SUPERCHARGED SCIENCE

Unit 8: Chemistry

www.ScienceLearningSpace.com

Appropriate for Grades:
Lesson 1 (K-12), Lesson 2 (K-12)
Duration: 10-25 hours, depending on how many activities you do!

This unit on Chemistry is chocked full of demonstrations and experiments for two big reasons. First, they're fun. But more importantly, the reason we do experiments in chemistry is to hone your observational skills. Chemistry 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 chemistry demonstrations to help you develop your observing techniques.

Table of Contents

Materials for Experiments

We're going to be using real chemicals in this Unit, some of which are corrosive, hazardous, and most are toxic. This Unit is NOT for small children or households with loose pets (so stick Rover outside while you work). As you gather your equipment for this section, please keep ALL chemicals out of reach and sealed until you need them. We'll show you how to safely store, mix, and clean up your chemicals. You can order all your chemicals from the same supplier (links provided below). We'll be using this chemistry set for the rest of the year.

Make sure you have **goggles and gloves** for all experiments, and protect your table (put it near a window for good ventilation) with a thick plastic tablecloth. You'll be using **clear, disposable plastic cups and popsicle sticks** to do your experimenting, so grab a box of each to last the entire year.

Acids & Bases

- Red cabbage
- Strainer or colander
- Blender (or stove and sauce pan)
- Liquids/solids to test (OJ, milk, baking soda, etc.)

Bouncy Balls

- Sodium Silicate (from Unit 3)
- Ethyl Alcohol (check your pharmacy)

Best Slime

- Clear glue
- Yellow highlighter pen
- Chemicals from *Chemical Kinetics* (see below)

Chemical Kinetics

- four empty water bottles, four balloons, steel wool, vinegar, water, salt
- Advanced Chemistry Kit

All experiments in this unit use chemicals from this kit. Check the eScience website for the order link to the set we recommend using.

- OPTIONAL: Glassware Set

If you don't already own glassware just for chemistry, we've found an inexpensive set you can use all the way through college. (Or use an old set of kitchen glassware.)

For Grades 9-12:

- Advanced Chemistry Kit

  All experiments in this unit use chemicals from this kit. Check the eScience website for the order link to the set we recommend using.

- OPTIONAL: Glassware Set

  If you don't already own glassware just for chemistry, we've found an inexpensive set you can use all the way through college. (Or use an old set of kitchen glassware.)

Iodine Rainbow

- Iodine (clear, non-ammonia)
- Hydrogen peroxide (3% solution)
- Vinegar (distilled white is best)

Copper to Silver to Gold

- Sodium Hydroxide
- Zinc Powder
- Table salt (a few tablespoons)
- Vinegar (about a cup)
- Pennies (minted after 1982)
- Metal Tongs (not included in the glassware set, so pick up a pair)
- Beaker and Burner with Stand (both of these are included in the glassware set mentioned above)

Can I use my kitchen glassware?

NO. Use either disposable plastic cups or glassware specifically designated for chemistry. Lots of chemicals will adhere to the glass and need to be etched off in order to get it 'clean' again. Don't take chances…everything that comes in contact with a chemical – including the measuring spoons – is now part of your chemistry set

Note: See the eScience website for order links for most of the items listed here.

Key Vocabulary

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

Atoms are made of a core group of neutrons and protons, with an electron cloud circling the nucleus.

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.

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.

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

Splitting the water molecule into parts (hydrogen and oxygen) requires power (**electrolysis**) to break the bonds.

Thin layers of metal can be moved from one object to another using the **electroplating** technique.

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

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.

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

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

Unit Description

This unit on Chemistry is chocked full of demonstrations and experiments for two big reasons. First, they're fun. But more importantly, the reason we do experiments in chemistry is to hone your observational skills. Chemistry 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 chemistry demonstrations to help you develop your observing techniques.

In most standard chemistry lessons, a teacher walks in and says, "Now I will demonstrate the insolubility of barium sulfate by mixing equal volumes of zero point one molar barium chloride and zero point one molar sodium sulfate and observe what happens." *Anyone still awake?*

In this unit, you'll be mixing up things that bubble, ooze, slither, spit, change color, crystallize, and fizz. (I think there's even one that belches.) And rather than announcing things in a dull and boring fashion, I'm just going to outline the steps and ask YOU to notice any and all changes, no matter how strange or weird. Or small. Even a tiny temperature difference can indicate something big is about to happen.

A Note about Safety

A lot of folks get nervous around chemistry. You can't always 'see' what's going on (are there toxic gases generated from that reaction?), and many people have a certain level of fear around chemicals in general. Dr. Walker, a professor of physics at Cleveland State Univseriity (and the editor of *Scientific American*), states that *"The way to capture a student's attention is with a demonstration where there is a possibility that the teacher may die."*

I don't want you dipping your hands in molten lead or lying on a bed of nails while someone with a sledgehammer breaks a cinder block on your stomach. (It turns out that Dr. Walker has been injured multiple times, mostly through accidents.)

