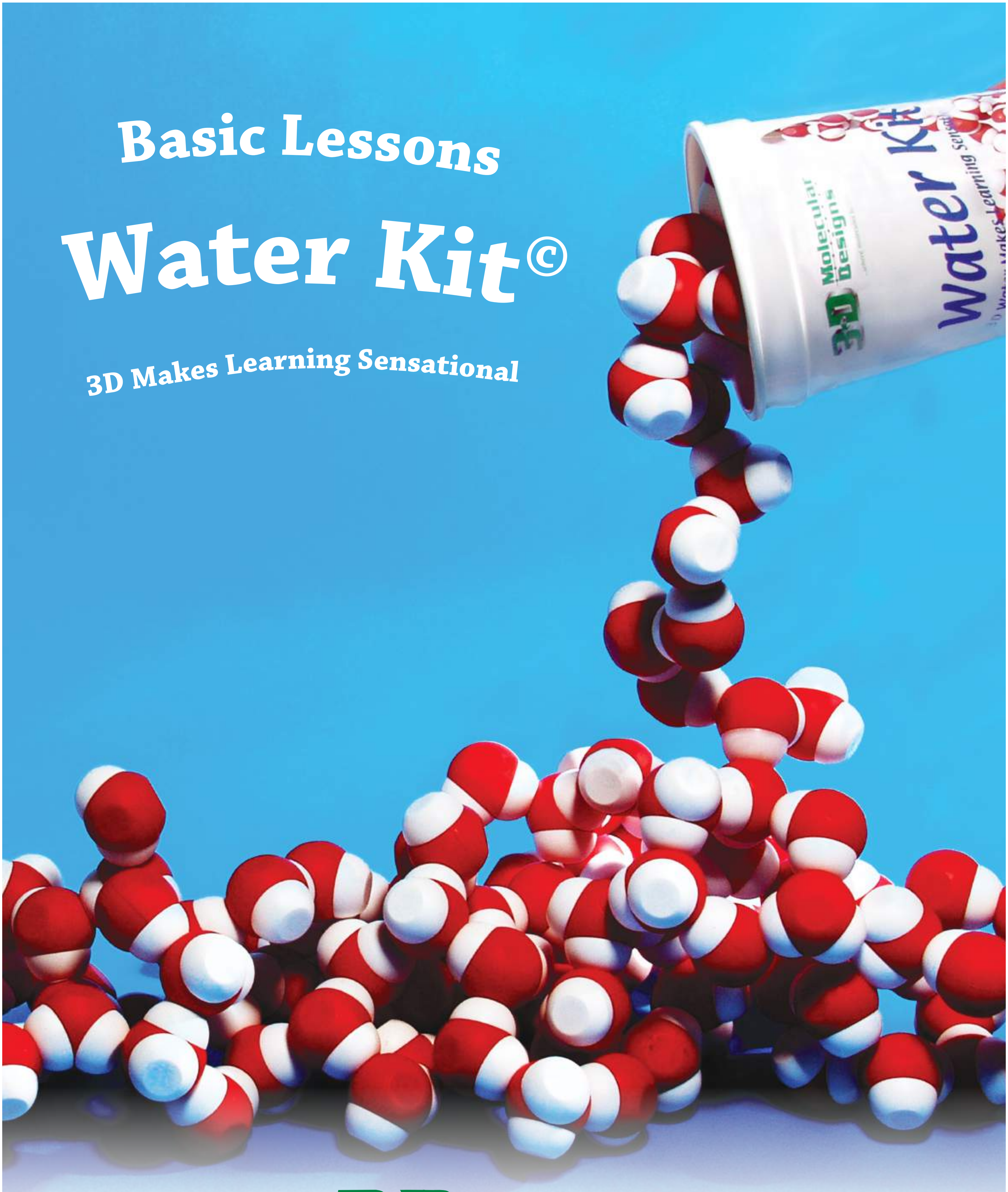
Basic Lessons

Water Kit©

3D Makes Learning Sensational



3-D Molecular Designs

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Project WET (Water Education for Teachers)

3D Molecular Design's Water Kit© can be used to teach many of the concepts in Project WET's K-12 Curriculum Guide. Project WET is a nonprofit water education program that facilitates and promotes awareness, appreciation, knowledge and stewardship of water resources through the dissemination of classroom-ready teaching aids. Teachers can use the Water Kit© as part of many Project WET lessons or as an extension to the lessons. Please see the document Project WET and the Water Kit©. The chart shows which Project WET lessons the Water Kit© can be used with to enhance understanding.

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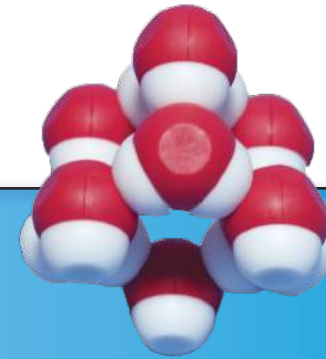


Basic Lesson Plans

Polarity

General Information

Understanding the unique characteristics of water begins with understanding polarity.

Polarity refers to the partial positive charge (+) and partial negative charge (-) that a molecule has when electrons are unequally shared between two or more atoms. Molecules that have partial charges are polar molecules. Water molecules are **polar molecules**.

In a water molecule, each hydrogen atom has a partial positive charge and the oxygen atom has two partial negative charges.

Some molecules do not have unequal regions of charges and therefore do not interact with polar molecules. These are **nonpolar molecules**. Oil and ethane are examples of a liquid and a gas composed of nonpolar molecules.

Water Kit©

The water molecules in the Water Kit© have been embedded with magnets to help students experience what positive (+) and negative (-) charges feel like as they interact with other polar molecules. Through manipulation of the 3D water molecule models, it becomes easy for students to understand the physical and chemical properties of water.

Embedded magnets are positioned at 105º from each other.

There are two magnets embedded in the oxygen at 105º degrees from each other. These represent the two partial negative (-) charges.

One magnet in each of the hydrogen atoms represents the partial positive (+) charges. The hydrogen molecules are also positioned 105º degrees apart.

The location of these four magnets (representing charges) makes it possible for your students to create a *tetrahedral* structure. A tetrahedral structure is formed when one water molecule interacts with four other water molecules.

Tetrahedral Structure

In the Classroom

Hand out one 3D water molecule model to each student.

