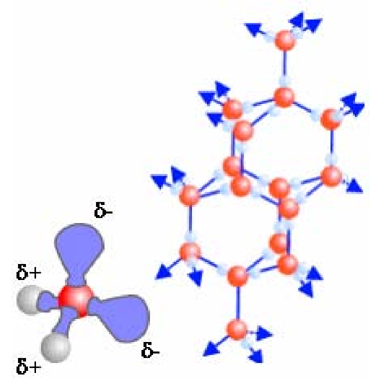
MAIN MENU

ICE HAS STRUCTURE: H_2O

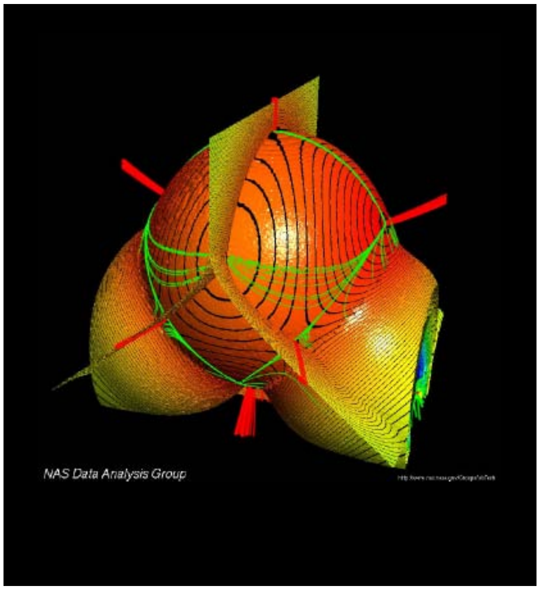
LESSON DIRECTORY

PHOTO GALLERY



This activity develops precursor understanding about the meaning of H_2O by modeling the known structure of ice and exploring the implications.

SCIENCE & LITERATURE



(Image source: NASA Ames, NAS Data Analysis Group)

By understanding the small-scale geometry of the water molecule, we can better understand the large-scale structure and behavior of water and ice. Even though we cannot see molecules directly, scientists have developed a variety of ways of measuring and modeling molecular structure.

> “In the study of ice…we must begin with a study of the water molecule, for it is from the individuality of the structure of that molecule that most of the unusual properties of ice and water arise.”
>
> —N. H. Fletcher,
> *The Chemical Physics of Ice*
> *Cambridge University Press, 1970.*

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CONCEPT OVERVIEW

This activity develops precursor understanding about the meaning of H_2O by modeling the known structure of ice and exploring the implications.

Concepts:

- Modeling
- Molecules
- Bonds
- Force Fields

This Activity Provides a Concrete Experience of:

- Why the scientific name for both water and ice is H_2O
- Modeling the molecular structure of H_2O

PRE K–GRADE 2 CONCEPTS

- Molecules are made up of combinations of atoms, tiny building blocks of nature, made up of very tiny particles, held together by bonds
- The scientific name for all forms of water (vapor, steam, liquid water, ice) is H_2O, which means that a water molecule has two atoms of hydrogen attached to one atom of oxygen
- We know from X-ray measurements that a water molecule is triangular in shape and we can make a model of a water molecule

GRADE 3–5 CONCEPTS

- Molecules are made up of combinations of tiny constantly vibrating atoms, held together by flexible, spring-like bonds and force fields
- A water molecule is composed of two hydrogen atoms bonded to one oxygen atom, and therefore known as H_2O
- As measured by X-rays, each water molecule has a triangular shape: the two hydrogen atoms form an angle of about 104° between them, which widens to about 109° as it freezes
- As ice forms, the molecules of water bond together using hydrogen bonds, forming slightly twisted hexagonal tetrahedrons
- Even though a molecule is too small to see with our eyes, we can use scientific measurements to construct a model of what water molecules are like and how they bond together to form ice

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LESSON SUMMARY & OBJECTIVES

This lesson invites young students to explore the molecular geometry and mechanics of ice. One objective of this lesson is to give meaning to the notion of how ice has structure, described by the term H_2O.