I strongly disagree with his approach – demonstrations of this kind that result in injury are the ones forever burned in the memory of the audience, who are now fearful and have made the generalization that chemicals are dangerous and their effects are bad. In fact, every chemical is potentially harmful if not handled properly. That is why I've prepared a special set of chemistry experiments that include step-by-step demonstrations on how to properly handle the chemicals, use them in the experiment, and dispose of them when you're finished.

Chemistry is predictable, just as dropping a ball from a height always hits the floor. Every time you add 1 teaspoon of baking soda to 1 cup of vinegar, you get the same reaction. It doesn't simply stop working one time and explode the next. I'm going to walk you through every step of the way, and leave you to observe the reactions and write down what you notice. At first, it's going to seem like a lot of disjointed ideas floating around, but after awhile, you'll start to see patterns in the way chemicals interact with each other. It's just like anything else that you try for the first time – you're not very good when you're new at it. Keep working at Chemistry and eventually it will click into place. And if there's an experiment you don't want to do, just skip it (or just watch the video).

One of the best things you can do with this unit is to take notes in a journal as you go. Snap photos of yourself doing the actual experiment and paste them in alongside your drawing of your experimental setup. This is the same way scientists document their own findings, and it's a lot of fun to look back at the splattered pages later on and see how far you've come. I always jot down my questions that didn't get answered with the experiment across the top of the page so I can research it more later. Are you ready to get started?

Objectives

Lesson 1: Molecules

By studying tiny bits of matter called atoms, you can figure out why chemicals do what they do – some explode when they touch water (like cesium), while other just sit there for years (like a twinkie). Some chemicals are particularly nasty, like sodium (which explodes on contact with water) and chlorine (which is lethal). but when you combine these two together, you get table salt. So what gives?

If you've ever wondered *why* two hydrogen stick to an oxygen to form water, then you're in the right place. Let's start by taking a look at the highlights for understanding molecules, atoms, and the tiny universe inside matter.

Highlights:

- Atoms are made of a core group of neutrons and protons, with an electron cloud circling the nucleus.
- The jiggling motion in atoms is called heat.
- 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.
- Endothermic reactions are reactions that absorb heat when they react (like a cold compresses).
- Exothermic reactions release energy in the form of heat, light, and sound (think fireworks).
- A physical change happens when the molecules stay the same, but the volume and/or shape change (like wadding up tissue).
- A chemical change rearranges the molecules and atoms to create new molecule combinations (like a campfire).
- Acids are sour (like a lemon), react with metals, and can burn your skin. They register between 1 and 7 on the pH scale.
- Bases are bitter (like baking soda), slippery, and can also burn your skin. They measure between 7 and 14 on the pH scale.

Objectives

Lesson 2: Chemical Kinetics

By figuring out how to change the speed a reaction takes place as well as what gets created in the process, you can get a better handle at creating the things you want.

We're going to learn why fish don't drown, create glowing slime, turn water into ink you can really write with, make a solution that appears by breathing on it, how to create rubber-like bouncy balls out of clear liquid, shake up a rainbow of colors, learn how to get a lemon to light up a light bulb, and discover what fire really is made of.

It all comes down to controlling the reaction and figuring out what you want to get out of the process. Are you ready?

Highlights:

- Different indicators are used for specific ranges of acids and bases. Phenolphthalein changes from clear to pink when added to a base.
- Splitting the water molecule into parts (hydrogen and oxygen) requires power (electrolysis) to break the bonds.
- Thin layers of metal can be moved from one object to another using the electroplating technique.
- Chemists 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.
- Polymers are long chains of slippery molecules. Coagulation happens when you cross-linking the chains into a fishnet-looking design.

Textbook Reading

Matter

Why study chemistry? Baking is chemistry. Cars use chemistry to zip down the street. Your body converts food into energy using chemistry. Everything you see, touch, taste, and smell is a chemical.

Studying chemistry is like peeking under the hood of a racecar – you know you put gas in and it goes, but that's all you can tell from the outside. Chemistry gets you into the inner workings on the molecular level.

Soon you'll be able to explain everyday things, like why baking soda and vinegar bubble, why only certain chemicals grow crystals, what fire really is made of, how to transform copper into gold, and how to make cold light. Once you wrap your head around these basic chemistry ideas (like acids, polymers, and kinetics), you can make better choices about the products you use everyday like pain relievers, cold compresses, and getting a loaf of bread to rise.

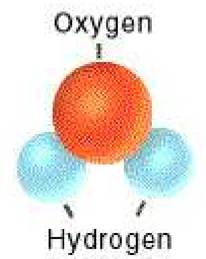
What is stuff made of?

Let's find out by using a thought experiment (Einstein called these "gedanken experiments" – he really hated to *do* experiments, and would rather just *think* about them instead).

Suppose we have a drop of water. If we look at it very closely, we'll see a drop of water, nice and smooth. If we grab a microscope and magnify it roughly 2,000 times (the drop is now 40 feet across, the size of a large classroom) and look very closely, we'll still see relatively smooth water, but there are wiggly things floating around (paramecia). We could stop here and study these interesting little critters, but then we'd sidetrack ourselves into biology. So let's focus more on the water.

