

Reading

This experiment demonstrates state changes of matter. When hot vapor rises (like from the hot core of a gaseous planet) and hits a cold front (like the coldness of outer space in the upper atmosphere), the vapor condenses into liquid drops and rains, or can even freeze solid into ice chunks. Neptune and Uranus both have methane ice in their upper atmospheres. Both Jupiter and Saturn have upper cloud decks of water vapor and clouds of ammonia. The water vapor clouds are right at the freezing temperature of water.

Exercises

1. Which combination made it rain the best? Why did this work?
2. Draw your experimental diagram here, labeling the different components:
3. Add in labels for the different phases of matter. Can you identify all three states of matter in your experiment?

Lesson #20: Soaking up Rays

-

Overview: It's a blistering hot day and you want to wear something cool. Will you choose the dark- or light-colored outfit? Is there science involved in fashion? You bet!

What to Learn: You should discover that the sun transfers its heat in a process called radiation and that dark colors absorb the infrared radiation while light colors reflect it.

Materials

- 2 ice cubes, about the same size
- white piece of paper
- black piece of paper
- a sunny day

Experiment

1. Put the black paper and white paper on a sunny part of the sidewalk.
2. Put the ice cubes in the middle of the pieces of paper.
3. Wait. Record approximately how long it took for each ice cube to melt.

Soaking Up Rays Data Table

Color of Paper	Size of Ice Cube	Time to Melt

Reading

There are three ways to transfer heat: conduction, which means two objects touching; convection, where one of the objects is a fluid like water or air; and radiation, which doesn't need to be touching anything at all. Heat is transferred by radiation through electromagnetic waves. Energy is vibrating particles that can move by waves over a distance. If those vibrating particles hit something and cause those particles to vibrate, those particles begin to move faster, causing a temperature increase. The types of electromagnetic waves that transfer heat are infra-red waves.

If you hold your hand near an incandescent light bulb, you begin to feel heat on your hand. This is an example of heat traveling like a wave. This type of heat transfer is called radiation.

Now, don't panic. This is not a bad kind of radiation like you get from X-rays. It's infra-red radiation. Heat was transferred from the light bulb to your hand. The energy from the light bulb caused the molecules in your hand to resonate. Since the molecules in your hand are now moving faster, they have increased in temperature. Heat has been transferred! In fact, an incandescent light bulb gives off more energy in heat than it does in light. They are not very energy-efficient.

Now, if it's a hot sunny day outside, are your students better off wearing a black or white shirt if they want to stay cool? This experiment will help them figure it out. What they should eventually see is that the ice cube on the black sheet of paper melts faster than the ice cube on the white sheet. Dark colors absorb more infra-red radiation than light colors. Heat is transferred by radiation easier to something dark-colored than it is to something light-colored and so the black paper increases in temperature more than the white paper.

So, to answer the shirt question, a white shirt reflects more infra-red radiation so it will stay cooler. White walls, white cars, white seats, white shorts, white houses, etc. all act like mirrors for infra-red (IR) radiation. This is why you can aim your TV remote at a white wall and still turn on the TV. Simply pretend the wall is a mirror (so you can get the angle right), and bounce the beam off the wall before it gets to your TV. It looks like magic!

Exercises

1. How long did it take for the ice cube on black paper to melt? ____________________________

2. How long did it take for the ice cube on white paper to melt? ____________________________

3. What can you discover about light versus dark colors and the infra-red radiation of the sun based on this experiment?

4. What are three ways heat can be transferred?

Chemistry 1 Evaluation

Student Worksheet

Overview: Today you're going to take two different tests: the quiz and the lab practical. You're going to take the written quiz first, and the lab practical at the end of this lab. The lab practical isn't a paper test – it's is where you get to show your teacher that you know how to do something.

