The Molecules Around Us

a mini-course designed by

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Abstract

The behavior of molecules can help to explain everything from the properties of water to color changes that occur in changing leaves and ripening vegetables. Although this mini-course is a combination of molecular biology and biochemistry, the focus for younger students is on general biological and chemical sciences and getting them interested and excited about science. Activities can be tailored to class and student interests. Initial activities include fun facts about molecules that kids are familiar with (for example, water, or the content of air), and later experiments involve growing crystals and making messy polymers. More advanced classes can extend the course to include discussions on the wonders of DNA.

Course Description

Introduction

This mini-course was created for the 4th grade students of Miss Allison Crivello at the Immaculate Conception School, and worked well in the small class of 8 students. All sessions centered on the fact that molecules make up everything around us, even though we can't see the molecules themselves. The main goal is to take simple scientific concepts and use them in demonstrations and experiments that get kids interested in the world around them and excited about science. The sessions of this course integrate general science teachings with building molecular models, layering liquids, making "goop," growing crystals, and painting with vegetables. Some lessons can easily be combined into one session, especially for older students, and the course material can be integrated with chapters found in most general science textbooks. This course is ideal for students in 2nd to 5th grade, but can be expanded to any level up to 9th grade with the addition of supplemental material. For grades 6 and above, this course could easily be expanded to talk more about DNA and proteins, with added demonstrations. A lesson on nutrition (i.e., the molecules that make foods nutritious or not) could also be incorporated for any age group.

Mini-Course Goals

-Get students excited about science and spark their curiosity about the world around them.

-Reinforce basic science concepts with demonstrations and experiments.

General Suggestions

-I used Powerpoint slides for every session, although it is not necessary. A quick search on the internet (www.google.com/images) brings up pictures relevant to every session, and helps to keep students interested.

-For many of the demonstrations, I asked students to participate as assistants. This seems to get them more excited than just watching an experiment.

-Some of the demonstrations and hands-on experiments can be messy, so I always brought in wet wipes and paper towels, and often covered the table with old newspapers. If there is a sink in the classroom it helps a lot!

Graduate Student Biography

I am in my 3rd year at Cornell University working towards a Ph.D. in Molecular Biology and Genetics. I'm originally from upstate New York, and got my undergraduate degree in Biology from Goucher College, a small liberal arts school in Baltimore, Maryland. My research in the Alani laboratory focuses on how cells maintain the integrity of our genetic material, and I am interested in how cells defective in these maintenance processes become prone to cancer. While I spend most of my time doing lab research, I also enjoy gardening, listening to music, ballet dancing, and learning to paint. My husband and I own a house near Ithaca where we live with our two kitties, Mu and Rufus.

Session 1: What Are Molecules?

Learning Outcomes

Upon completion of this session, students will:

- Understand that molecules are made up of atoms, and that atoms are the smallest amount of an element that still retains the properties of that element.
- Realize that molecules are extremely tiny; billions and billions of molecules are present in something as small as just one spoonful of sugar.
- Recognize the periodic table of the elements and be familiar with the idea that matter is made of elements.
- Students above 6th grade should be familiar with atomic structure (nucleus + electrons) and gain some understanding of the bonding that takes place between atoms via the electrons to create molecules.

Duration

This session can be short (20 minutes) or can be expanded to a full hour by combining with session 2.

Activities

Simple demonstration of the number of molecules in a spoonful of sugar and a cup of water.

Materials

- A large periodic table is useful, either on a poster or a projector.
- Spoonful of sugar
- Glass of water

Background Information

Notation for molecules is the one-letter symbol of the element followed by the number of atoms of that element that are found in the molecule. For example, a water molecule is made up of 2 hydrogen atoms and one oxygen atom, and so is written H_2O. This notation of the atoms that make up a molecule is called the molecular formula.

Atoms link to each other by forming bonds. While there are several different types of bonds, bonds in general are a mixing or sharing of the electrons from one atom with the electrons of another atom. For the purpose of this mini-course, I used a simplified view of ionic bonding and thus called salt a molecule, though in reality, salt dissociates into ions when, say, dissolved into water. This point does not have to brought up unless a student asks.

Most molecules that make up living things are composed primarily of carbon, oxygen, nitrogen, and hydrogen.

For the molecular structure of sugar (sucrose), see http://web1.caryacademy.org/chemistry/rushin/StudentProjects/CompoundWebSites/1999/Sucrose/structur.htm. For a 3D structure of sugar: http://www.3dchem.com/molecules.asp?ID=59).