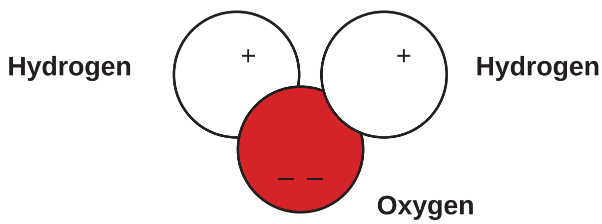
- What is the chemical formula of water?
  H_2O

Have your students discuss what the H and the O represent. Refer to the periodic table of elements.

- What does the 2 between the hydrogen and oxygen stand for?
  When a number # is placed after a symbol, it means there is more than one atom of that element and when there is no number after a symbol, it means there is only one atom of that element.

Have your students identify which parts of the model represent the hydrogen and which the oxygen. Clarify that the colors on the model are used by chemists to represent hydrogen (white) and oxygen (red), but water, as a real molecule, is not colored. Emphasize that it is impossible to see a single water molecule with the naked eye or even with the most powerful light microscope.

Have your students draw and label a water molecule. Remind your students that each hydrogen atom has a partial positive charge and the oxygen atom has two partial negative charges. Explain that they can show this on their drawing by placing a + symbol on each hydrogen and two – symbols on the oxygen.

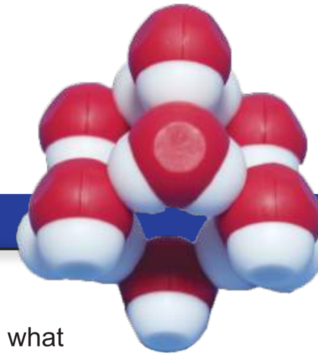


Your students can now predict, what will happen when water molecules interact. Hand out one more 3D water molecule model to each student and let him or her investigate whether his or her prediction is correct.

- What will happen when two water molecules bump into each other?
  - When the oxygen atoms of 2 different water molecules come together, they repel.
  - When the hydrogen atoms of 2 different water molecules come together, they repel.
  - When an oxygen atom and a hydrogen atom from two different water molecules come together, they attract.

Have the students draw and label what they have discovered. Then, have your students write about what they have observed.

(In the Classroom Continue)



Difference Between Magnetism and Polarity

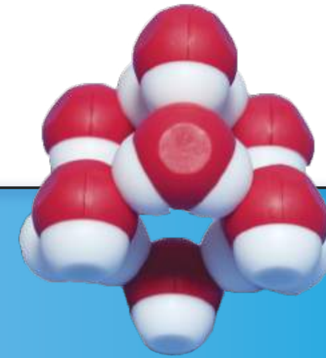
Display two large horseshoe-shaped, or other, magnets and ask your students what they know about magnets. List and diagram the student's answers on the board.

- What are the similarities and differences between magnets and water molecules?
  Atoms are not really magnetic. However, the north and south poles of magnets can be used to effectively model the partial positive and partial negative charges that exist on the polar water molecule.

Water Facts

- How many water molecules are in a single drop of water?
  There are 3×10^{21} of molecules in one drop of water (3,000,000,000,000,000,000,000). This number can be read, "three times ten to the twenty first power."

- At the scale of the water molecule models, how large would a water drop be?
  Clarify that it is impossible to see a single water molecule with the naked eye or even with the most powerful microscope. A water drop made of 3×10^{21} of 3D water molecule models would be ***larger*** than the earth.



Hydrogen Bonding

General Information

A **covalent bond** is formed when two atoms share two electrons. A covalent bond is an ***intramolecular*** bond within one molecule. Covalent bonds can be either polar (which have partially charged atoms) or nonpolar (without charged atoms).

Hydrogen bonds are intermolecular forces between two molecules where a positively charged hydrogen atom interacts with a negatively charged fluorine, nitrogen or oxygen atom in a second molecule.

• ***Water fact:*** *A hydrogen bond is about 1/20 as strong as a covalent bond.*

An **ionic bond** is the complete transfer of an electron between two atoms resulting in one positively and one negatively charge atom. *Ionic bonds are intramolecular bonds within one molecule.*

Ions are charged atoms that have gained or lost electrons as a result of an ionic bond.

Water Kit©

The magnets in the 3D water molecule models simulate the intermolecular force of two polar water molecules forming a hydrogen bond. All of the bonds between multiple water molecules are hydrogen bonds. The bonds between water molecules and the OH group on the ethanol are hydrogen bonds.

In each individual 3D water molecule models, the bonds between the hydrogen atoms and the oxygen atom are covalent bonds. Covalent bonds are also formed between all of the atoms that form ethane and ethanol. These are all intramolecular bonds. Water molecules and ethanol molecules are polar covalent molecules while the ethane is a nonpolar covalent molecule.

Ionic bonds are formed between the sodium and chloride ions. This is an ***intra***molecular bond.

Intramolecule force

The attraction between the negative charge of the oxygen and the positive charged of the sodium ion is an ***inter***molecular force.

Partially positively charged hydrogen atoms (see water and ethanol molecules) will interact with negatively charged chloride ions. ***This is not called a hydrogen bond because the chloride ion is not one of the three elements listed above (fluorine, nitrogen or oxygen)***. This is another type of intermolecular force that is covered in the Solubility Section.

Hydrogen Bond Activity and Questions

Give each student two 3D water molecule models.

Have your students *break* the hydrogen bond between the water molecules by pulling them apart. Next, have them compare this to the relative strength of a covalent bond by pulling a hydrogen atom off a water molecule. (Use a fingernail to pry the hydrogen off the oxygen if needed.)

- What is the intermolecular force that holds these two water molecules together?
  Hydrogen bond.

- What is the intramolecular bond that holds the hydrogen atoms and oxygen atom within a water molecule?
  Covalent bond.

- Is a water molecule a polar covalent molecule, or a nonpolar covalent molecule? Why?
  Water molecules are polar covalent molecules because electrons are shared within the molecule and the sharing of the electrons is unequal which results in partially positively charged hydrogen atoms and a partially negatively charged oxygen atom.

Ethane

Give each group of students an ethane molecule.