Lab Test & Homework

1. Your teacher will call you up so you can share how much you understand about section 1: Crystals, Atoms, Molecules, Polymers, Chemical Reactions, and States of Matter, and how it works. Since science is so much more than just reading a book or circling the right answer, this is an important part of the test to find out what you really understand.
2. While you are waiting for your turn to show your teacher how much of this stuff you already know, you get to get started on your homework assignment. The assignment is due next week, and half the credit is for creativity and the other half is for content, so really let your imagination fly as you work through it. Here it is:

Unit 1 Homework Assignment

Part I. Using a periodic table, go on an element hunt! Write the name of each element in the first column, and the symbol of each element in the second column:

Fe	______________________	zinc	______________________
Ni	______________________	potassium	______________________
Na	______________________	hydrogen	______________________
Ba	______________________	helium	______________________
O	______________________	fluorine	______________________
Xe	______________________	gold	______________________
W	______________________	mercury	______________________
Si	______________________	lead	______________________
C	______________________	neon	______________________
S	______________________	nitrogen	______________________

Part II. Develop a game to test your knowledge about the names and symbols of these 20 elements.

Periodic Table of the Elements

Chemistry Reference Sheet

California Standards Test

Key

11 — Atomic number
Na — Element symbol
Sodium — Element name
22.99 — Average atomic mass*

Period	1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 8B	10	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1	1 H Hydrogen 1.01																	2 He Helium 4.00
2	3 Li Lithium 6.94	4 Be Beryllium 9.01											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
3	11 Na Sodium 22.99	12 Mg Magnesium 24.31											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95
4	19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.87	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.39	31 Ga Gallium 69.72	32 Ge Germanium 72.61	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80
5	37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.60	53 I Iodine 126.90	54 Xe Xenon 131.29
6	55 Cs Cesium 132.91	56 Ba Barium 137.33	57 La Lanthanum 138.91	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.84	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.98	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
7	87 Fr Francium (223)	88 Ra Radium (226)	89 Ac Actinium (227)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (269)	109 Mt Meitnerium (268)									

58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium (145)	62 Sm Samarium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.97
90 Th Thorium 232.04	91 Pa Protactinium 231.04	92 U Uranium 238.03	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

* If this number is in parentheses, then it refers to the atomic mass of the most stable isotope.

Chemistry 1 Quiz

Name____

1. Name at least three examples of chemical change.
2. What are crystals?
3. Why is it necessary to make a supersaturated solid solution to get sugar crystals?
4. What are polymers?
5. Was making slime a physical or chemical reaction? How do you know?
6. Why is moon sand called a non-Newtonian fluid?
7. What is sublimation? When did you witness this event?
8. Why does an egg "turn to rubber" when placed in vinegar?
9. What are the four types of matter?
10. How does skin detect temperature?

11. Why do drops of water form on the outside of a cup of ice water?

12. How were you able to make rain clouds?

13. Explain the difference between wearing light and dark colors in the sun. What happens to each?

14. How does a microwave heat things?

15. What happens when you mix water and oil? What does this tell you about the density of oil?

16. How does a lava lamp work?

Chemistry 1 Lab Practical

Student Worksheet

This is your chance to show how much you have picked up on important key concepts, and if there are any holes. You also will be working on a homework assignment as you do this test individually with a teacher.

Materials:

- 50 pennies
- borax (laundry whitener)
- water
- white glue
- disposable cups
- popsicle sticks
- tablespoon
- teaspoon
- chalk
- distilled white vinegar

Lab Practical:

- Use these pennies to show how atoms and molecules are spaced in a solid, liquid, and gas.

- Using borax, water, and glue, demonstrate how you can generate a chemical change. Explain how you know this is a chemical change.

- Show there is hidden carbon dioxide in a piece of chalk.