Procedures

1. Begin by questioning the student on what they know about molecules: What are they? How big are they? How many are there? What are they made of? Can you name any? List some common molecules: carbon dioxide (CO_2), oxygen (O_2), water (H_20), sugar ($C_{12}H_{22}O_{11}$), proteins, DNA.
2. Matter is made up of molecules, but just how many are there? Do a demonstration of how small molecules are and how many millions there are in matter. In a spoonful of sugar there are approximately 300,000,000,000,000,000,000,000 molecules of sugar (that's more than a billion billions!). In a cup of water there are 10,400,000,000,000,000,000,000,000 water molecules!
3. Talk briefly about how molecules are made up of smaller pieces called atoms. Show a diagram of an atom with a nucleus and electrons moving around it (this image will be somewhat familiar to most kids, although they're unlikely to know what it is). An atom is the smallest particle of an element that has the properties of that element.

4. Show the students the periodic table of the elements. The details are not important, but tell the students that each box represents an element. Matter is made up of elements, and this chart shows all of the elements and some of their characteristics, including how much they weigh. Make a big deal about some common elements they have heard of: Hydrogen (H) (top left, the smallest element and thus the smallest atom), Helium (He) (top right), Oxygen (O) (2^{nd} row on the right), Carbon © (2^{nd} row on the right), Nitrogen (N) (2^{nd} row on the right), metals like Copper (Cu) and Zinc (Zn) (center). The periodic table is organized according to the weight of the elements, and the columns often group elements with similar properties. Gases are found in the right-most column. Most molecules that make up living things are composed primarily of carbon, oxygen, nitrogen, and hydrogen.
5. Molecules can be made up of atoms of the same element, like hydrogen (H_2) or Oxygen (O_2) gas, or molecules can be made up of a mixture of atoms of different elements, like in water (H_20) and sugar ($C_{12}H_{22}O_{11}$).

Suggestions

Drawing or showing the structures of some of these simple and common molecules creates a nice visual aid. (See Resource Materials for links to structures.)

Fun facts about molecules will keep the students interested. Some of my examples:

- DNA is a molecule. If all the DNA molecules in your body were put end to end, it would reach to the sun and back over 600 times
- Hydrogen gas is the smallest molecule, and consists of two hydrogen atoms (H_2).
- There are more molecules in the human body than there are stars in the sky!
- What is air made out of? Air is mostly nitrogen gas (N_2) and oxygen gas (O_2), but also contains carbon dioxide (CO_2), argon, and very small amounts of water vapor.

Session 2: Common Molecules

Learning Outcomes

Upon completion of this session, students will:

- Recognize that sugar, water, DNA, protein, carbon dioxide, and other common things they know of are molecules.
- Have a deeper understanding of how atoms link together to form molecules, and how molecules can join together to form larger molecules.

Duration

This session takes at least 30 minutes for 4^{th} graders (45 minutes is better).

Activities

In this session, students will build models of some common molecules using gumdrops, marshmallows, and toothpicks.

Materials

- Large gumdrops, preferably a different color for each element (carbon, oxygen, nitrogen, etc.)
- Miniature marshmallows ("hydrogen")
- Toothpicks ("bonds")
- "Maps" of common molecules showing which atoms are connected to each other (print-outs or projected slides work).

Background Information

Information on the molecules in this activity: Thymine ($C_5H_6N_2O_2$) is a nitrogenous base molecule found in DNA (structure of thymine at http://hal.weihenstephan.de/genglos/images/thymine.gif). Leucine is an essential dietary amino acid that is a building block of proteins (molecular structure of leucine at http://www.biochem.northwestern.edu/holmgren/Glossary/Images/pics/amino_acids/Leucine.gif). Fructose is fruit sugar, and glucose is the storage form of sugar in the body that most nutrients are converted to upon digestion [Structures at http://hyperphysics.phy-astr.gsu.edu/hbase/organic/imgorg/fructose.gif and http://www.greenspirit.org.uk/resources/glucose.gif. Glucose serves as the body's main energy source. Propane is used as a fuel (http://www.purchon.com/chemistry/images/propane.gif). Vinegar is used in foods, and is also known as acetic acid ($C_2H_4O_2$) (http://wwwchem.csustan.edu/consumer/vinegar/analys1.jpg).

Note to the instructor: In molecular structures you find in a book or on the internet, one line connecting two atoms represents a single bond, whereas two or three lines represent double or triple bonds, respectively. If you come across "CH_3," it is common knowledge that all three hydrogen atoms are each bonded to the carbon directly. Likewise, NO_2, NO_3, CO_2, CO_3, SO_4, and the like all have the oxygens directly bonded to the central atom (same idea with NH_2, NH_3, etc.). If you see COOH, it means that both oxygens are attached to the carbon, one with a single bond and one with a double bond. The hydrogen is attached to the oxygen that is singly bonded to the carbon. Some structures you find will not show the carbons, as carbon is assumed if no atom is listed. Some structures also tend to leave off hydrogen molecules, so I have tried to choose websites which show all the atoms for the purpose of this mini-course.