Ethane CH_3CH_3

- What is ethane?
  Ethane is a short hydrocarbon. Hydrocarbons are combinations of carbon and hydrogen atoms. Ethane is an odorless, colorless gas that can be used as a fuel, a freezing agent, and in making other chemicals.

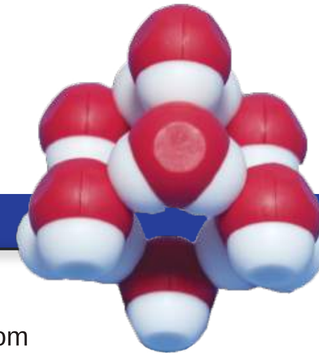
- What do the different colors on the ethane molecule represent? What is the chemical formula of ethane?
  White represents hydrogen atoms and the gray represents carbon. CH_3CH_3.

- What is the intramolecular bond that holds the hydrogen and carbon atoms within an ethane molecule?
  Covalent bonds.

- Is an ethane molecule a polar covalent molecule, or a nonpolar covalent molecule? Why?
  Ethane molecules are nonpolar covalent molecules because electrons are equally shared within the molecule. This equally charged molecule is nonpolar.

- Will ethane form a hydrogen bond with water? Why or why not?
  No, ethane will not form a hydrogen bond, or ionic bond with water or any other polar molecule because it is nonpolar. Ethane does not have any partial positive or negative charges.

- Will two ethane molecules form bonds with each other? Why or why not?
  No. Ethane molecules will not form covalent, ionic or hydrogen bonds with each other. Ethane molecules have small intermolecular forces and will interact under the certain temperature and pressure conditions to form liquids and solids.



Hydrogen Bond Activity and Questions (continued)

Give each student group an OH (hydroxyl) group* and have them replace the detachable hydrogen with the OH group. They have just changed the model from ethane to ethanol.

- What do the different colors represent? What is the chemical formula of ethanol?
  White represents hydrogen atoms, the gray represents carbon atoms, and the red represents oxygen atoms. CH_3CH_2OH.

- Will ethanol and water interact? How?
  The water molecules will form hydrogen bonds with the oxygen atom and the single polar hydrogen atom on the ethanol.

- Will ethanol molecules interact with each other? Why?
  Yes. Ethanol will form hydrogen bonds with other ethanol molecules.

- What is sodium chloride?
  Show sodium chloride to your class.

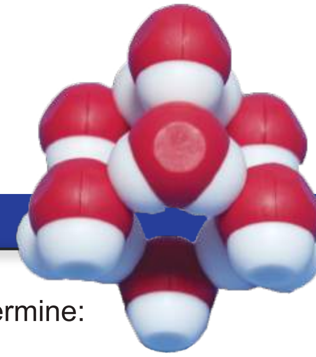
  Sodium chloride is an ionic compound often called table salt or rock salt.

- What do the colors represent? What is the chemical formula of sodium chloride?
  The blue atom represents sodium, the green chlorine. NaCl.

- The *intra*molecular bond that holds these ions together is ionic. What does this mean?
  Ionic bonds are formed when an electron is completely transferred from one atom to another. This results in a positively charged ion (the atom that looses an electron) and a negatively charged ion (the atom that gains an electron).

- Will a water molecule interact with sodium chloride? Why?
  Yes, water molecules and sodium chloride ions will interact. The partially charged water molecule will interact with the fully charged sodium chloride. These are intermolecular forces.

* The OH group, also called a hydroxyl group, is a functional group of the ethanol molecule. It is a way to refer to the part of the molecule that is polar – the oxygen atom and the hydrogen atom that is covalently bonded to the oxygen atom.



Hydrogen Bond Activity and Questions (continued)

Give each group of students the sodium chloride ions. Ask them to determine:
• which ion the hydrogen atoms interacts with.
• which ion the oxygen atom interacts with. Have your students record their findings.

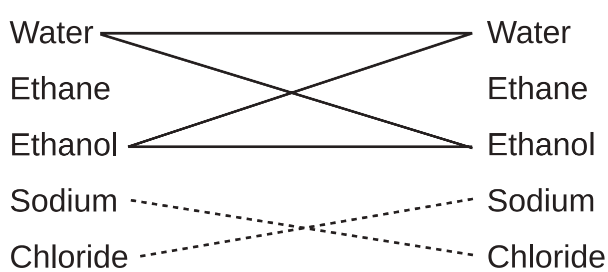
• Are chloride ions positively or negatively charged? Why?
Chloride ions interact with hydrogen atoms in water molecules. Since hydrogen atoms are partially positively charged, the chloride ions are negatively charged.

• Do hydrogen atoms and chloride ions form hydrogen bonds? Why?
No, the intermolecular force between the hydrogen atom and chloride ion is not a hydrogen bond because hydrogen bonds are only formed between hydrogen and fluorine, nitrogen and oxygen atoms.

• Are sodium ions positively or negatively charged? Why?
Sodium ions interact with oxygen atoms in water molecules. Since oxygen atoms are partially negatively charged, the sodium ions are positively charged.

•Will sodium chloride interact with ethane? With ethanol? Why or why not?
Sodium chloride will not interact with ethane because ethane is nonpolar. Sodium chloride will interact with the ethanol.

Have your students list water, ethane, ethanol, sodium and chloride in two columns. First, have them draw solid lines between the molecules that will form hydrogen bonds. Second, have them draw dotted lines between the ions that will form ionic bonds.



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Adhesion, Cohesion & Capillary Action

General Information

The attraction between two like molecules is **cohesion**.

The attraction between two unlike molecules is **adhesion**.

Adhesion and cohesion are intermolecular forces between two molecules. These forces are only called hydrogen bonds when a hydrogen atom and a fluorine, nitrogen, or oxygen atom are attracted to each other. Capillary action is the spontaneous rising of a liquid in a capillary (small diameter) tube.

Capillary action in plants is a good example of adhesion and cohesion. The inner surface of the xylem, the cell wall of a plant, contains positive and negative charges. Water forms hydrogen bonds with the xylem. This is called adhesion. As water creeps up the sides of the xylem (adhesion) the water molecules in the middle connect to other water molecules because of cohesion. The water moves up as the water molecules at the top of the xylem enter the leaves and evaporate (move out of the stomata in the leaf). When a water molecule leaves the leaf, the molecule behind it moves up causing a general movement of the water up the tree.