Let's magnify the water 2,000 times again, so it's roughly 15 miles across. When we look at it very closely now, we see what looks like a teeming mob of Super Bowl fans making their way to the nearest exit. There's lots and lots of movement, but it's still fuzzy and hard to make out. Now we'll magnify it another 250 times (total magnification of 1 billion times), and we'll see two kinds of "blobs":

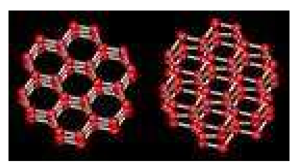
hydrogen atoms and oxygen atoms arranged in a little group like an upside-down Mickey Mouse (image right). Each little group of these atoms is called a *molecule.*



This picture on the right is idealized in a few ways, but most important is that the picture of the molecule doesn't move on the page, whereas the real molecule wiggles and jiggles as we watch it magnified 1 billion times. Another way this picture is not quite right is that it looks as if the atoms are really stuck together like glue, much the same way magnets attract each other. But unlike magnets, if you squeeze these atoms together too hard, they repel each other.

So the molecules dance and jiggle around all the time, and the jiggling motion is what we call *heat*. When we increase the temperature (say, by putting a pot full of water on a hot stove), the jiggling increases, and the volume between the atoms also increases. When enough energy (from the gas flame on the stove) is pumped into the water molecules, they dance around so much that they jiggle themselves free and zoom into the air (as steam).

Suppose we decrease the temperature of our water. Now we find that the jiggling motion decreases and the attractive force between the atoms takes over, and at very low temperatures, the atoms lock together into a new pattern called ice. The interesting thing is that there is a place for every atom in its solid form (a crystalline array). Water is one of only a few molecules to expand when solidified. You can see that each of the crystal structures has a big hole in the center, making it larger when it's a solid. The crystal pattern of ice is shown at right — it has many holes in it.



This open structure collapses when the atoms jiggle hard enough to shake themselves loose (*melting*) and rush to fill in the gaps as the temperature (and jiggling) increases. So the water shrinks when it turns into a liquid.

How big is an atom? If an apple were magnified to the size of the earth, the size of the atoms in the apple would be the size of the original apple. Look out over the horizon and imagine you're walking along not on the surface of the earth, but on the surface of a gigantic apple. The size of an apple atom is now about the size of your fist.

How far away is the electron from the nucleus? The distance from the electron to the nucleus is very great. If you further magnified the atom itself, so that now the atom (say, a hydrogen atom) were magnified to the size of the earth, the nucleus (in this case, only one proton) would be only about the size of a basketball at the center of the earth — and the electron would be found somewhere in earth's atmosphere.

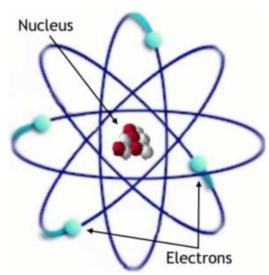
What is an Atom?

We've covered this stuff before, but let's review for a moment, as it's probably been a little while since we tackled these ideas together. Are you ready?

My definition of an atom is the smallest part of stable matter. There are things smaller than an atom, but they are unstable. (Not like my Aunt Edna is unstable but rather like they can't be around for long on their own.) Atoms are very stable and can be around for long, long, long periods of time. Atoms rarely hang out on their own though. They are outgoing little fellows, on the whole, and love to get together in groups. These groups of atoms are called molecules. A molecule can be made of anywhere from two atoms to millions of atoms. Together these atoms make absolutely everything.

All matter is made of atoms. Shoes, air, watermelons, milk, wombats, you, everything is made of atoms. Hundreds, and billions, and zillions of atoms make up everything. When you fly your kite, it's atoms moving against the kite that keep it in the air. When you float in a boat, it's atoms under your boat holding it up.

What's Inside an Atom?

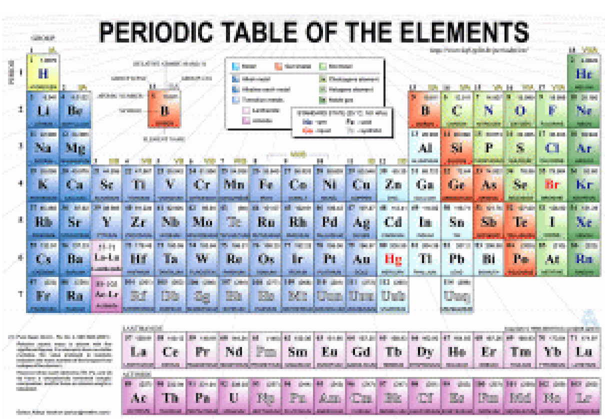


Atoms are made up of bunches of particles, but we will concern ourselves with only three of those particles for now. Atoms are made of protons, neutrons, and electrons. The protons and the neutrons make up the nucleus (the center) of the atom.

The electron wanders around outside the nucleus and, as we'll see next lesson, is a wacky little fellow. Protons and neutrons are made up of smaller little particles, which are made of smaller little particles and so on. Atoms can have anywhere from only one proton and one electron (a hydrogen atom) to over 300 protons, neutrons and electrons in one atom. It is the number of protons that determines the kind of atom an atom is, or in other words, the kind of element that atom is. We'll talk more about elements in a bit.