Objective 1: Notice that the name, H_2O, describes how water is composed of atoms combined into molecules.
Scientists use the term H_2O to describe the molecular structure of water. This means that water is formed through the bonding together of one atom of oxygen and two atoms of hydrogen.

Objective 2: Notice that a water molecule has a consistent shape.
A water molecule has a consistent triangular shape. This affects the properties of water (its polarity, for instance) and how ice forms into crystals that are *hexagonal tetrahedrons* in shape.

Objective 3: Notice that making a model of H_2O can help us explore the phenomenon of ice
We can model the shape of a water molecule in various ways and explore how water forms into ice crystals when it freezes. For young students, the *model itself* is a concrete experience. An explicit connection between the *reality* of ice and the *model* of ice must be kept in focus.

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STANDARDS

PROJECT 2061 BENCHMARKS

11B Common Themes Models

GRADES K–2, PAGE 268

- A model of something is different from the real thing, but can be used to learn something about the real thing.

GRADE 3–5 PAGE 268

- Seeing how a model works after changes are made to it may suggest how the real things would work if the same were done to it.
- Geometric figures, number sequences, graphs, diagrams, sketches, number lines, maps, and stories can be used to represent object, events, and processes in the real world, although such representations can never be exact in every detail.

4D The Physical Setting Structure of Material

GRADES K–2, PAGE 76

- Things can be done to materials to change some of their properties, but not all materials respond the same way to what is done to them.

GRADE 3–5 PAGE 77

- Heating and cooling cause changes in the properties of materials. Many kinds of changes occur faster under hotter conditions.

NSES:

Content Standard Unifying Concepts and Processes: Evidence, models, and explanation

GRADES K–12, PAGE 117

- Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

Content Standard A Science as Inquiry: Understanding about scientific inquiry

GRADES 5–8, PAGE 148

- Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories. The scientific community accepts and uses such explanations until displaced by better scientific ones. When such displacement occurs, science advances.

Content Standard B Physical Science: Properties of objects and materials

GRADE K–4 PAGE 127

- Matter can exist in different states—solid, liquid, and gas. Some common materials, such as water, can be changed from one state to another by heating or cooling.

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ESSENTIAL QUESTION

How Does the Structure of Water Help Us Understand Ice?

How do scientists observe the molecular structure of ice? What is the molecular structure and geometry of ice? What makes water shaped the way it is?

ACTIVITY QUESTION

What Can We Learn About Ice Through Models?

How can we model the triangular shape of the water molecule and the hexagonal shape of ice crystals? What features of the structure and geometry of ice can we represent? What can we say, draw, write about the structure of ice that we look at, touch, and examine in class?

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BACKGROUND

Molecular Structure Helps Understand Large Structures

To gain a proper understanding of the behavior of a complex system we must first appreciate the structure and properties of the elementary units of which it is composed. **In the study of ice** this means that **we must begin with a study of the water molecule, for it is from the individuality of the structure of that molecule that most of the unusual properties of ice and water arise**.
—N. H. Fletcher, *The Chemical Physics of Ice Cambridge University Press, 1970*

Young Children and H_2O

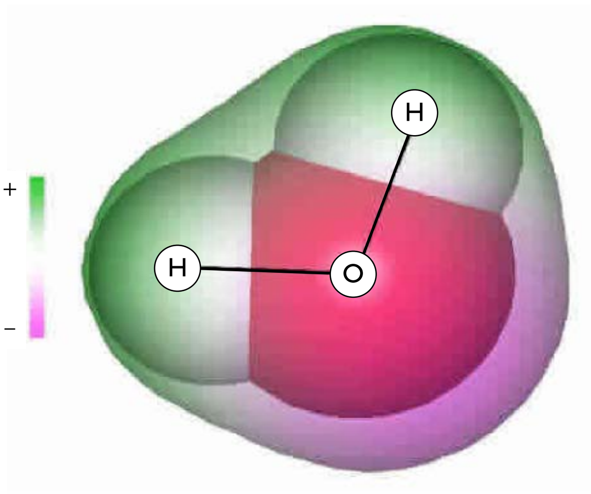
Even very young children may have heard that water is H_2O. One objective of this lesson is to give meaning to that commonplace term, H_2O, that water is made of one atom of oxygen (8 protons and 8 electrons) and two atoms of hydrogen (1 proton and 1 electron) in a triangular shape.