Answers to Exercises

Lesson #1: Chemical Matrix of Acids and Bases

1. What is an indicator? (A compound that changes color when you combine it with different things.)
2. What examples of chemical changes did you observe? (Heat, color change, bubbles, foam, gel, ooze, cold, etc.)
3. What types of physical changes did you observe? (None.)
4. Why did some mixtures get hot? What type of reaction was this? (It was an exothermic reaction, which means energy was given off. The chemical-bond energy was converted to thermal energy, or heat.)
5. Why did other mixtures get cold? What type of reaction was this? (It was an endothermic reaction, which absorbs energy. The heat from the mixture was converted to bond energy.)

Lesson #2: Laundry Soap Crystals

1. Why did the sodium tetraborate solution need to be supersaturated in order to form crystals? (When the solution cooled, it could not hold as many crystals of borax, so the rest "fell out" of solution onto the pipe cleaner shape)
2. The concentration of a solution is the amount of dissolved substance (borax) in a given volume of solvent (in this case, water!). Was the borate solution more concentrated when it was cool or hot? Why? (Hot, because more borate was dissolved in the same amount of water).
3. Why was it necessary to put a pipe cleaner into the sodium tetraborate solution? (The crystals need something to cling to.)

Lesson #3: Non-Messy Squishy Slime

1. How could you make the polymer stretchier? (Answers will vary. Ex: add a sticky substance like glue, add more water)
2. Does the amount of cornstarch added change the slime? (Yes, it becomes drier.)
3. Why should the squishy slime polymer be stored in a Ziploc bag? (so it doesn't dry out)
4. Does the amount of water added to the polymer affect the gooeyness of the slime? (Yes, the more water, the gooier it becomes!)

Lesson #4: Moon Sand

1. Name a substance that is very viscous. (Answers may vary. The correct answer will be something thick like syrup or gravy)
2. Why is moon sand called a non-Newtonian fluid? (its viscosity changes)
3. What can you add to corn starch to make it more viscous? (water)
4. If you were going to make gravy and needed it to be thicker, what could you add to it? (corn starch)

Lesson #5: Rubber Eggs

1. Describe what the eggshell looked like before the reaction. (Answers may vary but should include details such as color, thickness of shell, what type of surface the shell has, etc.)
2. Describe the acetic acid (answers may vary but should include details such as color, viscosity, smell).
3. The product you witnessed in this chemical reaction was carbon dioxide, a colorless, odorless gas. How can you tell there really was a chemical reaction? (Bubbles formed.)
4. Why did the egg turn to "rubber?" (The vinegar dissolved the calcium of the egg.)

Lesson #6: Microwaving Soap

1. Now that you have observed this experiment, explain in your own words how microwaves work. (They send out invisible lights called electromagnetic waves which excite water molecules in foods, making them vibrate and heat up)
2. What might happen if you put something in the microwave that doesn't have any water in it? (it would be dangerous, since there would be nowhere for all that energy to go. It could break the microwave, or even start a fire)
3. Name three types of light waves you cannot see (Answers will vary, including sunlight, microwaves, X-rays, radio waves.)
4. What has more energy: ice, water, or steam? (steam)What happens to the water molecules as they get heated up? (They vibrate more and more.)

Lesson #7: Salty Eggs

1. Density measures how tightly packed atoms and molecules are. If you add two substances together, will the denser substance stay on top or sink to the bottom? (sink to the bottom)
2. When the egg was placed in the fresh water, what happened? What was denser, the water or the egg? What was less dense? (The egg sank. The egg was more dense and the water less dense.)
3. When the water got salty enough, what did you observe? What was denser, the salty water or the egg? What was less dense? (The egg floated. The salt water was more dense, and the egg less dense.)
4. Based on your observations, which is denser: salt water or regular water? How do you know? (Since the egg floated only when salt was added, it means the denser salt water must have sunk to the bottom of the container, allowing the egg to float.)