Tip: *Adhesion* **adds** *a different molecule to the substance.*

Water Kit©

When 3D water molecule models are attracted to another substance, the force is adhesion.

When 3D water molecule models are attracted to each other, the force is cohesion.

Activity

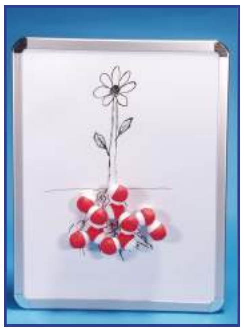
Demonstrate adhesion and cohesion by tying a string (dental floss or fishing line works well) around a 3D water molecule models. Hold the string in one hand and another 3D Water Molecule your other. Slowly bring the second 3D Water Molecule toward the one on the string. Students should see the hanging molecule move toward the molecule in your hand. Explain that this attraction is cohesion.

Next, bring an ethanol molecule toward the hanging 3D water molecule models.

Adhesion, Cohesion & Capillary Action

- What is the attraction between these molecules?
  The force is called adhesion because two different molecules are attracting.
  Test your students' grasp of adhesion and cohesion by hanging an ethanol molecule. Bring a second ethanol molecule toward the first.

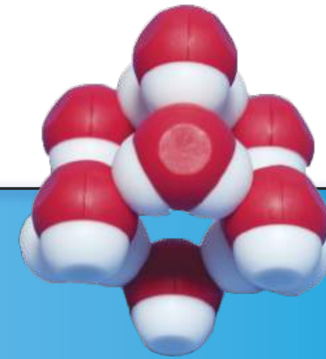
- What is the attraction between these molecules?
  The force is called cohesion because two like molecules are attracting.



Demonstrate capillary action by drawing a plant on a whiteboard. If your whiteboard is not magnetic, use a small magnet white message board. Place 11 of the 3D water molecules at the root of the outlined plant. Pull the molecules up the roots, through the stem and out the leaves of your plant with the molecule attached to the string. Note: Some of the water molecules will bond with the board and some to other water molecules.

Explain that this is capillary action. Water molecules form hydrogen bonds with cellulose in the xylem. The cellulose is composed of carbon atoms with hydroxyl groups (sugars). In addition, water molecules also form hydrogen bonds with each other.

- Does capillary action involve adhesion or cohesion?
  Capillary action involves both adhesion and cohesion. When water molecules are attracted to the xylem (as drawn on the board), adhesion is involved. When the water molecules are attracted to each other, cohesion is involved.



Surface Tension

General Information

Surface tension is due to the cohesion between molecules at the surface of a liquid. In a liquid, molecules are pulled in all directions by intermolecular forces. At the surface of a liquid, the molecules are only pulled downward and toward the sides. Surface tension is the amount of energy required to stretch or increase the surface of a liquid by a unit of measure.

Water Kit©

Water molecules are polar and have a relatively strong attraction to each other, called hydrogen bonds. This attraction (explained in the section labeled Hydrogen Bonding) is responsible for surface tension. Surface tension explains why water forms rounded drops on nonpolar surfaces like the waxy surface of an apple or a recently waxed car.

Activity

Have your students place drops of water on a variety of substances to test surface tension. Drops can be placed on paper, wax paper (or draw a solid rectangle with crayon on paper to simulate wax paper), paper towels, glass, plastic, fabric, plant leaves, etc. Have your students record the substance and draw the relative height of the drop.

Office Paper | Wax Paper | Paper Towel

- **Why does water bead up on some substances, like wax, and soak into others, like paper?**
  Water does not interact with nonpolar substances. Wax is a nonpolar substance; the water molecules are only being pulled toward each other, forming a sphere. Office paper has a coating which is more polar than wax, but less polar than paper towels. This results in a dome-shaped drop. Paper towels are more polar than office paper. Paper towels actually break the surface tension of water to absorb it.

- **Can anything walk on water?**
  Yes. Some insects, like the water strider, can walk on water.

- **Can you explain how an insect does this?**
  The hydrogen bonds are strong enough that certain insects can't break them and therefore can walk on the water molecules.

Surface Tension

Have your students pool 3D water molecule models together on a tray. Place a small toy insect on top and have your students gently shake the tray. The insect will stay on the molecules. Explain that this is surface tension.

- **Why can't all animals walk on water?**
  Their total mass is sufficient to break the intermolecular force of the hydrogen bonds between water molecules and they sink.

- **What would happen if an insect tried to walk on a nonpolar liquid (molecules that do not have charges)? Record your hypothesis.**

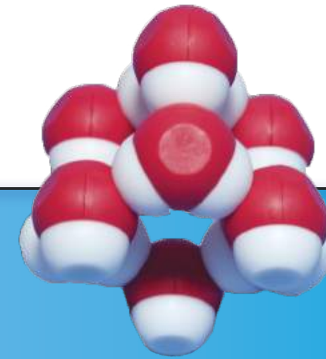
Pool several ethane molecules on a tray. Place a plastic insect on top and gently shake the tray. The insect will fall off.

- **Why did the insect fall through the surface of the nonpolar molecules?**
  There are no hydrogen bonds (cohesion) between the nonpolar molecules, therefore the insect falls between the molecules. While there are weak intermolecular forces between the ethane molecules, they are not strong enough to support the insect.

- **Can you predict what would happen if an insect tried to walk on a slightly polar liquid?**
  Have your students change the ethane to ethanol and repeat the activity. Results will vary with the weight of the insect and the number of hydrogen bonds formed by the ethanol. Now, have your students predict what will happen with actual liquids. Give each group a glass of water and one of vegetable oil representing 3D water molecule models and ethane, respectively. In addition, give each group a fork and several small metal paperclips.

- **Predict what will happen when you lay a paperclip on top of each surface. Why? Record your hypothesis and reasons.**
  Have students carefully place a small metal paper clip on the surface of a glass of water. Note: Students may have to practice this several times before they are successful. Using a fork to place the paperclip on the water can help. Paperclips should be dried thoroughly before trying to place them on a liquid again.

- **What is keeping the paperclip on top of the water? Is it floating?**
  No, the paperclip is not floating. The paperclip is resting on top of the water because the surface tension is stronger than the weight of the paperclip.



States of Water

General Information

Like other compounds, water can convert between solid, liquid, and gas phases. The remarkable property of water is that it is a liquid over a very large temperature range.