This activity presents two main challenges: 1. to update the accuracy of our own adult understanding about atoms and molecules; and 2. to use models to refer to a phenomenon that the children cannot directly observe and to be aware of possible misconceptions inherent in the models we are using.

Thinking About Atoms and Molecules

Molecules are special combinations of atoms. A water molecule is composed of two atoms of hydrogen bound to one atom of oxygen, or H_2O. We know this because, through electrolysis, we can break water molecules apart and put them back together. Nicholson and Carlisle first discovered this in 1801 and Michael Faraday made this discovery famous in the 1820s through a series of public demonstrations.

Michael Faraday was one of the pioneer scientists studying the properties of electricity. He delivered a series of popular lectures about the *law of electro-chemical decomposition*, or *electrolysis*,* which means literally, using electricity to break something apart. When he placed two electrodes into water, he found that the electrical energy was sufficient to break apart the bonds holding the constituent parts of water. The result is the release of two gases. He captured the released gases and identified them by introducing a glowing ember: a lighter than air gas that reacts explosively and leaves a residue of water (hydrogen), and a second gas that makes a glowing ember brighten (oxygen).



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* Not to be confused with the use of the word to refer to a method of hair removal.

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Faraday was explaining the Nicholson & Carlisle electrolysis demonstration, which was first discovered in 1801.

Hydrogen was discovered by Henry Cavendish who described it in his work “On Factitious Airs” published in 1766, and was originally called “inflammable air”.

Joseph Priestly discovered oxygen, which makes up about one fifth of our atmosphere, in 1774. Because of its involvement in burning, it was often called “fire air”.

A single molecule of water is too small to be seen directly. Scientist’s infer the shape of molecules by measuring patterns of vibration in the combination of its constituent atoms. Recent advances have led to more detailed ways to model the shape of atoms and molecules. For example, X-rays can be used to measure the charge densities around a molecule that define the space taken up by its electron cloud (see: X-ray crystallography section of Resources).

Imagining Water Molecules ‘Mimediately’

Atoms can be thought of as vibrating spherical fields composed of a dense fist-like nucleus of positive charge surrounded by a finger-fluttering cloud of negative charge. If you were to act it out: you could let one hand fold into a fist and be the positively charged nucleus. Let the other hand flutter about the fist as the negatively charged electron cloud. At the scale of a nucleus the size of your fist, if you were standing in the middle of a sports stadium (pick your own favorite sports stadium image: baseball, football, soccer), your arm would need to be able to reach to the outer bleachers as it flits about to show the space projected by the electron cloud! The shape of the atom is defined by all of the space reachable by the electron cloud (the whole volume of the stadium).

To form a water molecule, hydrogen and oxygen atoms bind together by overlapping their outer regions of electron cloud space in a way that interweaves and balances the vibrating fields of positive and negative charges of the atoms involved. The shape of the space occupied by a molecule’s electronic charge density (the electron cloud) can be measured and the results can be mapped to make a model.

Knowledge of the shape helps us understand the phenomenon. The water molecule is consistently triangular in shape. The two hydrogen atoms bind at an angle of about 104° in liquid water and stretch to about 109° in solid ice.

This structure tends to cluster the electron cloud around the oxygen more densely than around the two hydrogen atoms—this results in a polarity—the oxygen side of the water molecule has a negative polarity and the hydrogen side has a positive polarity. The slight stretching as water freezes also defines how water molecules fit together as hexagonal tetrahedrons bind to form ice. Even so, scientists still have much to learn about water and ice.