Procedures

1. Begin by briefly reviewing session one and how molecules are made up of atoms. Ask the students to list some molecules they've heard of.
2. Talk about how atoms of the same element can join together to form molecules. Atoms of different elements can also form molecules.
3. Molecules can also join together to form larger molecules. At the end of class we are going to build a large molecule from two smaller ones.
4. As a group, have everyone build a few small molecules using gumdrops, mini-marshmallows, and toothpicks. Carbon with an oxygen atom on either side forms carbon dioxide (CO_2). Oxygen with a hydrogen atom (marshmallow) on either side forms water (H_2O). Two oxygen atoms bonded together makes oxygen gas (O_2).

5. Split the students into groups of two and give each one a station with different colors of gumdrops, a cup of "bonds" (toothpicks), and a cup of hydrogens (mini-marshmallows). Each group should be given a full-size diagram (fits on a regular sheet of paper) of the molecule they're going to build. Molecules that I used: propane, vinegar, glucose, fructose, leucine, and thymine. Building takes longer than it looks!
6. Reiterate that molecules can join together to form larger molecules. For example, DNA is made up of sugar, bases, and phosphate molecules. Proteins are made up of amino acids. Sugar is also made of smaller molecules. The sugar we eat is sucrose, $C_{12}H_{22}O_{11}$. It is made up of fructose ($C_6H_{12}O_6$) and glucose ($C_6H_{12}O_6$) hooked together (one H2O molecule is lost when the two molecules bond together). Fructose is a small sugar found in fruit. Glucose is the form of sugar the human body uses to store energy. As a group, take the molecule of glucose that one group built and the molecule of fructose built by another group and hook them together to make sucrose (table sugar).
7. Do not eat the gumdrops or marshmallows after they've been handled!

Suggestions

It may be difficult to lift the completed molecules without them falling apart, so combining glucose and fructose to make sugar may have to be done on a table.

Session 3: States of Matter and their Different Properties

Learning Outcomes

Upon completion of this session, students will:

- Be able to list the three main types of matter.
- Be able to explain what makes a solid a solid, a liquid a liquid, and a gas a gas.
- Understand that different types of liquids have different properties from each other, as do different solids and different gases.

Duration

This session may take 45 minutes to an hour. Material can also be repeated during another session.

Activities

Demonstration of layered liquids, as well as a very messy cornstarch and water activity.

Materials

- Vegetable oil
- Water (optional food coloring added)
- Cornstarch
- Water
- Plastic cups and spoons for mixing
- Drop cloth or newspapers to cover table/desks
- Wet wipes!

Background Information

For properties of liquids, solids, gases, see a general science text or dictionary. The molecules in a solid are much closer together than the molecules in a liquid, and the molecules in a liquid are closer together than the molecules of a gas. The one exception to this rule is water, since solid water is actually less dense than liquid water (hence the reason ice floats). This simply has to do with the shape of the water molecule and the structure that is formed when molecules of water bond to each other. Ice has a very regular lattice structure to it that has lots of open space in it, whereas water molecules in a liquid can move around and take up that space. The idea of solids usually being more dense can be confusing for students since the most common visual of ice floating on water is an exception to the rule. In this session the students will create a messy substance that is technically not a liquid or a solid, but rather sort of a mixture of the two. Cornstarch and water together form a type of matter known as a suspension, which acts like a solid when a force is applied to it, but has properties of a liquid when left alone.

Procedures

1. Begin the session with a demonstration. Pour water (colored or not) into a clear plastic cup, and then slowly and carefully pour vegetable oil into the cup as the students watch. [I also used a third liquid, glycerol, but it may be difficult for most people to find a third liquid that does not mix with either oil or water.] Explain that while both oil and water are liquids, the liquids have different properties. Water and oil have different densities, meaning that for the same amount of volume, one is heavier than the other. (If you have a scale, you can show this.) Another reason that water and oil do not mix is that that are not miscible- water is hydrophilic ("water-loving"), while oil is hydrophobic ("oily", or "water-hating").
2. As an introduction to the rest of the session, talk about the three main states of matter, solids, liquids, and gases and give examples of each. What makes a solid a solid? A liquid a liquid? A gas a gas? What are their similarities and differences?
3. For the rest of the session, the students will do an activity. In a mixing bowl or cup (large enough to fit hands in), pour cornstarch. Slowly add water and mix, either with a plastic spoon or with the hands. If the mixture is too watery, add more cornstarch. If you can see cornstarch powder, add more water. The

substance will drop out of your hands if left alone, but will feel solid when squeezed.

4. Throughout the activity, have students describe aloud what the feel and see. What properties does the substance have? Is it a solid or a liquid?
5. At the end of class, after hands have been washed, have students make a list of the properties that the cornstarch substance has as a group. Take a vote on whether it is a solid or a liquid.
6. Finally, tell the students that the cornstarch and water mixture that they made is actually a rare form of matter called a suspension. A suspension has some properties of liquids as well as some properties of solids. Quicksand is another example of a suspension. By definition, a suspension is a type of matter that acts like a solid when a force is applied to it, and acts like a liquid when left alone.
7. Safety tips: Do not eat any of the materials!