Here science does us a bit of a favor since it's relatively easy to tell how many electrons, protons, and neutrons are in an atom. The number of protons, basically tells you how many neutrons and electrons are in the atom. If an atom has 4 protons, it probably has 4 neutrons and 4 electrons. I say probably because in the world of atoms you can never be completely sure. These guys do some wacky stuff. Protons and electrons are usually equal in an atom. The number of protons and neutrons are not necessarily equal in some of the larger atoms.

So how do you know how many protons are in an atom? Look at the periodic chart.



A periodic chart has a bunch of boxes. Each box represents 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.

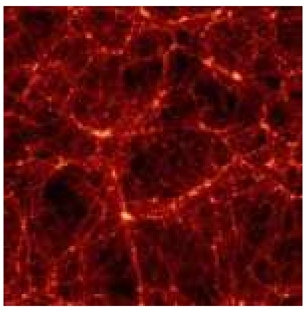
Once you know that, you know the probable number of electrons and neutrons in that atom! To the right you see how oxygen would look in a periodic table. The atomic number is eight so you know there are eight protons, neutrons and electrons. Isn't it nice when nature makes things simple?

We will talk more about this in future lessons but just to let you know, protons have a positive charge, neutrons have no charge, and electrons have a negative charge. Atoms like to be electrically neutral so that's why the number of protons and electrons tend to be equal. Ten positive protons plus ten negative electrons equals zero net electrical charge. A neutral atom. An atom that is not neutral is called an ion.

(You can read more about elements and electron shells in Unit 3: Matter.)

Different States of Matter

Now, that you've spent some quality time with atoms and that wacky electron fellow you have a bit of an understanding of what is inside everything. The next thing you need to know is...*what's everything?*



Everything is matter. Well, except for energy, but that's everything else (and we'll get to that later). Everything you can touch and feel is matter. It is made up of solid (kind of) atoms that combine and form in different ways to create light poles, swimming pools, poodles, jello and even the smell coming from your pizza.

Traditionally, there have been three states of matter. State of matter means the way the atoms tend to hang out together. Not to be confused with a state like Utah, Wyoming, or confusion. The three states are solids, liquids and gases. However, leave it up to a science teacher to tell you that that's not the whole story.

There are two more states of matter. They are *plasma* and (are you ready for this next one?) the *Bose-Einstein condensate*. I'm just going to spend a little bit of time talking about these last two states of matter since they are both pretty uncommon on Earth.

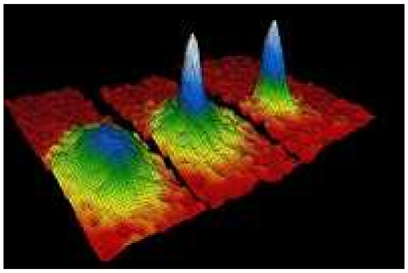
Plasma

Believe it or not, plasma makes up a very large percentage of the matter in the universe. Are you wondering how come you've never heard of it before? (By the way, blood plasma is different from this stuff, and a good thing too!) Plasma doesn't have a definite shape or volume.

Well, there is very little of it on Earth and the plasma that is here is very short lived or stuck in a tube. Plasma is basically ionized gas or in other words it is gas that is electrically charged. The stuff in florescent light bulbs is plasma. Plasma TV's have plasma (go figure) inside of them. Lightning and sparks are actually plasma! Would you like to see some plasma right now? Then try the Plasma Grape Experiment in Unit 3!

Bose-Einstein Condensate

Now let's talk a bit about the Bose-Einstein condensate or the BEC if you want to be hip. Each form of matter corresponds with a level of energy. Plasma is the highest energy state of matter. So energetic, in fact, that it can give off light. BEC is the lowest energy state of matter.



In fact, BEC only happens at energy levels that are almost as low as possible. Basically temperature is a measurement of energy. The higher the temperature, the higher the energy of something and vice-versa. Theoretically the coldest anything can ever get is 0 degrees Kelvin, (the same as -273 degrees Celsius, or -459 degrees Fahrenheit). This temperature is called absolute zero. At absolute zero, there is no energy and no atomic movement. Space is 3 degrees Kelvin. (We'll get deeper into this concept when we get to the thermal energy lessons.)

Scientists have discovered that if you get certain types of atoms cold enough (less than one millionth of a degree above absolute zero) you get this bizarre thing called a Bose-Einstein condensate. When the atoms get that cold they move so slowly that they kind of blend together into one big atomic mush. Satyendra Nath Bose and Albert Einstein predicted that this state of matter existed in 1924. Seventy one years later in 1995, two scientists at the University of Colorado using magnets and lasers made it happen.

Solids

So now that we've gotten those bizarre states of matter out of the way, let's talk about some stuff that really matters (haha... couldn't resist at least one pun). Something to keep in mind is that everything is made of the same stuff, atoms. What makes the solids, liquids, gases etc. different is basically the energy (motion) of the atoms. From BEC, where they are so low energy that they are literally blending into one another, to plasma, where they are so high energy they can emit light. Solids are the lowest energy form of matter that exist in nature (BEC only happens under laboratory conditions).