Lesson #8: Quick and Easy Density

1. What material had the highest density? How do you know? (If you used the materials suggested, it was the honey. If not, whatever layer was on the bottom.)
2. What liquid was the least dense? How do you know? (Again, answers may vary according to what materials were used, but alcohol was the least dense of the materials suggested. It should have ended up at the top).
3. What did you observe in the experiment using cold water and hot water? In which one did the food coloring move faster? Why was this? (It moved faster in the hot water, because the water molecules were less dense).
4. What did you observe when you flipped the two jars on top of each other? (answers will vary)

Lesson #9: Lava Lamp

1. What happened when you mixed the water and oil? (They didn't mix.) Which one was on top? (oil)
2. What is denser: water or oil? How do you know? (water, because it sank to the bottom)
3. Fill in the blanks to determine what happened: When I sprinkled salt on the oil and water mixture, the salt combined with the _____(oil)_________ and dropped to the bottom of the container. Eventually the ____(oil)_____ broke free and floated to the top, while the ______(salt)_______ stayed at the bottom.
4. What did the food coloring mix with? The oil or the water? (water) Based on what you learned about the differences between oil and water, does this make sense? (Yes, water easily makes bonds, while oil doesn't.)

Lesson #10: Penny Crystal Structure

1. Explain what happened when you pushed the pennies together. (They formed a pattern)
2. Draw a diagram of the structure your pennies formed. (answers will vary but should show a roughly hexagonal pattern)

3. You observed how the pennies broke into a straight line when pushed around with a ruler. What is this called? (Cleavage) Do you think all crystals break into a perfectly straight line? Why or why not? (No, because crystals are made of molecules with different shapes, so they will cleave differently….some very smooth, others fairly rough)
4. Are atoms closer together in a liquid or a solid? (solid)
5. You learned that many solids form into crystalline shapes but that some don't. What are these called? (amorphous)

Lesson #11: Rock Candy Crystals
1. Why was it necessary to make a supersaturated solid solution to get crystals? (With a normally saturated solution, the sugar crystals would simply dissolve in the water to make hot sugar water. When it cooled, it would make cool sugar water. With a supersaturated solution, the sugar "falls out" of solution as it cools, because it can no longer hold all of the sugar, and crystals are formed)
2. A solute is the material you dissolve. And a solvent is what you dissolve something in. What was the solute in today's experiment? (sugar) What was the solvent? (water)
3. Sometimes when this experiment is done, students end up with a huge chunk of sugar right away. What could have happened? (they dissolved too much sugar in the water)
4. What might be the problem if crystals don't form, or take weeks and weeks to form? (not enough sugar was added; the solution was not supersaturated)

Lesson #12: Bouncy Putty Slime
1. Think about a ladder. If the glue solution is one side of the ladder and the borax solution is the other side, what is holding the two sides together? (Water molecules.)
2. Is glue a solid or a liquid? (liquid) How about the bouncy ball? (solid)
3. Was this a physical or chemical change? (chemical) How do you know? (it forms a completely new substance)
4. Why does the ball bounce? (The polymer forms a fishnet structure which gives it elasticity)

Lesson #13: Glowing Slime
1. What is the "spaghetti" in this experiment? (sodium tetraborate and glow juice mixture) What is the "sauce"? (glue and water mixed together)
2. What are polymers? (long chains of molecules)
3. Is your slime a solid, a liquid, or a bubbly gas? (Answers will vary. The best slimes have all three states of matter simultaneously: solid chunks suspended in a liquid form with gas bubbles trapped inside!)
4. What causes the glow juice to glow? (it absorbs the UV light and spits out visible light, which appears to glow)

Lesson #14: Bouncy Ball
1. Before the reaction, what was the sodium silicate like? Was it a solid, liquid, or gas? What color was it? Was it slippery, grainy, viscous, etc.? (clear liquid, slippery, viscous)
2. What was the ethanol like before the reaction? (clear liquid, runny)
3. How is the product (the bouncy ball) different from the two chemicals in the beginning? (it forms a temporary ball which bounces, and is white in color)
4. Is the bouncy ball a solid or a liquid? How do you know? (It acts like a solid but is really a liquid because it takes the shape of its container).
5. Was this reaction a physical or chemical change? (chemical change)