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Molecular Modeling

In the molecular mechanics model, a molecule is described as a series of spherical charges (atoms) linked by springs (bonds) that can bend, stretch and twist. The model simplifies things by disregarding the effect of the electrons. A mathematical function (the force-field) describes the freedom of the bond-lengths, bond angles, and torsions to change. The force field also contains a description of the van der Waals and electrostatic interactions between atoms that are not directly bonded. The force field is used to describe the potential energy of the molecule or system of interest.

The Role of Models in Scientific Inquiry and Science Learning

Models are powerful intellectual tools of scientific inquiry. Scientists use models to propose explanations about difficult-to-understand phenomena. If you were to listen in as scientists talk with each other, you would hear them argue about models. A scientist might say, "this model works to explain *this*, but it fails to account for *that*." By testing how well the model fits the data, scientists develop and refine a model. This discourse is a way for scientists to discuss the *intangible* features of the phenomenon itself, through the *tangible* features of the model. But scientists also know that *the model is not the phenomenon*.

In school science, explanatory models are also used. The distinction between the *model* and the *phenomenon* it seeks to explain is sometimes blurred. In teaching about atoms and charges, for example, textbooks have used the convention of red as illustrating positive charge, blue as negative charge, and black as neutral. This inadvertently resulted in many students thinking that protons are actually red, electrons are really blue, and neutrons are truly black—none of which is accurate. The concrete experience of making and working with a model is a *precursor* to the abstract understanding of the phenomenon it seeks to explain.

Playing with different ways to model the shape and structure of water molecules can lead to deeper understanding, as long as we also remain aware of the constraints involved. No model perfectly communicates accurate understanding. *Why not let the students in on this along the way?* As students play with the model-making process, invite them to discuss what they think the *model* has to do with the *reality* of the water molecule?

Knowing about the H_2O molecular structure helps explain the behavior of liquid water and the crystalline structure of ice. While a molecule is too small to see directly, we have science instruments that reveal the patterns of molecular vibrations—from these measurements, scientists are confident of the geometric arrangement of H_2O: the two H atoms forming an angle of $\sim 104°$ as liquid water and $\sim 109°$ as solid ice. Yet, there is still much more to understand about H_2O.

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ACT OUT THE SCIENCE

Whole Group Mime Activity: Movement
Integration Mediating Experience
The Story of H_2O

Narrative	Movement	Meaning
You've probably heard that water and ice are made of H_2O. What does this really mean? Let's explore this *mimediately*. Everyone stand up. Let's see if we can figure this out together.	Have everyone stand up in an open area. Make sure everyone has plenty of room to move without bumping into anyone or anything.	We are going to use the hands and then the whole body to create an experiential model of H_20.
First, put up your hands, shake them out. Roll your hands into a fist, and then unroll. Good.		
Okay, now we are going to make models of molecules of water—out of ourselves! So, what is H_2O? First, let's explore what the H means: hydrogen. What's hydrogen? It's a tiny atom with a proton and an electron. Hydrogen is what stars are made of. And it's mostly what we are made of. Hydrogen is in a lot of the foods we eat: have you ever heard of proteins and carbo*hydrates*? Got hydrogen? When we eat proteins and carbohydrates and when we drink water, we're *hydrogenating* ourselves!	Invite students to mention and mime different protein and carbohydrate foods that have hydrogen as part of their structure.	This illustrates H_2O in a dynamic, kinesthetic way, comparable to a graphic illustration. This sequence builds a precursor understanding of atoms and molecules.
So let's start making a model of Hydrogen. Let one hand roll into a fist. We'll call this fist a powerfully positive proton. It is the center, or the *nucleus*, of an atom of hydrogen.	Have everyone form one fist, in the air, to show a proton.	