In solids, the atoms and molecules are bonded (stuck) together in such a way that they can't move easily. They hold their shape. That's why you can sit in a chair. The solid molecules hold their shape and so they hold you up. The typical characteristics that solids tend to have are they keep their shape unless they are broken and that they do not flow. Let's take a look at a couple of terms that folks use when talking about solids. Click here to read more about solids.

Liquids

A liquid has a definite volume (meaning that you can't compress or squish it into a smaller space), but takes the shape of its container. Think of a water-filled balloon. When you smoosh one end, the other pops out. Liquids are generally incompressible, which is what hydraulic power on heavy duty machinery (like excavators and backhoes) is all about.

Gases

A gas doesn't have a definite volume or shape. You can squish it, expand it, or shove it into a hole and it'll happily go there. Gases you are already familiar with are air (nitrogen and oxygen), helium (in balloons), and neon (the red OPEN signs in stores). There's also xenon (in photography flash lamps), argon (in fire extinguishers and incandescent light bulbs), and krypton (used in high-speed photography flash lamps and by astronomers for measuring stars).

What is an acid?

When dissolved in water, an acid has more hydrogen ions than regular water and a pH lower than 7.0. Generally, acids are sour in taste, change pH indicators red or pink, react with metals to produce a metal salt and hydrogen, react with bases to produce a salt and water, and conduct electricity. Strong acids often produce a stinging feeling on mucus membranes.

What is pH?

pH stands for "power of hydrogen" and is a measure of how acidic a substance is. We can make homemade indicators to test how acidic (or basic) something is by squeezing out a special kind of juice (dye) called anthocyanin. Certain flowers have anthocyanin in their petals, which can change color depending on how acidic the soil is (hibiscus, hydrangeas, and marigolds for example). The more acidic a substance, the more red the indicator will become. We'll be making several different indicators in our experiments soon.

Polymers

When you think of slugs, snails, and puppy kisses, what texture do you imagine? Is it sticky, slithery, or slippery? Any way you picture it, slime is just plain icky — and a perfect forum for learning about polymers.

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 (called polymers) don't clump together until you add the sauce - something that cross-links the molecule strands (polymer) together.

If you've ever mixed together cornstarch and water, you know that you can get it to be both a liquid and a solid at the same time. (If you haven't you should definitely try it! Use a 2:1 ratio of cornstarch:water.) The long molecular chains (polymers) are all tangled up when you scrunch them together (and the thing feels solid), but the polymers are so slick that as soon as you release the tension, they slide free (and drips between your fingers like a liquid).

Scientists call this a non-Newtonian fluid. You can also fill an empty water bottle or a plastic test tube half-full with this stuff and cap it. Notice that when you shake it hard, the slime turns into a solid and doesn't slosh around the tube. When you rotate the tube slowly, it acts like a liquid.

Reaction Rates

Chemical kinetics is the study of the speed that stuff happens on a molecular level that controls reaction rate and the products we get out of the reaction. Why do we want to control the speed of a reaction? Think of air pollution. If we could control the reaction rate of the ozone depletion, we could control the problem better.

Chemical reactions can happen slowly (think of a boat on the ocean rusting away) or quickly (like an explosion). The speed of the reaction depends on a lot of different things, including the temperature, how much of each chemical used, whether the chemicals are powdered or solid chunks, and other things like that.

We are going to learn how to control the rate of a reaction so we can direct what comes out the other end. If we figure out what has the greatest effect on the reaction speed, then we can use that to hurry up or slow down the process. (You wouldn't want your car to rust in the rain overnight, would you?) Let's take a look at what affects the reaction rates:

A catalyst is something you add to a mixture and the only thing it affects is the speed. It doesn't get used in the process, so it's completely recoverable. For example, hydrogen peroxide normally decomposes (transforms) on its own into water and oxygen, but it does this very slowly.

If you toss a chunk of carbon (like charcoal or graphite) into a water bottle filled with hydrogen peroxide, you'll see oxygen bubbles forming, which tells you that this reaction is going along much quicker than usual. If you clamp a balloon onto the neck of the bottle, you'll get a balloon full of pure oxygen. The carbon will still be there next week in the same amounts, as none of it reacted with the peroxide. That's what a catalyst is all about. It changes the speed of the reaction without getting used up.

Do you think surface area matters? It sure does! If you try to ignite a pile of flour, it will sit there and burn. However, if you blow a fine mist over a candle flame, it will explode with a flash (you don't have to do this one at home – it's on video for you!) The more surface area you expose to react, the faster the reaction will occur. This is why we dissolve chemicals (reactants) in a solvent (liquid, usually water), so the particles are fully exposed to interact with each other.

If you have a cup of vinegar, does it matter how much baking soda you add? Sure it does! If you only sprinkle in a tiny bit, you'll get only a few bubbles surfacing. However, if you dump the whole box in there, you'd better get the mop. The more chemical you use, the more it's going to react. A bottle of 50% rubbing alcohol is actually half water, while a 91% rubbing alcohol solution is mostly alcohol (so if you're using the 50% alcohol solution in our Burning Money experiment, you'll need to omit the water, as it's already included in the bottle).