Lesson #15: Sewer Slime
1. Describe your slime using as many details as you can. (answers will vary)
2. The guar gum is a polymer. What does this mean? (It is a long chain of molecules)
3. Why did the borax make it look like slime? (It cross-linked all those chains together)
4. Was this a physical or chemical reaction? How do you know? (chemical because it changed two substances into something completely different)

Lesson #16: Hidden CO2
1. How do you know carbon dioxide was inside the chalk, baking soda, and washing soda? (When combined with vinegar, carbon dioxide bubbles were produced.)
2. When the carbon dioxide bubbles popped, where did the carbon dioxide go? (It stayed in the cup as an invisible gas.)
3. What would happen to the chalk if you left it in the vinegar? (It would eventually dissolve.)
4. What is sublimation? (when a substance goes from a gas to a solid)
5. If you completed the bonus experiment, did carbon dioxide weigh more or less than air? How do you know? (Carbon dioxide weighs more because when poured onto the scale it caused that side to lower.)

Lesson #17: Plasma Grape
1. Describe in detail what you observed in the plasma grape experiment. Was there a flame? What color was it? About how high did it go? How long did it last? (answers will vary but should include good details)
2. What are the four types of matter? (solid, liquid, gas, and plasma)
3. The textbook definition of plasma is "an ionized gas." What does this mean in plain English? (gas that has been heated enough so the electrons break free and zoom around)
4. Why do you think it was necessary to make sure there was a bit of skin connecting the two halves of the grape? What do you think happens to the electrons traveling across this "bridge?" (The electrons move across this bridge of skin very quickly until they burst into flame, which is what ionized the air around the grape and caused the plasma to form.)

Lesson #18: Sensing Temperature
1. How did the hot finger feel when it was placed into the room-temperature water? (cold)
2. How did the cold finger feel when it was placed into the room-temperature water? (hot)
3. Based on your observations, what can you infer about how a skin detects temperature? (The skin detects temperature change but not the actual temperature.)
4. After taking a hot shower, a student noticed something interesting. When she put on her glasses and went into the hallway, her glasses fogged up with tiny droplets of water. What was happening? (When she took her warm glasses into the colder hallway, the air around her glasses cooled off, causing the air to change to drops of liquid water.)

Lesson #19: Indoor Rain Clouds
1. Which combination made it rain the best? Why did this work? (The greater the temperature difference, the better this experiment will work. The more water you have, the less the temperature will fluctuate for each glass, thus making it able to rain for longer periods of time.)
2. Draw your experimental diagram here, labeling the different components:
3. Add in labels for the different phases of matter. Can you identify all three states of matter in your experiment? (Ice = solid; water = liquid, gas between two glasses is water vapor, nitrogen, and oxygen.)

Lesson #20: Soaking up Rays

1. How long did it take for the ice cube on black paper to melt? (answers will vary)
2. How long did it take for the ice cube on white paper to melt? (answers will vary)
3. What can you discover about light verses dark colors and the infra-red radiation of the sun based on this experiment? (Light colors reflect the infra-red radiation of the sun, and dark colors absorb it.)
4. What are three ways heat can be transferred? (conduction, convection, and radiation)