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Narrative	Movement	Meaning
Now, let the other hand, with its fingers opening and closing and zipping around, sometimes in close to your powerfully positive proton, sometimes jumping about. This represents an energetic electron cloud.	One hand remains playing the part of the powerfully positive proton, as the other hand moves around as the energetic (and negatively-charged) electron cloud.	
If you could move your hand as fast as an electron, it would seem to be everywhere all at once as far as it could reach.		
If a proton were really as big as your fist, your arm would have to be 100 to 200 yards long. We'd have to reach from here to …select a familiar spot to make this point… and move so fast as to be everywhere in every direction filling up that space.	Let everyone stretch their arms, imagining that they are getting longer and longer.	Scale: if you were standing on the pitcher's mound, your arm would have to reach to the outer bleachers and race around in all directions to fill up the volume of space defined by the electron cloud
Together, your powerfully positive proton and your energetic electron cloud make up an atom of Hydrogen. When two of them join up with an oxygen atom, it makes H_2O. Got water?	Together, the fist and the rapidly moving open hand, represent an **H atom**.	An H atom—with proton nucleus and electron cloud.
Let's make a new model to fit this all together: imagine now, that your head is an atom of oxygen, O, and each of your hands, a hydrogen atom ready to connect, forming a covalent bond, which you can show as your arms. Hey, they're already connected!	Take a moment to shift the scene from the two hands showing the H atomic structure to the H_2O: the head is now the O atom; the two fists are the two H atoms. The arms represent the covalent bond that holds the H close to the O.	

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Narrative	Movement	Meaning
Oxygen attracts two H atoms to make a triangular shape. Stretch your arms as if you were about to give a bear hug (~104°). Notice that it's a little wider than if we were making the shape of the corner of a square (90°).	The two arms become the two H atoms that seek to join the O	This forms a covalent bond, a sharing of electron cloud space.
Now each of us is a water molecule. H– shake your fist—2– shake both your fists—O– bob your head. Hey, look, we're *bobbled water!*		
At room temperature, we all just slosh and bobble around as liquid water, but if it gets colder… down close to within 4°C of freezing, we start moving closer together, more densely packed—but just as we reach freezing, we water molecules expand and connect!		These connections are *hydrogen bonds*. This also anticipates understanding why ice floats
Slightly widen your bear hug angle to ~109° and you'll notice that we just fit six of us to form a ring, hand to shoulder—this shape is a six-sided hexagon, and we are now frozen ice crystals!	The precise difference between 104° and 109° angle is not so important. But it is important to understand that the slightly larger bear hug makes a difference—between water and ice.	The difference between 104° and 109° is very slight, yet the distinction is critical because it helps explain structurally why ice is less dense than water.

Note: The diagram on page 13 will help you guide the 'frozen H_2O molecules' into a hexagonal arrangement.

MATERIALS

The activity enables students to apprehend the structure of ice. The activity works best when a variety of media can be accessed to make the models.

For All Activities, to Record Reflections, Observations, Calculations, etc.

- Science Notebooks: writing and drawing utensils.

Demonstration

- Images to support telling of Faraday's story of the decomposition of water.
- Props for describing Faraday's experiment: long black and red pipe-cleaners, clear container of carbonated water

Main Activity

- Varied 2D and 3D visual, graphic, and dynamic molecular modeling representations of H_2O
- PreK–2: Drawing materials for 2D; Modeling clay for 3D
- 3–5: Various art and crafts materials to be used to construct models of H_2O ice. For example: Drawing materials, modeling clay, molecule model kits, spheres of different sizes that can connect together

Science Resource Materials

- Pages from textbooks and scientific papers that illustrate and explain H_2O.