Electrochemistry

If you guessed that this has to do with electricity and chemistry, you're right! But you might wonder how they work together. Back in 1800, William Nicholson and Johann Ritter were the first ones to split water into hydrogen and oxygen using electrolysis. (Soon afterwards, Ritter went on to figure out electroplating.) They added energy in the form of an electric current into a cup of water and captured the bubbles forming into two separate cups, one for hydrogen and other for oxygen.

But how did they know which bubbles were which? You can tell the difference between the two by the way they ignite (don't' worry – you're only making a tiny bit of each one, so this experiment is completely safe to do with a grown up).

It takes energy to split a water molecule. (On the flip side, when you combine oxygen and hydrogen together, it makes water and a puff of energy. That's what a fuel cell does.) Back to splitting the water molecule - as the electricity zips through your wires, the water molecule breaks apart into smaller pieces: hydrogen ions (positively charged hydrogen) and oxygen ions (negatively charged oxygen). Remember that a battery has a plus and a minus charge to it, and that positive and negative attract each other.

So, the positive hydrogen ions zip over to the negative terminal and form tiny bubbles right on the wire. Same thing happens on the positive battery wire. After a bit of time, the ions form a larger gas bubble. If you stick a cup over each wire, you can capture the bubbles and when you're ready, ignite each to verify which is which.

Activities, Experiments, Projects

Lesson 1: Molecules

Note: This section is an abbreviated overview of the experiments online.

Experiment: Chemical Matrix

If you love the idea of mixing up chemicals and dream of having your own mad science lab one day, this one is for you. You are going to mix up each solid with each liquid in a chemical matrix.

In a university class, one of the first things you learn in chemistry is the difference between physical and chemical changes. An example of a physical change happens when you change the shape of an object, like wadding up a piece of paper.

If you light the paper wad 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 the light sticks used around Halloween), or 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.

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!

Materials:

- sodium tetraborate (borax, laundry aisle): solid
- sodium bicarbonate (baking soda, baking aisle): solid
- sodium carbonate (washing soda, laundry aisle): solid
- calcium chloride: solid
- citric acid (spice section): solid
- ammonium nitrate (single-use disposable cold pack): solid
- isopropyl rubbing alcohol: liquid

• hydrogen peroxide: liquid

• acetic acid (distilled white vinegar): liquid

• water: liquid

• liquid dish soap (add to water): liquid

• muffin tin or disposable cups

• popsicle sticks for stirring and mixing

• tablecloths (one for the table, another for the floor)

• head of red cabbage (indicator)

Cover your kitchen table with a plastic tablecloth (and possibly the floor). Place your chemicals on the table. A set of muffin cups make for an excellent chemistry experiment lab. (Alternatively, you can use empty plastic ice cube trays.) You will mix in these cups. Leave enough space in the cups for your chemicals to mix and bubble up — don't fill them all the way when you do your experiments!

Set out your liquid chemicals in easy-to-pour containers, such as water bottles (be sure to label them, as they all will look the same): alcohol, hydrogen peroxide, water, acetic acid, and dish soap (mixed with water). Set out small bowls (or zipper bags if you're doing this with a crowd) of the powders with the tops of your water bottles as scoopers. The small scoopers regulate the amounts you need for a muffin-sized reaction. Label the powders, as they all look the same.

Although these chemicals are not harmful to your skin, they can cause your skin to dry out and itch. Wear gloves (latex or similar) and eye protection (safety goggles), and if you're not sure about an experiment or chemical, just don't do it. (Skip the peroxide and cold pack if you have small kids.)

Prepare the indicator by coarsely chopping the head of red cabbage and boiling the pieces for five minutes in a pot full of water. Carefully strain out all the pieces with a fine-mesh strainer; the reserved liquid is your indicator (it should be blue or purple).

When you add this indicator to different substances, you will see a color range: hot pink, tangerine orange, sunshine yellow, emerald green, ocean blue, velvet purple, and everything in between. Test out the indicator by adding drops of cabbage juice to something acidic, such as lemon juice, and see how different the color is when you add indicator to a base, such as baking soda mixed with water.

Have your indicator in a bottle by itself. An old soy sauce bottle with a built-in regulator that keeps the pouring to a drip is perfect. You can also use a bowl with a bulb syringe, but cross-contamination could be a problem. Or it could not be — depending on whether you want the kids to see the effects of cross-contamination during their experiments. (The indicator bowl will continually turn different colors throughout the experiment.)

Start mixing it up! When I teach this class, I let them have at all the chemicals at once (even the indicator), and of course, this leads to a chaotic mix of everything. When the chaos settles down, and they start asking good questions, I reveal a second batch of chemicals they can use. (I have two identical sets of chemicals, knowing that the first set will get used up very quickly.)

After the initial burst of enthusiasm, your kids will instinctively start asking better questions. They will want to know why their green goo is creeping onto the floor while someone else's just bubbled up hot pink, seemingly mixed from the same stuff. Give them a chance to figure out a more systematic approach, and ask if they need help before you jump in to assist.