Suggestions

I highly suggest that the instructor try the cornstarch activity on their own first to understand it and work out the "bugs" before teaching the students. It may be ideal for this activity to be done in groups of two, so that everyone gets to touch and play with the suspension.

A "take home" version of how to make the cornstarch and water suspension is provided in the appendix.

Session 4: Mixing Molecules

Learning Outcomes

Upon completion of this session, students will:

- Understand that some solids can dissolve in liquids to form solutions.
- Grasp that some types of matter have chemical reactions when mixed together.
- Know that polymers are formed when many of one type of molecule are joined together to make a larger molecule.

Duration

Roughly 45 minutes, but the activity can easier take longer.

Activities

After beginning with a demonstration of the mixing of baking soda and vinegar, students will make goop out of glue, water, and borax.

Materials

- Vinegar
- Baking soda
- Borax (can be found in the laundry soap aisle at the grocery store)
- Water
- Elmer's white glue (other glues or types of Elmer's don't work as well)
- Plastic cups and spoons for mixing
- Wet wipes!

Background Information

Two solids can be mixed together (think of mixing salt and sugar). Two liquids can also be mixed together (think about mixing juice and milk). Air is a mixture of several different gases. There are also ways of mixing molecules to create something new. A solution is the result of dissolving a solid into liquid water. The small solid molecules are able to fit in between the water molecules, and so you no longer see them. Some solids will dissolve into water just by stirring, while others take a long time and may require heating the water (heating water makes the water molecules get farther apart). A saturated solution is a solution that can no longer hold any more molecules of the solid. The only way to dissolve more of a solute (the solid) into a saturated solution is to heat the solution. When heated, the molecules move farther apart and allow more solute to be dissolved into it. In later sessions we will use such super-saturated solutions to grow crystals.

Some chemicals have chemical reactions when mixed. When baking soda is mixed with vinegar, the acetic acid in the vinegar reacts with the baking soda (sodium bicarbonate) to form sodium acetate, water, and carbon dioxide gas. The bubbles you see are carbon dioxide escaping into the air. [This reaction is often used to make toy volcanoes.]

The structure of sodium bicarbonate (baking soda) can be found at http://www.cas.astate.edu/draganjac/structure_.gif.

Procedures

1. Begin the session by talking about the different ways to mix molecules.
2. Demonstrate (with a student assistant, and a drop cloth!) what happens when baking soda (powder) is added to a cup of vinegar. Explain that when mixed, some kinds of matter create chemical reactions. [The bubbles that form are the result of an acid/base reaction that releases a small amount of carbon dioxide gas).
3. Next, explain that some solids can mix into liquids to form solutions. A solution just means that the molecules of the solid can fit in between the water molecules and still retain the properties of a liquid.
4. As a demonstration or in small groups, create a solution using borax (solid) and water. Start with a small spoonful of borax and stir. Continue adding

borax and stirring until no more solid will go into solution (=saturation). Talk about what it means for a solution to be saturated.

5. Describe that polymers are simply large molecules made of repeating units of smaller molecules. Common examples are plastics, DNA, rubber.
6. After discussion of polymers, students will do a somewhat messy activity in which they create their own polymer. Equal volumes of white Elmer's glue and a saturated borax solution should be mixed together using the end of a plastic spoon. Stir until a solid forms. Students can then play with the goop with their hands. Adding excess borax solution will ensure that no sticky glue is left behind.
7. Safety tips: Do not eat any of the items used in the demonstration or experiment. Always wash your hands after an experiment.

Suggestions

A good way for kids to understand saturation is to think of it as "fullness." Once the solution is "full" of solute molecules, no more can dissolve.

It may be more effective to try adding vinegar to the baking soda instead of vice versa. See which works better in your situation and whether all the students will be able to see it.

It does not take very much of the borax solution to create the goop polymer.

When making goop, I suggest adding the borax solution to the glue, since it is difficult to get all the glue out of its container. Otherwise, add slightly more glue than borax solution to ensure that the goop will polymerize.

Students may want to take the goop home in a plastic bag. (It will keep for some time if not allowed to dry out.) A "take home" version of how to make goop is provided in the appendix.

Food coloring can be added to the glue in order to make colored goop, but it will stain the hands.

Session 5: Crystals, part 1

Learning Outcomes

Upon completion of this session, students will:

- Recognize that sugar, salt, and snowflakes are crystals
- Be able to use "observation words" to describe the differences between crystals of common household substances
- Know how to make a solution from sugar, salt, etc. and water

Duration

This session takes at least 45 minutes, and could be stretched to twice that.

Activities

Students will observe and describe the differences between common compounds, and later will make supersaturated solutions of these compounds and set them up for growing crystals.