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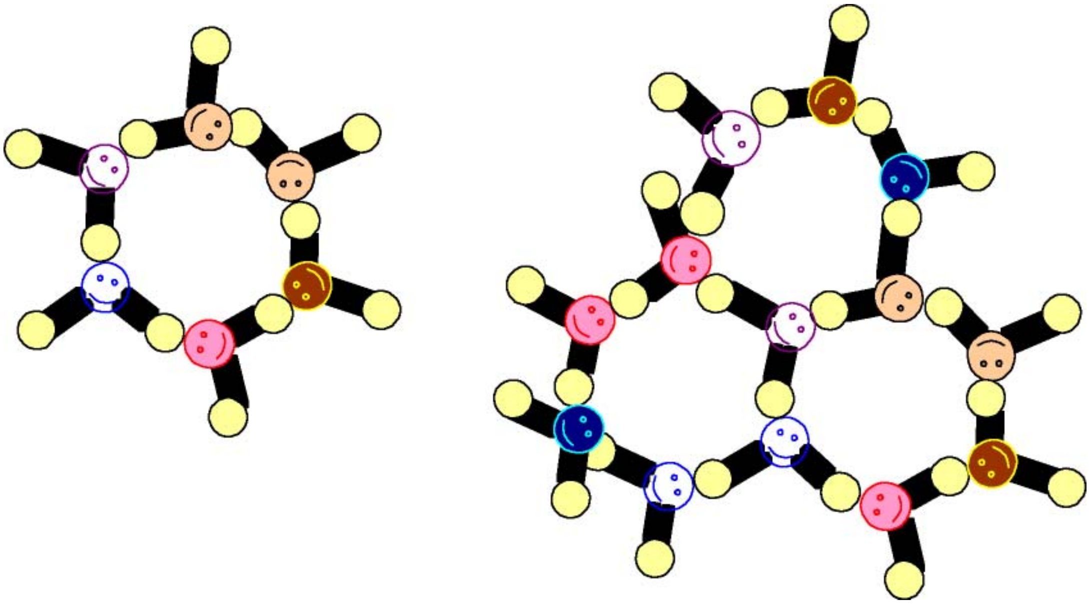

Arrangement of student 'water molecules' in hexagons, representing ice.

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DEMONSTRATION

Tell the Story of Faraday's Classic Demonstration of the Composition of Water

Purposes:

- To demonstrate how we know that water is H_2O;
- To communicate the history of a significant scientific result.

One way to understand the structure of something is to take it apart and put it back together. We can take apart molecules of water using electricity.

PRE K–5

Story: Tell in a highly animated, highly gestured manner.

Today, anyone can go to the store to buy a battery to make something work. (Invite 2 students to be your assistants) Back in the 1800's, people were just beginning to understand electricity. Back then, they were just learning about batteries. Michael Faraday found that if he created a *positive charge* in one wire (hand one student the red pipe-cleaner) and a *negative charge* in another wire (hand the other student the black pipe-cleaner) and put them several inches apart into a bowl of water (have students place the pipe-cleaners into a bowl of carbonated water), each wire would generate bubbles. He was curious—what were the bubbles made of? So he captured the bubbles by putting a glass tube over each wire in order to catch the bubbles as they percolated up through the water. (teacher or other students mime this) He found that on the positive side, he caught a volume of gas twice the volume as on the other. What was going on?