What's happening with the indicator? An indicator is a compound that changes color when you dip it in different things, such as vinegar, alcohol, milk, or baking soda mixed with water. There are several extracts you can use from different substances. You'll find that 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?) You'll need to get the anthocyanin out of the cabbage and into a more useful form so you can use it as a liquid indicator.

Tip for Testing Chemical Reactions: Periodically hold your hand under the muffin cups to test the temperature. If it feels hot, it's an exothermic reaction (giving off energy in the form of heat, light, explosions …). The chemical-bond energy is converted to thermal energy (heat) in these experiments. If it feels cold, you've made an endothermic reaction (absorbing energy, where the 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).

Variations for the Indicator: Red cabbage isn't the only game in town. You can make an indicator out of many other substances, too. Here's how to prepare different indicators:

- Cut the substance into smaller pieces. Boil the chopped substance for five minutes. Strain out the pieces and reserve the juice. Cap the juice (indicator) in a water bottle, and you're ready to go.
- What different substances can you use? We've had the best luck with red cabbage, blueberries, red and green grapes, beets, cherries, and turmeric. You can make indicator paper strips using paper towels or coffee filters. Just soak the paper in the indicator, remove and let dry. When you're ready to use one, dip it in partway so you can see the color change and compare it to the color it started out with.
- Use the indicator both before and after you mix up chemicals. You will be surprised and dazzled by the results!

Teaching Tips: You can make this lab more advanced by adding a postage scale (to measure the solids in exact measurements), small beakers and pipettes for the liquid measurements, and data sheets to record temperature, reactivity, and acid/base indicator levels. (Hint: Make the data sheet like a matrix, to be sure you get all the possible combinations.)

Activities, Experiments, Projects

Lesson 2: Chemical Kinetics

Note: This section is an abbreviated overview of the experiments online.

Experiment: Glowing Slime

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 real science.

But which ingredients work in making a truly slimy concoction, and why do they work? Let's take a closer look…

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.

To make this slime, combine ½ cup of water with 1 teaspoon of sodium tetraborate (also known as 'Borax') in a cup and stir with a popsicle stick.

In another cup, mix equal parts white glue and water. Add a glob of the glue mixture to the sodium tetraborate mixture. Stir for a second with a popsicle stick, then quickly pull the putty out of the cup and play with it until it dries enough to bounce on the table (3 to 5 minutes). Pick up an imprint from a textured surface or print from a newspaper, bounce and watch it stick, snap it apart quickly and ooze it apart slowly …

To make glowing slime, add one simple ingredient to make your slime glow under a UV light (or in sunlight)! You'll need to extract the dye from the felt of a bright yellow highlighter pen and use the extract instead of water. (Simply cut open the pen and let water trickle over the felt into a cup: instant glow juice.) For the best slime results, substitute clear glue or glue gel for the white glue.

Don't forget: You'll need a long-wave UV source (also known as a "black light") to make it glow (fluorescent lights tend to work better than incandescent bulbs or LEDs). This slime will glow faintly in sunlight, because you get long-wave UV light from the sun — it's just that you get all the other colors, too, making it hard to see the glow.

Is your slime a solid, a liquid, or a bubbly gas? The best slimes we've seen have all three states of matter simultaneously: solid chunks suspended in a liquidy form with gas bubbles trapped inside. Yeeccccch!!

What other stuff glows under a black light? Loads of stuff! There are a lot of everyday things that fluoresce (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), which is why "black lights" were named that. 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. (More on this in Unit 9.)

Exercises

Lesson 1: Molecules

1. What does **endothermic** mean? (a) the study of bugs (b) when a chemical reaction gives off heat (c) when a chemical reaction absorbs heat (d) the study of chemical reactions

2. Why does red cabbage work to indicate acid or bases?

3. Where can you find acetic acid in your house right now?

4. Turmeric needs to be mixed with what before it can be used as an indicator? (a) hydrogen peroxide (b) rubbing alcohol (c) acetic acid (d) cold water

5. When the red cabbage indicator is added to acetic acid, it turns (a) pink (b) blue (c) green (d) purple (e) yellow

6. What happens when you heat up your cobalt chloride painting?

7. In the electrolysis experiment, which gas gives you the "POP!" ? (a) hydrogen (b) oxygen (c) nitrogen (d) sulfur hexafluoride

8. If you splash chemicals in your eyes, what is the first thing you should do? (a) put on your safety goggles (b) scream (c) rinse with running water, like from the sink or hose (d) call poison control

9. If your dog accidentally eats your chemicals, what should you do? (a) lock him up (b) take him to the vet (c) call poison control (d) palpate his abdomen

10. Which of these are chemical changes? (a) setting a wad of paper on fire (b) chewing gum (c) eating raisins (d) initializing a cold pack

11. Which of these are physical changes? (a) light sticks (b) splashing in a puddle (c) drinking water (d) making slime

Exercises

Lesson 2: Chemical Kinetics

1. What are the most toxic chemicals in this unit? (a) sodium ferrocyanide & ferric ammonium sulfate (b) calcium hydroxide & calcium chloride (d) ammonium nitrate & copper sulfate (d) dihydrogen monoxide & sodium chloride