Materials

- Magnifying glasses (optional, but nice to have)
- Sugar
- Salt
- Epsom salts (found in the first aid section of the grocery store)
- Borax (found in the laundry aisle in the grocery store)
- Hot water (the closest to boiling, the better)
- Optional: baking soda, alum (found in the spice section of the grocery store)
- Small dishes for observing sugar, salt, etc.
- Plastic dishes for growing crystals (wider is better)

Background Information

Supersaturated solutions, as described in the previous session, are solutions that have been heated and then saturated with the solute. When a solution is absolutely super-saturated, there will not be enough room in the solution for all the molecules once the solution begins to cool, since cooling causes molecules to get closer together. Thus, upon cooling solids will come out of solution, forming crystals. Since it is not always practical to boil a solution in the classroom, a super-saturated solution can be made by heating and saturating a solution as much as possible and then allowing further saturation by evaporation over time. The longer it takes to cool and evaporate a solution, the larger the crystals may be.

Crystals are ordered solids with very rigid structures. Crystals made of different elements often have different shapes; some may be cubic, some may be pointy, some are very regular, and some are extremely irregular.

Information on the chemicals used for the sessions on crystals: Borax is sodium borate ($Na_2B_4O_7$). Salt is table salt, sodium chloride (NaCl). Epsom salts, magnesium sulfate, are often used for soaking aching feet and muscles (Mg_3SO_4). Alum is aluminum sulfate ($Al_2(SO_4)$), and is used in making pickles and in dyeing fabric. Baking soda is sodium bicarbonate, $NaHCO_3$, and is used in baking. Sugar, $C_{12}H_{22}O_{11}$, is the same sucrose molecule used in early sessions of this mini-course.

Procedures

1. Before class, take samples of sugar, salt, Epsom salts, and any other optional solids and number them as unknown samples.
2. After a brief discussion of crystals and their molecule structure (I recommend getting some images from the internet), break the students up and have them look at the unknown samples one at a time and write down descriptions of each using the observation sheet provided in the appendix.
3. While the other students are recording their observations, have the remaining students work on the Molecules word search that is also provided in the appendix.
4. In preparation for growing crystals, take hot or boiling water and for each solute (salt, sugar, etc.), dissolve as much in the water as possible. Pour the super-saturated solution into another container for crystallization in order to

leave behind the extra solute in the bottom of the container. Leave crystal growing solutions undisturbed for at least a week until crystals are visible.

5. Safety tips: Do not eat any of the crystals! Always wash your hands after an experiment.

Suggestions

I found it useful to put "observation words" on the board to get students to describe the crystals and compare them to each other. Popular and useful words: fine, powdery, shiny, sparkly, dull, square, rectangular, round, triangular, smooth, white, clear, long, irregular, uniform, angular, rough. I like to stress to the students that taking good observations is one of the things that scientists have to do a lot, and it takes practice.

The Molecules word search proved pretty difficult for most 4^{th} graders, so working in pairs may be better. Writing descriptive words about the unknown samples takes some coaxing and repetition of the key words that are most helpful.

Epsom salts and alum will grow the best crystals with the least effort. Sugar crystals, when done very cleanly, are the same as rock candy. They can be grown on a stick or on a string, and this helps to increase crystallization.

A "take home" version of how to grow crystals is provided in the appendix, and includes some more helpful tips.

The students seemed to be very excited to find out that sugar and gemstones are actually crystals.

Session 6: Crystals, part 2

Learning Outcomes

Upon completion of this session, students will:

- Understand that solids dissolved into a solution can be re-gained by cooling and/or evaporating off the water.

Duration

This session can be completed in as little as 20 minutes.

Activities

As a group the students and instructor will tell each other how they described each "unknown" crystal substance, and each will be revealed. Small crystals used for the observations can also be compared to any crystals that grew since the last session.

Materials

- Crystal unknowns (salt, sugar, etc.)
- Observation sheets from last session including the students' descriptions
- Crystals that have grown since the last session

Background Information

There is no new information required since this is mostly a review of the material from the last session.

Procedures

1. One by one, go through the unknown samples with the class, with students giving examples of how they described each sample of crystals. Reveal the name of each (or let them guess!), and then compare it with any crystals that have grown since the last session.
2. Dishes of crystals can be passed around, but for safety reasons, do not allow students to touch or eat them!

3. Safety tips: Do not eat any of the crystals! Always wash your hands after an experiment.

Suggestions

Epsom salts and alum form the best crystals after one week. Salt crystals are generally very small and crusty. Students will be tempted to touch and taste the salt, sugar, and other samples they are looking at. It is best to stress that although these are familiar chemicals, they are for use in the experiments only. Again, I found it useful to put "observation words" on the board to get students to describe the crystals and compare them to each other (fine, powdery, shiny, sparkly, dull, square, rectangular, round, triangular, smooth, white, clear, long, irregular, uniform, angular, rough, etc.).

One to two weeks is a good amount of time to have between this session and the previous one.

A "take home" version of how to make the cornstarch and water suspension is provided in the appendix.

Session 7: Exploring Color, Part 1: How Are Molecules Related to Color?