Water Kit©

3D water molecule models can be used to **demonstrate** the different phases of water as shown below.

Gas – 12 molecules separated. In the gas state individual water molecules are moving too fast and are too far apart to form hydrogen bonds.

Liquid – 12 molecules clumped together. In liquid water, the hydrogen bonds between water molecules are very short-lived. They are constantly forming, breaking, and reforming between other molecules.

Solid – 12 molecules connected in a repeating pattern or formation that form ice. In ice, the hydrogen bonds between water molecules are more stable and longer-lived.

Scientists have described 12 different structures of ice, many of which can be constructed with the Water Kit©. See pages 23 and 24 for directions on making hexagonal ice.

Activity

Demonstrate the three states of water as shown above.

Give each group of students 12 3D water molecule models. Challenge them to form an ice cube, an enclosed, stable ice lattice. After a few minutes, give students the hint that snowflakes, or ice crystals have six sides – they may want to try rings of six.

If your students are have trouble forming ice, print pages 23 and 24 for each group.

Display and discuss 12 3D water molecule models in the gas, liquid, and solid states.

- What are the differences between these groups of molecules? How does their volume differ?
  Water vapor, the gaseous state, has the greatest volume. The water vapor condenses to form liquid water. Then the water molecules expand to form the solid form of water, ice.

- Are these volume changes unique to water?
  All gases have greater volumes than liquids. Water, H_2O, is the only compound that expands as it freezes.

States of Water


Have your students discover how water expands as it freezes. They should form a lattice with 12 molecules and place it in a clear container, such as a bird feeder tube. Have your students measure and record the volume of water in this solid state. Next, they should gently push down on the molecules to break the hydrogen bonds until all the molecules are at the bottom of the container. Have you students measure and record the volume of the molecules in this liquid state.

Demonstrate that a 13th molecule can fit in the middle of an ice cube. Explain that when water freezes, the empty space, or void between the molecules increases.


Pool the ethane and ethanol molecules in separate containers and show them to your students.

- At room temperature, which substance is a gas and which substance is a liquid? Why?
  Ethane is a gas at room temperature because it is a nonpolar molecule which has a weak intermolecular force. It does not have a partial charge that would attract the molecules to each other. Ethanol is a liquid at room temperature because it is a polar molecule. The OH has a stronger intermolecular force, called hydrogen bonding, which attracts the molecules to each other.

Evaporation & Condensation

General Information

Evaporation is the transformation from a liquid to a gas. This occurs when a liquid absorbs enough heat, increasing the movement of the molecules, to cause the intermolecular forces between molecules to break the surface tension. This allows individual molecules to escape into the air. As water evaporates, the heat it absorbs breaks the hydrogen bonds and the liquid water becomes water vapor.

Condensation is the transformation from a gas to a liquid. This occurs when a gas is cooled enough that the molecules slow down to form stronger intermolecular forces with each other. As water condenses, the molecules slow down and form hydrogen bonds with each other as the water vapor cools.

Changes in pressure can also influence evaporation and condensation. As pressure increases, gases condense into liquids. As pressure decreases, liquids evaporate as gasses

Activity

- Have you ever tried to walk barefoot on hot sand, or black pavement in the summer? What was it like? What did you do?

  Tried to walk faster, keep my feet off the ground, find a cooler place to walk, put on shoes…

- When water molecules heat up they move faster as well. What happens when you heat, or boil, water?

  It evaporates.

Have your students rub their hands together to create friction.

- What are you producing with your hands?

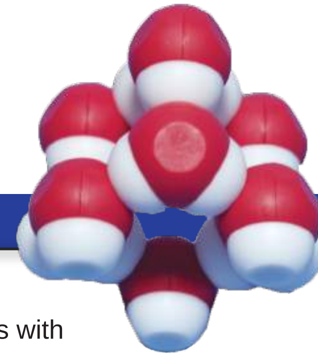
  Heat and/or energy.

Give each student three 3D water molecule models to hold between their hands. Have your students slowly move their hands together.

- What is happening to the water molecules (and the hydrogen bonds)?

  The molecules are moving around and slowly forming and breaking hydrogen bonds with each other.

This represents water in its liquid form. Have your students slowly increase the speed (heat) of their hands.



• What is happening to the water molecules now?

The water molecules are moving fast and are not forming hydrogen bonds with each other.

This represents evaporation and water in its gas state. To simulate condensation, have your students slow down their hands, drawing heat away from the molecules.

To help your students understand evaporation, have them place one drop of water and one drop of rubbing alcohol 4 cm apart on their forearms. Start a timer. Your students should observe and record findings.

• What did you observe?

The water forms a rounded drop due to its strong surface tension, while the rubbing alcohol flattens.

The rubbing alcohol evaporates within 2 minutes. Water takes much longer.

Explain to your students that body heat provides enough energy for the rubbing alcohol molecules to move fast enough to leave the surface of your skin. It takes about 290 cal per gram of rubbing alcohol for the molecules to evaporate, whereas, it takes 580 cal per gram of water to break hydrogen bonds between water molecules (calories are measurements of energy). Your body temperature at rest is not high enough to evaporate water rapidly.

Water fact: *580 cal of heat are needed to evaporate one gram of water at room temperature.*

Solubility

General Information

In the presence of water, salt dissolves. Water molecules always hydrate the sodium chloride.

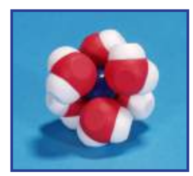
Ions are charged atoms that have gained or lost electrons as a result of an ionic bond.

Water Kit©

The Water Kit© comes with a blue sodium (Na) ion model and a green chloride (Cl) ion model. These two ions form an ionic bond to make sodium chloride (NaCl), often called table salt.

When water dissociates sodium chloride, the hydrogen atom interacts with the negatively charged chloride ion and the oxygen atom interacts with the positively charged sodium ion.

Note: The Water Kit© can demonstrate the principle behind hydration, but it cannot simulate the true chemical reaction. Many more water molecules would be needed.