Quiz #1

Answer Key

1. Name at least three examples of chemical change. (Heat, color change, bubbles, foam, gel, ooze, cold, etc.)
2. What are crystals? (organized grouping of atoms or molecules that form specific patterns)
3. Why is it necessary to make a supersaturated solid solution to get sugar crystals? (With a normally saturated solution, the sugar crystals would simply dissolve in the water to make hot sugar water. When it cooled, it would make cool sugar water. With a supersaturated solution, the sugar "falls out" of solution as it cools, because it can no longer hold all of the sugar, and crystals are formed.)
4. Was making slime a physical or chemical reaction? How do you know? (chemical because it changed two substances into something completely different)
5. Why does an egg turn "turn to rubber" when placed in vinegar? (the vinegar dissolves the calcium of the egg)
6. What are the four types of matter? (solid, liquid, gas, and plasma)
7. How does a microwave heat things? (It uses electromagnetic waves to heat water molecules.)
8. Which has more density, a plain slice of bread or a squished-up ball of bread? How do you know? (The squished-up ball, because the bread molecules are more tightly packed, taking up less space.)
9. Object A has a mass of 20 grams and a volume of 20 liters. Object B has a mass of 20 grams and a volume of 40 liters. Which has the largest density? Why? (Object A, because the same amount of mass is packed into a smaller area.)
10. A certain liquid has a mass of 30 grams and a volume of 10 milliliters. What is its density? (Density is mass ÷ volume, so $30 \div 10 = 3$ g/mL.)
11. What happens when you mix water and oil? What does this tell you about the density of oil? (They don't mix. The oil stays at the top, so it is less dense.)
12. How does a lava lamp work? (It uses materials that won't mix together—like oil and water—and have slightly different densities.)

Quiz #2

Answer Key

1. How does skin detect temperature? (The skin detects temperature *change* but not the actual temperature.)
2. Why do drops of water form on the outside of a cup of ice water? (The warmer air comes into contact with the cold glass, making the air molecules slow down and form water molecules.)
3. How were you able to make rain clouds? (When hot vapor rose from the hot cup and hit the cold air from the icy cup, the vapor condensed into liquid drops.)
4. Explain the difference between wearing light and dark colors in the sun. What happens to each? (Light colors reflect the infra-red radiation of the sun, and dark colors absorb it.)
5. The textbook definition of plasma is “an ionized gas.” What does this mean in plain English? (gas that has been heated enough so the electrons break free and zoom around)
6. What are polymers? (long chains of molecules)
7. Why is moon sand called a non-Newtonian fluid? (its viscosity changes)
8. What is sublimation? When did you witness this event? (When a substance goes from a gas to a solid. It was seen when vinegar dissolved chalk to make carbon dioxide gas.)

Homework Assignment

Answer Sheet

Part I. Using a periodic table, go on an element hunt. Write the name of each element in the first column, and the symbol of each element in the second column:

Fe	**iron**	zinc	**Zn**
Ni	**nickel**	potassium	**K**
Na	**sodium**	hydrogen	**H**
Ba	**barium**	helium	**He**
O	**oxygen**	fluorine	**F**
Xe	**xenon**	gold	**Au**
W	**tungsten**	mercury	**Hg**
Si	**silicon**	lead	**Pb**
C	**carbon**	neon	**Ne**
S	**sulfur**	nitrogen	**N**

Vocabulary for the Unit

Acids are sour (like a lemon), react with metals, and can burn your skin. They register between 1 and 7 on the pH scale.

An **atom** is the smallest part of stable matter. Atoms are made up of protons and neutrons that are in the center of an atom (the nucleus) and electrons that are moving around outside the nucleus. Atoms differ from one another by how many protons, neutrons, and electrons they have in them.

Bases are bitter (like baking soda), slippery, and can also burn your skin. They measure between 7 and 14 on the pH scale.

A **chemical change** rearranges the molecules and atoms to create new molecule combinations (like a campfire).

Chemists study **chemical kinetics** when they want to control the speed of a reaction as well as what gets generated from the process (the products of the reaction). Several factors affect the speed of a chemical reaction, including catalysts, surface area, temperature, and concentration.

Cleavage in a solid refers to the way in which the crystals break apart, usually in a straight line.

A **combustion reaction** gives off energy, usually in the form of heat and light.

Condensation is the process by which a gas or vapor changes into a liquid.

Chemicals form various **crystal structures** when they freeze. Water is one of the few molecules which expand when changing from a liquid to a solid. Atoms in a solid have a tendency to form **crystals**, since the molecules are pulled close together and tight, causing them to form specific patterns.