Learning Outcomes

Upon completion of this session, students will:

- Understand that molecules called pigments are responsible for the remarkable colors found in vegetables, flowers, and changing leaves.

Duration

This session can be short (20 minutes), or can be combined with Session 8.

Activities

Students will learn about the molecules responsible for color in most plants, and there will be a demonstration of how the addition of baking soda and vinegar can change the color of grape juice.

Materials

- Colorful leaves, fruits, and vegetables as visual aids.
- Grape juice
- Vinegar
- Baking soda

Background Information

Tree leaves use the pigment chlorophyll to get energy for the sun via photosynthesis. Chlorophyll also is what makes leaves green. In the fall, the sun is less bright and leaves start to use other red, yellow, and orange pigments to gather sunlight rather than the green chlorophyll pigments, and this makes the leaves change to red, yellow, and orange. Leaves turn brown when they accumulate toxins and stop gathering and storing energy.

The addition of baking soda or vinegar to grape juice changes the molecular structure of the pigment molecule present in grape juice, which causes it to reflect different colors of light. See "Procedures" for information on pigments and antioxidants.

Procedures

1. Begin the session with a colorful demonstration: Fill a clear container about half way with grape juice. Have an "assistant" certify what color it is and then show the students what it looks like. Have the assistant add baking soda to the grape juice, and observe what happens (it should be darker). Have a student described what changed. Once everyone has looked at it, add vinegar and repeat observations (it should be more pink, especially on the top where bubbles might form.)
2. Explain briefly that the color in grape juice is caused by a pigment molecule. The pigment molecules change when baking soda is added, and so the color turns darker. When vinegar is added, the reaction is reversed and the color becomes lighter and more pink.
3. If you have fall leaves, or pictures of them, discuss the relationship between pigments and leaf color. This is especially effective if students have already learned about plants and/or photosynthesis.
4. Pigments are molecules that reflect light to make an object look a certain color. There are three main types of natural pigments: chlorophylls, which make vegetables and other plants look green, red-blue pigments called anthocyanins that color blueberries, concord grapes, cherries, blackberries, cranberries, red cabbage, radishes, eggplant, plums, and apples, and the yellow-orange-red pigments called carotenoids and carotenes, which color carrots, tomatoes, red peppers, hot peppers, corn, and daffodils.
5. Besides creating pretty colors, pigments are also very healthy because they act as antioxidants. Antioxidants are molecules that take toxins and harmful chemicals out of your body and keep you healthy. Thus, in general, fruits and vegetables with deep colors tend to be the most nutritious (think of spinach-full of antioxidants!).
6. Safety tips: Do not drink the grape juice after anything has been added!

Suggestions

- This session could be turned into an end-of-the-mini-course food-tasting event! It also could easily be integrated with more information on nutrition (proteins, fats, carbohydrates, etc.).

Session 8: Exploring Color, Part 2: Natural Pigments and Chemical Reactions

Learning Outcomes

Upon completion of this session, students will:

- Understand that chemical reactions can change the colors produced by a pigment molecule.

Duration

This activity can take 40 minutes or longer.

Activities

Students will then use pigments from common vegetables and fruits to create artwork, and will also modify the colors by adding either a baking soda solution or vinegar.

Materials

- Grape juice concentrate, melted
- Baking soda
- Water
- Vinegar
- Q-tips for "painting" with grape juice
- Red cabbage
- Radishes
- White paper
- Wet wipes!
- Smocks would be a good idea!

Background Information

Same as previous session.

Procedures

1. Have a student mix some baking soda into a cup of water.
2. Give each student at least one piece of white paper.
3. Allow students to create their own artwork using a variety of natural pigments from radishes, red cabbage, raspberries, grape juice concentrate, and any available flower petals.
4. Use Q-tips to cover some parts of the picture with baking soda and observe the change. Next, try adding vinegar and see how the color changes.

Suggestions

This session is a lot of fun!

Whole radishes work quite well as crayons, as do pieces of red cabbage. Green stems can be used for supplemental color, but the pigment will not noticeably change upon addition of baking soda or vinegar.

This session ends with many messy hands. It is a good idea to cover the table well, and to have the students wear smocks or old shirts over their clothing.

Resource Materials

www.dictionary.reference.com

www.google.com

www.google.images.com

For the molecular structure of sugar:

http://web1.caryacademy.org/chemistry/rushin/StudentProjects/CompoundWebSites/1999/Sucrose/structur.htm

For a 3D structure of sugar: http://www.3dchem.com/molecules.asp?ID=59

For the molecular structure of thymine:

http://hal.weihenstephan.de/genglos/images/thymine.gif

For the molecular structure of leucine:

http://www.biochem.northwestern.edu/holmgren/Glossary/Images/pics/amino_acids/Leucine.gif

For the molecular structure of fructose:

http://hyperphysics.phy-astr.gsu.edu/hbase/organic/imgorg/fructose.gif

For the molecular structure of glucose:

http://www.greenspirit.org.uk/resources/glucose.gif

Molecular structure of propane: http://www.purchon.com/chemistry/images/propane.gif

Molecular structure of vinegar:

http://wwwchem.csustan.edu/consumer/vinegar/analys1.jpg

Structure of baking soda, sodium bicarbonate:

http://www.cas.astate.edu/draganjac/structure_.gif.