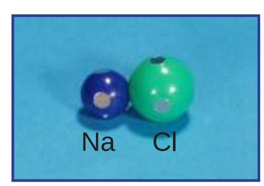
Activity

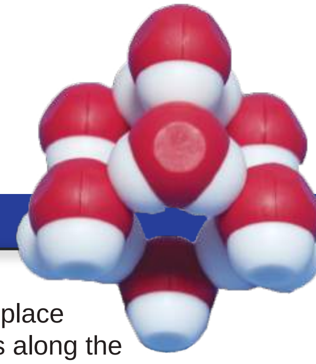
Hand out a sodium ion and a chloride ion to each group.
Have them explore what happens when they are brought together.

- Why did the sodium and chloride ions come together?
  Sodium has a positive (+) charge and chloride has a (-) negative charge. They form an ionic bond.

- What is the chemical formula for this? What is the compound?
  NaCl. NaCl is often called table salt.

- What happens when you put salt in a cup of water?
  It dissolves.





Solubility

Give each student group 12 3D water molecule models and a tray. Have them place the sodium chloride in the center of the tray and the 3D water molecule models along the edges. Your students should gently shake the tray.

- Using your 12 3D water molecule models and salt ions, can you explain what happens when you put salt in water?

  The sodium, a positively charged ion, is attracted to the oxygen of a water molecule and chloride, a negatively charged ion, is attracted to the hydrogen of the water molecule. Water molecules surround the entire sodium and chloride, breaking them apart.

- What happens when you keep adding salt to a glass of water? Why does this happen?

  Eventually, salt begins to form at the bottom of the glass when there are not enough water molecules to surround the salt.

- What is this called?

  This is a saturated solution. The solution contains the maximum concentration of a solute dissolved in a solvent. Additional solute will not dissolve when the solution becomes saturated.

- What happens to a glass of salty water when it is heated to boiling?

  The water evaporates leaving the sodium and chloride to bond to form salt again.

Give each group of students an ethane molecule. Have them put it in the center of the tray and the 3D water molecule models along the edge. Have your students gently shake the tray.

- Will water dissolve ethane? Why or why not?

  No. Water cannot dissolve ethane because ethane is nonpolar. Water cannot form hydrogen bonds with ethane.

Appendix

Just for Fun

The Water Kit© can be fun as well as educational! Here are some fun activities to do with your students.

Chain of Life

Have students guess how many 3D water molecule models can be strung on a chain before the chain breaks. Test their predictions.

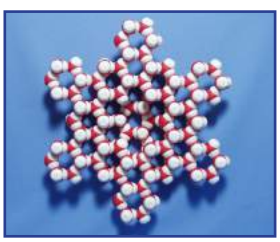
Keep Score with Water!

Hang one 3D water molecule model from the ceiling. As each student correctly answers a water-related question, have them add a molecule to the chain. After enough students have correctly answered questions – and the chain breaks, declare No Homework!

Building with Molecules

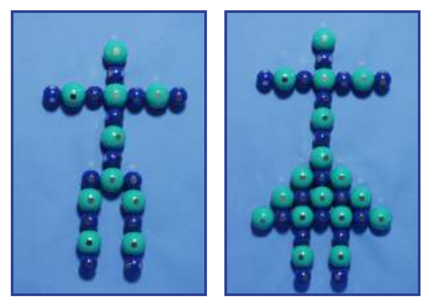
Try to build shapes with 3D water molecule models!

Snowflakes



Pyramid

NaCl



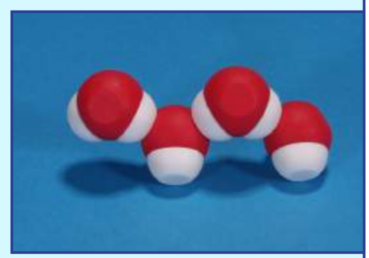
Just For Fun Activities

Cubic Ice

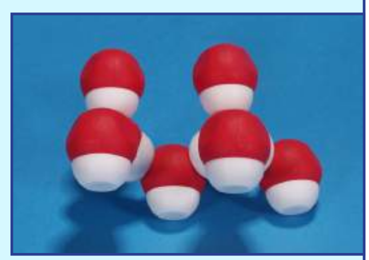
Cubic ice, (Ice 1c) is one of the 12 structures of ice identified by scientists. Cubic ice cubes can be created with as few as 10 molecules, while hexagonal ice requires 12. Check the 3D Molecular Designs website for more information on ice and how to construct some of the 12 different structures of ice. To create a cubic ice cube, follow the directions for either the *Step Method* or the *Pattern Method* (on the next page).

Step Method

1. Create the body of a dragon as shown in the first picture.

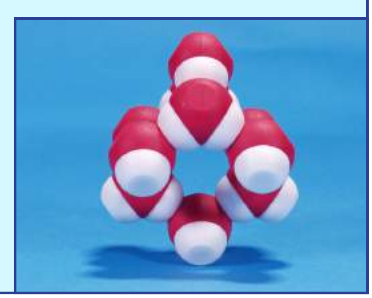


2. Add ears and wings to the dragon as shown in the second picture.
   Note: *the hydrogen atoms should point down on both the ears and wings.*



3. Connect each ear to a wing as shown in the third picture.

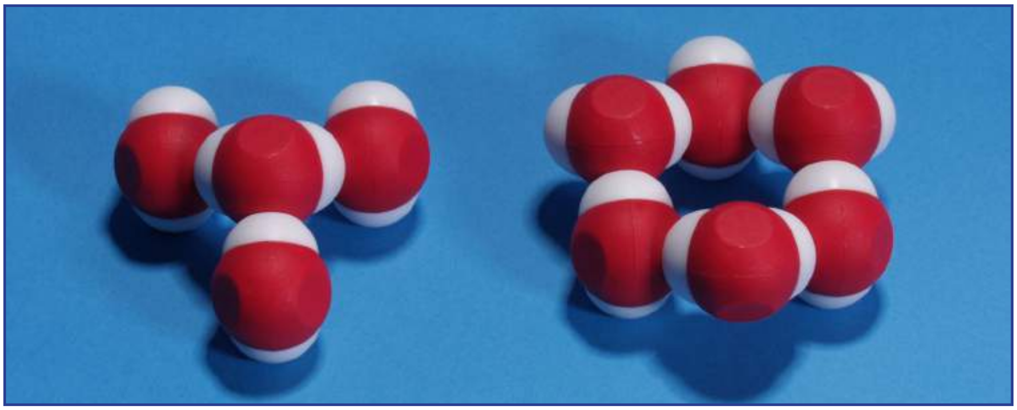
4. Remove the tail and place the final piece to create the cube as shown in the fourth picture.