Density is a measurement of mass and volume. The denser something is, the tighter its atoms are packed together. Mathematically, density is mass/volume.

Elasticity is the ability of a solid to be stretched, twisted or squashed and come back to its original shape.

Electrons don't orbit nuclei. They pop in and pop out of existence. Electrons do tend to stay at a certain distance from a nucleus. This area that the electron tends to stay in is called a shell. The electrons move so fast around the shell that the shell forms a balloon-like ball around the nucleus.

Elements A substance made up of only one particular kind of atom is called a chemical element, and you can find a whole slew of these on the periodic table. The number assigned to the chemical element refers to the number of protons in the nucleus. There are over 112 elements, 90 of which are found naturally. Twelve different elements are the major ingredients of over 90% of all matter. Five different elements are the major ingredients of all living things.

Endothermic reactions are reactions that absorb heat when they react (like a cold compress).

Exothermic reactions release energy in the form of heat, light, and sound (think fireworks).

Evaporation occurs when a liquid changes into a gas.

Gases have no bonds between the molecules.

The jiggling motion in atoms is called **heat**.

Different **indicators** are used for specific ranges of acids and bases. Phenolphthalein changes from clear to pink when added to a base.

Atoms that have an electrical charge are called **ions**, as they have a different number of electrons than protons.

Liquids have loose, stringy bonds between molecules that hold molecules together but allow them some flexibility.

Mass is a measure of how much matter (how many atoms) make up an object.

Matter is anything that has mass (anything that is affected by gravity). Most matter on our planet is made up of atoms and ions. Not all matter is made up of atoms, but all matter is made up of some kind of particle. Carbon, hydrogen, oxygen, nitrogen, and calcium are the five main elements that make up all living matter.

Changing from a solid to a liquid is called **melting**. Melting point is the temperature at which a material changes from solid to liquid. Objects absorb heat as they melt.

A **molecule** is the smallest unit of a compound that still has the compound's properties attached to it. Molecules are made up of two or more atoms held together by covalent bonds.

A **non-Newtonian** fluid, such as moon sand, is a substance that changes viscosity.

A periodic chart has a bunch of boxes, each representing one element. In each box is a ton of information about each element. In the upper left hand corner of each box is what's called the atomic number. The atomic number is the same as the number of protons in the atom.

pH stands for "power of hydrogen" and is a measure of how acidic a substance is.

A **physical change** happens when the molecules stay the same, but the volume and/or shape change (like wadding up tissue).

Plasma is basically a very high-energy gas. It is not very common on Earth but is the most common state of matter in the universe. Gas becomes plasma when the molecules move about so rapidly that they knock electrons off the atoms when they collide.

Polymers are long chains of slippery molecules. Coagulation happens when you cross-link the chains into a fishnet-looking design.

Radiation is heat transfer through waves.

Different factors affect the **rate of reaction**, or speed of the chemical reaction, including temperature, pressure, surface area, catalysts, and more. The main idea is that the more collisions between particles, the faster the reaction will take place.

Solids are the lowest energy form of matter on Earth. Solids are generally tightly packed molecules that are held together in such a way that they cannot change their position. The atoms in a solid can wiggle and jiggle (vibrate) but they cannot move from one place to another. The typical characteristics that solids tend to have are that they keep their shape unless they are broken and they do not flow.

Materials change from one **state** to another depending on the temperature and these bonds. All materials have given points at which they change from state to state. As objects change state they do not change temperature. The heat that goes into something as its changing phases is used to change the “bonds” between molecules. Freezing points, melting points, boiling points and condensation points are the “speed limits” of the phases. Once the molecules reach that speed, they must change state.

There are five known **states of matter**: Bose-Einstein condensate, solids, liquids, gases and plasma.

Sublimation is the process by which a solid goes directly to a gas.

Tension and **compression** happen when solids are bent. **Tension** is when things get pulled apart. **Compression** is when things get squashed together.