Glossary:

Atom – A unit of matter that is the smallest unit of an element that has all the characteristics of that element. Atoms have a dense, positively charged center called the nucleus that is surrounded by negatively charged electrons.

Compound – A substance consisting of two or more different elements that usually does not have the same properties as the individual elements.

Density – Amount of matter in a given space (weight divided by volume).

Element – A substance composed of atoms having an identical number of protons in each nucleus. Elements cannot easily be reduced to simpler substances.

Gas – The state of matter that is different from solids and liquids in its relatively low density and viscosity, relatively great expansion and contraction with changes in pressure and temperature, and the tendency to become distributed uniformly throughout any container.

Liquid – The state of matter in which a substance flows easily, has little or no tendency to disperse, and has relatively high incompressibility.

Mass – Amount of matter.

Matter – Anything that takes up space and has mass.

Mixture – A composition of two or more substances that are not chemically combined with each other and are capable of being separated.

Molecule – The smallest particle of a substance that retains the chemical and physical properties of the substance and is composed of two or more atoms; a group of like or different atoms held together by chemical forces.

Pigment – A substance, such as chlorophyll or melanin, that produces a characteristic color in plant or animal tissue.

Polymer – A usually high molecular weight compound consisting of many repeated units, each a relatively light and simple molecule.

Saturation – Act of filling to capacity.

Solid – The form of matter that is not liquid or gaseous, and has definite shape and volume.

Solution – A homogeneous mixture of two or more substances, which may be solids, liquids, gases, or a combination of these.

Suspension – A type of matter that acts like a solid when a force is applied to it, and acts like a liquid when left alone. Suspensions are systems in which microscopically visible particles are dispersed throughout a less dense liquid or gas.

Appendix

-Household Chemistry, Experiment 1: Homemade goop

-Household Chemistry, Experiment 2: Cornstarch suspension

-Household Chemistry, Experiment 3: Baking soda and vinegar volcano

-Observation Sheet

-The Molecules Around Us word search

-Instructions on how to grow crystals at home

Household Chemistry
Experiments you can do in your own kitchen!

Kids, always do these experiments with an adult!

<u>Experiment 1: Homemade Goop</u>

What you need:

Borax (available in the laundry detergent section of the grocery store)
White glue (regular Elmer's glue works best)
Water
Cups for mixing
Popsicle sticks or plastic spoons for stirring
Food coloring (optional)

Instructions:

- In one cup, mix equal volumes of white glue and water and stir until mixed.
- In another cup, stir a spoonful of borax into a cup of water until it dissolves. If all the borax dissolves, keep adding more until there is excess undissolved borax in the bottom of the cup.
- Slowly add some of the borax solution to the glue and water and mix. (This step can be done either in a cup or inside a Ziploc bag.) Add food coloring along with the borax to make colorful goop. Continue adding the borax solution to the glue mixture until there is no white liquid left.
- Have fun with your goop! Goop can be stored in a Ziploc bag.
- Make sure to wash your hands when you're finished!

Safety tips:

Never eat glue, borax, or goop!
Food coloring may stain hands temporarily and may stain other objects permanently, so use caution!

The science behind Goop:

White glue contains a polymer of vinyl acetate molecules. Borax acts as a crosslinking agent by connecting the poly(vinyl acetate) molecules to each other. The more borax you add, the more crosslinking occurs, and the slime gets thicker.

Household Chemistry
Experiments you can do in your own kitchen!

Kids, always do these experiments with an adult!

Experiment 2: Cornstarch Suspension

What you need:

Cornstarch (corn flour)
Water
Mixing bowl
Spoon for mixing (optional)

Instructions:

- Put cornstarch in a mixing bowl
- Slowly add water and mix with your hands (or a spoon)
- Squeeze it, pick it up, let it drip- is it a liquid or a solid?

- If the mixture is too watery, add more cornstarch
- If you can see cornstarch powder, add more water

The science behind it:

Is it a liquid or a solid? When mixed with water, cornstarch forms a suspension. A suspension is a type of matter that acts like a solid when a force is applied to it, and acts like a liquid when left alone. Try squeezing it- if you continue touching it, the cornstarch suspension will hold its shape. Try holding it in the palm of your hand- the suspension should start to drip off of your hand and take the shape of its container.

Household Chemistry
Experiments you can do in your own kitchen!

Kids, always do these experiments with an adult!

Experiment 3: Baking soda and vinegar volcano

What you need:

Baking soda
Vinegar
Clear cup or bowl
Larger container under the cup/bowl in case of overflow

Instructions:

- Sprinkle a couple spoonfuls of baking soda into a clear cup or bowl.
- Pour some vinegar on top of the baking soda
- Watch what happens!