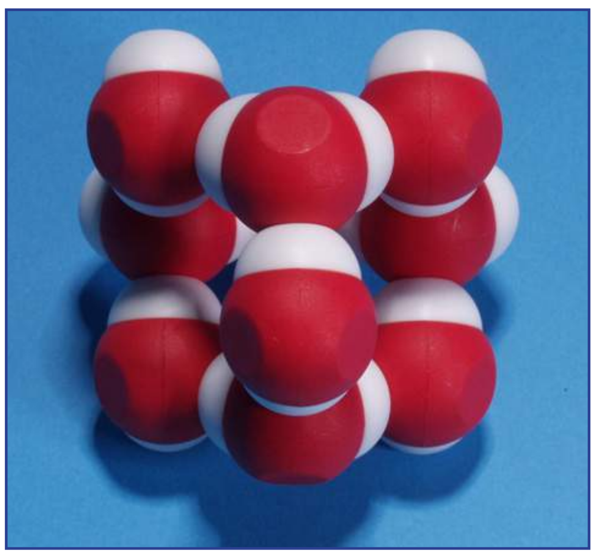


Just For Fun Activities (continued)

Pattern Method

Create a Y and a ring using the pattern below. Without rotating the Y, place it on top of the ring.

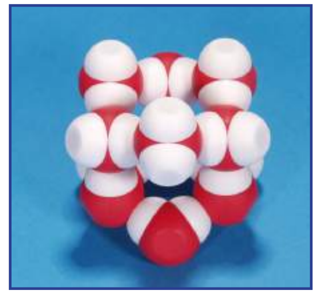




Just For Fun Activities (continued)

Hexagonal Ice

Scientists have described 12 structures of ice, many of which can be constructed with the Water Kit©. Check the 3D Molecular Designs website for more information on ice and how to construct some of the 12 different structures of ice. To construct Ice 1h, hexagonal ice, follow the directions for the *Step Method* or the *Pattern Method* (on the next page).



Step Method

1. Hold one molecule horizontally in front of you with the hydrogen atoms to the sides.

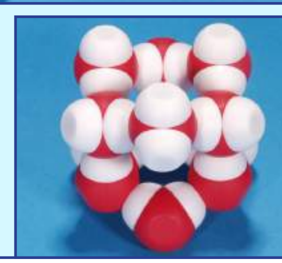
2. Add two vertical (hydrogen atoms pointing up and down) molecules to the two hydrogen atoms from the first step. *See the first picture on the right.*

3. Add a horizontal molecule to the lower hydrogen on each molecule added in step 2. *See the 2nd picture to the right.*

4. Add one vertical molecule to connect the hydrogen atoms from the molecules added in step 3. *See the 3rd picture to the right.*

5. Create a second hexagonal ring following steps 1-4.

6. Orient the two hexagonal rings the same way – then rotate one ring 180 degrees.



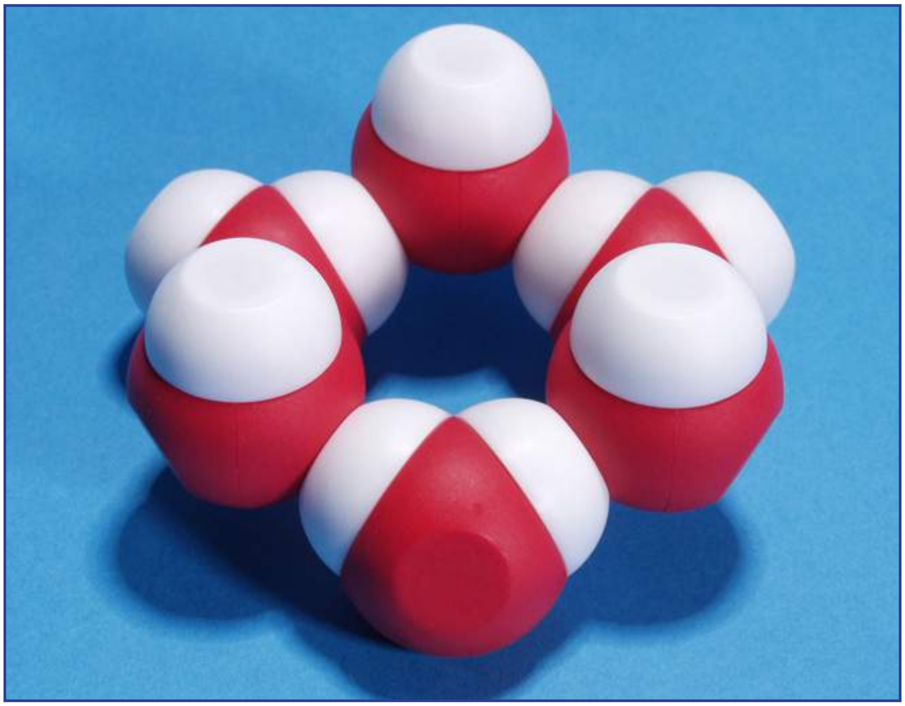
7. Place one hexagonal ring on top of the other. Do not flip one ring over – the hydrogen atoms on both rings should point the same way.

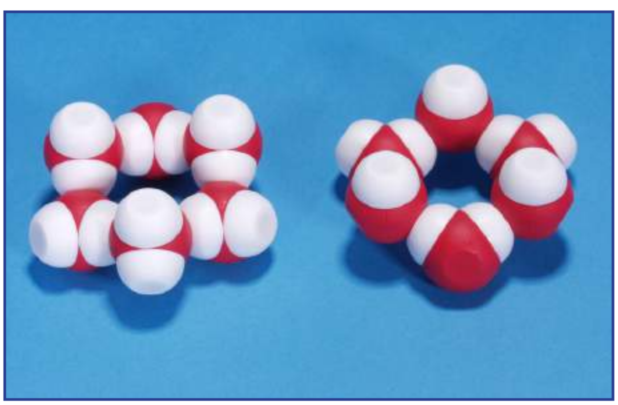
You have now formed a model of an ice cube. Note that it is possible to place a 13th water molecule into the hole formed by this lattice. Now you can see why ice floats. Ice has empty spaces in it. The same volume occupied by 12 water molecules in a solid ice lattice, can contain more water molecules in its liquid form.