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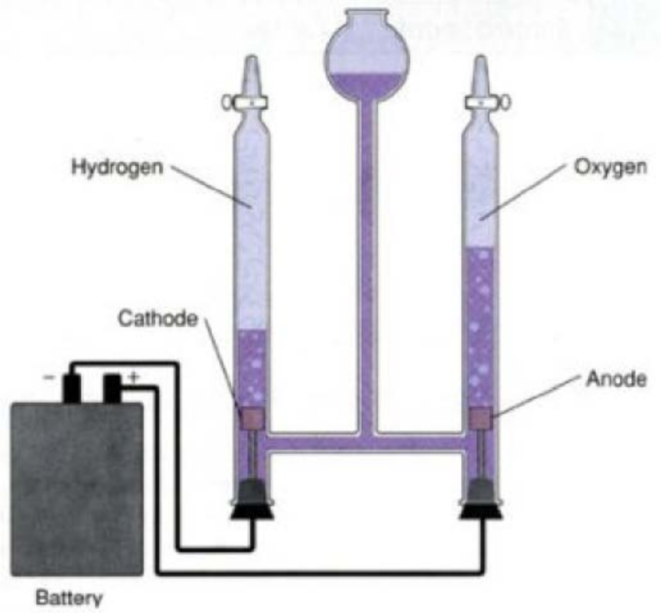
It turns out that the electrical charges *took apart the water.* The electricity literally broke the *covalent bonds* holding together the parts of the molecules. (Show older students the picture of the apparatus.) We call these parts, atoms. In the case of water, there are two kinds of atoms, that we call hydrogen and oxygen. How did Faraday know what the bubbles of gas were made of? He experimented! He introduced a glowing ember on the end of stick into the oxygen side; it glowed brighter, making the burning go faster, typical of oxygen. When he introduced a glowing ember to the other side, where there was twice as much volume of gas, it reacted by burning explosively with a pop!—but instead of ash, water was left over! The name *hydrogen* means, "generating water," that is, "making water".

So, what does this all mean? By taking water molecules apart, we learned that there was twice as much hydrogen as oxygen. The chemical symbol for hydrogen is H. The symbol for oxygen is O. So the recipe to make water calls for two parts H and one part O: that's why we call water H_2O.



Hoffman apparatus uses battery-generated electricity to split water into hydrogen (collected at the cathode side) and oxygen (collected at the anode side). This is the apparatus used originally by Nicholson and Carlisle and later by Faraday to demonstrate the composition of water and the principles of electrical decomposition.

Credit: Prof. Egenii Katz, Department of Chemistry, The Hebrew University of Jerusalem Givat Ram. http://chem.ch.huji.ac.il/%7Eeugeniik/history/nicholson.html

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MAIN ACTIVITY

PREPARATION

Create a gallery display of various 2D and 3D visual, graphic, and dynamic representations of H_2O in its different phases. You can select and print out a series of pictures from the gallery of images provided on this CD-ROM or on the web. You can make you own model of H_2O.

OPTION 1:

Arrange the pictures and models for viewing one by one as a whole group, in hard copy or computer-projected.

OPTION 2:

Arrange the pictures and models around the room as viewing stations.

TEACHING TIPS

Explore

The term H_2O is commonplace, but it is not necessarily easily understood. This activity utilizes the tremendous advances in imaging techniques and graphic renderings of H_2O. The MIME approach gives students a dynamic and experiential way of modeling the molecular structure. Invite parents to the classroom to help out with the modeling process and to involve them in refreshing their own knowledge of molecular structure.

Diagnose

Listen to student ideas about atoms and molecules, protons and electrons. How do students conceptualize down to the atomic and subatomic scale? What implications do students draw from hearing that water and ice are H_2O?

Design

There are many ways to represent H_2O graphically and in 3D models. Web searches generate many different ways to depict the structure of H_2O and ways to discuss the implications of its structure. Ask students to discuss how they might construct a model to show H_2O. Look at a range of designs from simple to complex. Young children can obtain precursor understanding by drawing and acting out the meaning of H_2O.

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Discuss

The term H_2O is so pervasive that nearly everyone has heard about it. Learning specifically how to understand what it means helps lay the foundation for conceptual understanding of the molecular structure of water and ice.

Use

This activity builds modeling skills. Results can be displayed as drawings, 3D constructions, and dynamic narrative and movement. The modeling activity can help explain properties of ice and water. A model can demonstrate the difference in the density between water (more dense, molecules closer together, taking up less space) and ice (less dense, molecules farther apart, taking up more space), as the ordered arrangement of ice crystals takes up more space than more fluid arrangement of liquid water. A model can help explain how molecules bond together to form snowflakes and other forms of ice.

WARM-UP AND PRE-ASSESSMENT

Consider asking students to talk about examples of things they know about only from pictures and models, but not from personal experience. Invite students to look at the variety of pictures describing the molecular shape of water and the crystalline structure of ice.