Safety tips:

- Wash your hands when you're done
- Do not eat!

The science behind it:

This is a simple acid/base reaction. Vinegar (dilute acetic acid) reacts with baking soda (sodium bicarbonate) to form sodium acetate, water, and carbon dioxide (CO_2). The bubbles you see are carbon dioxide escaping into the air.

Observation Sheet

Sample #1

Sample #2

Sample #3

Sample #4

Sample #5

Sample #6

Molecules Word Search

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E T A R O B M U I D O S B A Y K F E D B I D U P L
T L B S I S Q H I Q E L O L W T A V L J J M M L R
C G E L D X O U S V F D N U R E I F F Z B N L B R
G L R M D F Q L W U E K D M T R X S T D G J I L L
Z G Q G E I Q K I I Z I S I F U E N N V O L U M E
R N X Z L N F P V D V C S N G T L O B E Q I B L D
M H N C B N T U W H J S Y U O X U L F K D P E R G
P A O O Z K Z S S O D I U M B I C A R B O N A T E
O Y G D I E S O R C U S D S O M E B R E M J W S M
L E O N N S G D U N V A O U U P L L X I Q K O W E
Y W T Z E L N O O F F D I L C E O S S A M T R F D
M S J N U S R E Z G I R A F P T M S T H C E W B I
E O A C P R I F P U W C B A N X S O L U T I O N A
R I O G O X G U M S X C L T J V A A R B V A E T G
K S S C A Z X C M X U L F E T D O F Q P O P O Q K
E E H N G J H U Y S G S P K N R B A T C G M D C U
O M C Q U L V J G T U X M W F S T J E P B T F A C
W J M O O M U N S O G L G H S L Z N B R Z N B X W
T B V R Q B O L Q M B T F J U E P L Y T Z G A L L
J E I N W Q C U G E M X E A U Y Z Y Q Z F O E K Y
N D F Y X C G Y W R H N F R T P Y A Y B M Q V I C
E Q H S V F T C S N B W N A B E S Z B A S Q N S Q
W S M Q H Q P X Y L X W L D V N Q L I W E E L Z V
N V W H V S X I P A W O U H O G T P O R E H R G G
D I E L K X Z F U Z J J L U X K T V H F X Z B B U
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ATOM

BONDS

ELEMENTS

MOLECULE

MASS

VOLUME

DENSITY

POLYMER

MIXTURE

SOLUTION

SUSPENSION

GAS

SOLID

LIQUID

SUCROSE (sugar)

GLUCOSE

FRUCTOSE (fruit sugar)

SODIUM BICARBONATE (baking soda)

SODIUM BORATE (borax)

SODIUM CHLORIDE (salt)

MAGNESIUM SULFATE (epsom salts)

ALUMINUM SULFATE (alum)

Growing Crystals At Home

Always do these experiments with an adult!

Safety:

- Do not eat any crystals except for clean sugar crystals (also called rock candy).
- Have an adult boil the water, and handle it very carefully! Hot water can burn.

Materials:

Boiling water
Salt, sugar, or Epsom salts (alum, baking soda, or borax also work)
[All of these items can be found in the grocery store]
Spoon for stirring
Container for making the solution
Container for growing crystals

Instructions:

- Bring water to boiling and remove from heat.

- Dissolve solute in the hot water, stirring constantly, until no more will dissolve. There should be extra solute settled on the bottom of the container.

- Add the solution to a new, clean container for growing the crystals. Try not to include any undissolved material.

- Leave solution undisturbed for several days up to several weeks.

Helpful hints:

It is best to use disposable containers (e.g. plastic cups) for growing the crystals, since it is sometimes difficult to remove crystals from the container.

Food coloring can be added to the solution to create colored crystals.

Using a shallow, wide container will allow crystals to form more quickly, but the crystals tend to be smaller.

Sugar crystals require an absolutely super-saturated solution, so water must be boiling. A large amount of sugar will dissolve into the hot water, and the solution will expand, so use a lot of sugar and a large enough container!

If crystals do not form after 2 weeks, carefully hang a string or paper clip into the solution to give crystals something to stick to. You can also hang small crystals into a new solution to grow larger crystals.

Water can be cooler than boiling for some crystals (epsom salts, salt), but extra time may be required for crystal formation.

For larger crystals, try insulating the container. Slower cooling of the solution leads to larger crystals.

The science behind it:

Dissolving something in water until no more can dissolve creates a saturated solution. Since water molecules get farther apart when water is heated, more solids can dissolve in a hot solution than in a cold solution. Saturating boiling water creates a super-saturated solution.

As the solution cools, the molecules get closer together. As water evaporates from the solution over time, the molecules get even closer together. Eventually, there is not enough room in the solution for all the solute molecules, and they come out of solution and stick together to form solid crystals.