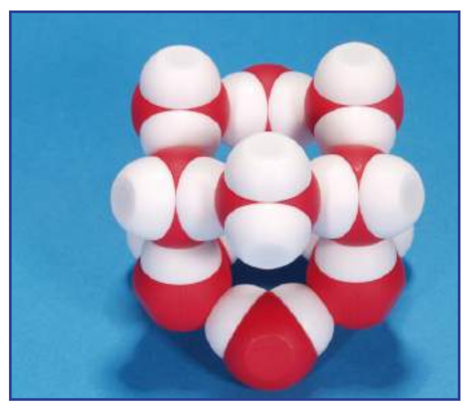
Just For Fun Activities (continued)

Pattern Method

Use this pattern to construct hexagonal Ice (Ice Ih). Create two rings, turn one 180 degrees, and stack one ring on top of the other.







3-D Molecular Designs

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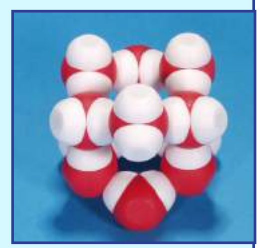
Just For Fun Activities (continued)

Snowflakes

Scientists have described 12 structures of ice, many of which can be constructed with the Water Kit©. To form a six-sided snowflake, you will need 6 or 7, 1-Cup Water Kits©.

Hexagonal Snowflakes

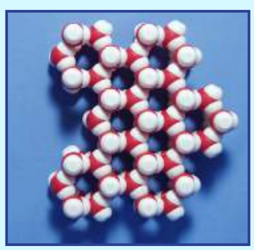
Make 6 or 7 ice cubes following the hexagonal ice instructions. Your cubes should look like the picture on the right.



Connect your hexagonal ice cubes to form a hexagon. Each cube will be oriented the same way.

If you have problems creating a hexagon, then try to connect six cubes around a center cube.

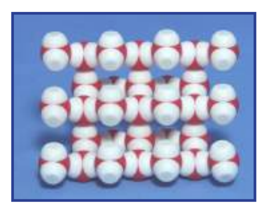
If you only have six cups, then remove the center cube and rotate it to complete the outer hexagon.



Without a center cube, which requires the seventh cup of the Water Kit©, this structure is not very strong.

Other Ice Crystals

If you do not create uniform cubes, it may be difficult to connect several cubes, and you will be unable to produce a six-sided snowflake. It is possible to create larger ice crystals by connecting several of the cubic ice cubes and some of the other 12 forms of ice described by scientists. Information on constructing other forms of ice will be posted on the 3D Molecular Designs website as they become available.



Glossary

Adhesion is the attraction between two unlike molecules.

Capillary action is the spontaneous rising of a liquid in a capillary (small diameter) tube.

Cohesion is the attraction between two like molecules.

Condensation is the transformation from a gas to a liquid. This occurs when a gas is cooled enough that the molecules slow down to form stronger intermolecular forces with each other. As water condenses, the molecules slow down and form hydrogen bonds with each other as the water vapor cools.

Covalent bonds are formed when two atoms share two electrons. A covalent bond is an intramolecular bond within one molecule. Covalent bonds can be either polar (which have partially charged atoms) or nonpolar (without charged atoms).

Evaporation is the transformation from a liquid to a gas. This occurs when a liquid absorbs enough heat, increasing the movement of the molecules, to cause the intermolecular forces between molecules to break the surface tension. This allows individual molecules to escape into the air. As water evaporates, the heat it absorbs breaks the hydrogen bonds and the liquid water becomes water vapor.

Hydrogen bonds are an intermolecular force between the two molecules where a positively charged hydrogen atom interacts with a negatively charged fluorine, nitrogen or oxygen atom in a second molecule.

Ionic bonds are the complete transfer of an electron between two atoms resulting in one positively and one negatively charge atom. Ionic bonds are intramolecular bonds within one molecule.

Ions are charged atoms that have gained or lost electrons as a result of an ionic bond.

Nonpolar molecules do not have unequal regions of charges and therefore do not interact with polar molecules. Oil and ethane are examples of a liquid and a gas composed of nonpolar molecules.

Polar molecules have partial charges. Polarity refers to the partial positive charge (+) and partial negative charge (-) that a molecule has when electrons are unequally shared between two or more atoms. Water molecules are polar molecules.

Surface tension is the amount of energy required to stretch or increase the surface of a liquid by a unit of measure. Surface tension is due to the cohesion between molecules at the surface of a liquid. In a liquid, molecules are pulled in all directions by intermolecular forces. At the surface of a liquid, the molecules are only pulled downward and toward the sides.

3-D Molecular Designs

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National Standards

Connections to: A Framework for K-12 Science Education

Practices, Crosscutting Concepts, and Core Ideas*

Dimension 1: Scientific and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
5. Using mathematics and computational thinking

Dimension 2: Cross Cutting Concepts

1. Patterns
2. Cause and effect: Mechanism and explanation
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter: Flows, cycles, and conservation
6. Structure and function
7. Stability and change

Dimension 3: Disciplinary Core Ideas:

Physical Sciences

PS1: Matter and Its Interactions
PS1.A: Structure and Properties of Matter
PS1.B: Chemical Reactions
PS2: Motion and Stability: Forces and Interactions
PS2.A: Forces and Motion
PS2.B: Types of Interactions
PS2.C: Stability and Instability in Physical Systems

Life Sciences

LS1: From Molecules to Organisms: Structures and Processes
LS1.A: Structure and Function
LS2: Ecosystems: Interactions, Energy, and Dynamics
LS2.A: Interdependent Relationships in Ecosystems
LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
LS2.C: Ecosystem Dynamics, Functioning, and Resilience

Earth and Space Sciences

ESS2: Earth's Systems
ESS2.A: Earth Materials and Systems
ESS2.C: The Roles of Water in Earth's Surface Processes
ESS2.D: Weather and Climate
ESS3: Earth and Human Activity
ESS3.A: Natural Resources
ESS3.D: Global Climate Change

**The NSTA Reader's Guide to A Framework for K-12 Science Education, National Research Council (NRC), 2011. A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Washington, D.C.: National Academies Press.*