2. What's true about phenolphthalein? (a) it goes from clear to pink when mixed with bases (b) it's impossible to spell (c) it is colorless in acidic solutions (d) soluble in water

3. Sodium ferrocyanide (a) can create a lethal gas if misused (b) should be handled with care (c) is only used once in this entire manual (d) should never be mixed with anything other than ferric ammonium sulfate

4. Which food do you expect to give the highest voltage for the fruit battery?

5. What else can you use for the copper strip in the electroplating experiment? (a) copper pipe (b) copper flashing (c) steel pipe (d) galvanized nails

6. How does increasing the hydrogen peroxide affect the rate of the iodine clock reaction?

7. Why does hydrogen peroxide come in dark bottles?

8. Which chemical turns coldest when added to water? (a) calcium chloride (b) aluminum sulfate (c) ammonium nitrate (d) citric acid

9. A polymer is: (a) a long piece of spaghetti (b) an element on the periodic table (c) a long molecular chain (d) a plastic bag

10. What does a cross-linking agent do?

11. Which of the following are cross-linking agents? (a) calcium (b) borax (c) white glue (d) starch (e) bubble gum

12. Which substance is both a solid and a liquid? (a) bubble gum (b) slime (c) cornstarch and water (d) last night's dinner

Answers to Molecules Exercises

1. What does **endothermic** mean? (a) the study of bugs (b) when a chemical reaction gives off heat **(c) when a chemical reaction absorbs heat** (d) the study of chemical reactions

2. Why does red cabbage work to indicate acid or bases? **Red cabbage contains a naturally occurring indicator, anthocyanin. Anthocyanin is what gives leaves, stems, fruits, and flowers their colors**.

3. Where can you find acetic acid in your house right now? **In the cabinet in a bottle labeled 'distilled white vinegar'.**

4. Turmeric needs to be mixed with what before it can be used as an indicator? (a) hydrogen peroxide **(b) rubbing alcohol** (c) acetic acid (d) cold water

5. When the red cabbage indicator is added to acetic acid, it turns **(a) pink** (b) blue (c) green (d) purple (e) yellow

6. What happens when you heat up your cobalt chloride painting? **A concentrated solution of cobalt chloride is red at room temperature, blue when heated, and pale-to-clear when frozen.**

7. In the electrolysis experiment, which gas gives you the "POP!" ? **(a) hydrogen** (b) oxygen (c) nitrogen (d) sulfur hexafluoride

8. If you splash chemicals in your eyes, what is the first thing you should do? (a) put on your safety goggles (b) scream **(c) rinse with running water, like from the sink or hose** (d) call poison control

9. If your dog accidentally eats your chemicals, what should you do? (a) lock him up (b) take him to the vet **(c) call poison control** (d) palpate his abdomen

10. Which of these are chemical changes? **(a) setting a wad of paper on fire** (b) chewing gum (c) eating raisins **(d) initializing a cold pack**

11. Which of these are physical changes? (a) light sticks **(b) splashing in a puddle (c) drinking water** (d) making slime

Answers to Chemical Kinetics Exercises

1. What are the most toxic chemicals in this unit? **(a) sodium ferrocyanide & ferric ammonium sulfate** (b) calcium hydroxide & calcium chloride (d) ammonium nitrate & copper sulfate (d) dihydrogen monoxide & sodium chloride (this one is the chemical name for water and salt)

2. What's true about phenolphthalein? **(a) it goes from clear to pink when mixed with bases (b) it's impossible to spell (c) it is colorless in acidic solutions** (d) soluble in water

3. Sodium ferrocyanide **(a) can create a lethal gas if misused (b) should be handled with care (c) is only used once in this entire manual (d) should never be mixed with anything other than ferric ammonium sulfate**

4. Which food do you expect to give the highest voltage for the fruit battery? **Very sour lemons.**

5. What else can you use for the copper strip in the electroplating experiment? **(a) copper pipe (b) copper flashing** (c) steel pipe (d) galvanized nails

6. How does increasing the hydrogen peroxide affect the rate of the iodine clock reaction? **By accelerating the first reaction, you can shorten the time it takes the solution to change color. There are a few ways to do this: You can decrease the pH (increasing H+ concentration), or increase the iodide or hydrogen peroxide. (To lengthen the time delay, add more sodium thiosulfate.)**

7. Why does hydrogen peroxide come in dark bottles? **Because it reacts with sunlight to turn into water and oxygen.**

8. Which chemical turns coldest when added to water? (a) calcium chloride (b) aluminum sulfate **(c) ammonium nitrate** (d) citric acid

9. A polymer is: (a) a long piece of spaghetti (b) an element on the periodic table **(c) a long molecular chain** (d) a plastic bag

10. What does a cross-linking agent do? **Coagulates the polymers.** (**Turns the long polymer chains into something that looks more like a fishnet.)**

11. Which of the following are cross-linking agents? (a) calcium **(b) borax** (c) white glue (d) starch (e) bubble gum

12. Which substance is both a solid and a liquid? (a) bubble gum (b) slime **(c) cornstarch and water** (d) last night's dinner