Explain to students that no one has ever seen a single water molecule directly! A water molecule is so tiny, that even a microscope doesn't help us see it. Yet we have all these pictures and 3D figures, don't we? These are models of water molecules and how water molecules form into ice crystals. These pictures show us what scientists understand about a structure so tiny that no one can actually see it directly.

What do these pictures and models get us thinking about as we look at them?

What questions do they raise in our minds?

What properties of water and ice do the pictures and models describe?

How would you draw or model your own version of H_2O*?*

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PROCEDURES

Modeling the Molecular Structure of Ice: H_2O

We select from what we know about the properties of a phenomenon to guide how we construct a scientific model. We can then use the model to ask questions and explore implications. In this case, we want to construct a model that will help us understand the structure of H_2O as a molecule and how it fits together to form ice crystals.

Here are several options that students can do at their desks or at exploratory zones with different sets of modeling materials.

- Draw water molecules and examples of ice crystal lattice structure
- Construct a "tinkertoy" model of ice
- Create mimediate models of water molecules and hexagonal ice
- Create a storyboard of an ice story from the molecular point of view

Conceptual Understanding	Modeling Process
a. Water is a molecule made up of one densely packed atom of oxygen and two atoms of hydrogen.	• Three round objects, color-coded (modeling clay, for example) • Shape is like "Mickey Mouse": face is O; ears are each H • The mime approach—students act out H_2O in a variety of ways • Use specially designed wooden balls and dowels
b. Scientists know this because they can measure the vibration signatures of water molecules	• Try out observing vibration patterns in a pan of water, using objects of various shapes (is there a wave pattern that marks an object shaped like H_2O?)
c. A water molecule has a triangular shape. As a liquid, molecules flow close together, occasionally clustering loosely	• Mime approach—have children in threes (as H_2O) flow about • Have each child think of their head as O and each of their hands as H, with their arms as the bonds, reaching out at 104° (a bear hug)
d. As water changes into ice, it needs more space for the hydrogen bonds to connect.	• Mime approach—have children enact the process of freezing in movement expression, if each child is a water molecule, with arms widening slightly to an angle of about 109°, holding that position, can form a slightly twisted hexagon

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DISCUSSION & REFLECTION

Why do scientists use models?

Scientists use models not only to describe what they know, but also to discover something new. No one has ever actually seen a water molecule directly. It's too small. But we can see many water molecules and we can detect its molecular motion, its vibrations. From those observables scientists infer the molecular structure of water and ice.

Scientists create a molecular model and then test to see if it fits as an explanation of what water and ice actually do. This work is still ongoing. Computer animated design techniques have greatly advanced our understanding of molecular structure. It is very possible that a young student could be the future scientist to refine the model.

With this in mind, it is quite appropriate to involve young students in this kind of modeling activity as active scientific inquiry. Young children can obtain precursor understanding by drawing and acting out the meaning of H_2O.

CURRICULUM CONNECTIONS

Modeling

Models are used to help us think about many things—and not just in science.

Young students are probably aware of models all around them, including computer models, scale models. Advertising uses modeling to display how a product might be used. While our focus is to draw out the science learning from these experiences and to create new knowledge about ice, watch for ways that build upon the language, visual, or kinesthetic learning potential.

Invite students to share the different kinds of models they have made. Evoke discussion about the purpose of models and how models help us think about things that are difficult to understand.

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ASSESSMENT CRITERIA

Exemplary

- Students explore a rich range of pictures and models of H_2O and relate it to prior shared experiences.
- Students recognize that H_2O expresses the molecular structure of water and ice.
- Students ask a rich and extensive range of questions about ice as H_2O.
- Students construct and display drawings, models, and dynamic enactments drawn from their new understandings about water and ice as H_2O.
- Students extend learning by considering implications of the molecular structure of H_2O.
- Students relate ideas to the whole context of exploring ice in the Solar System.

Emerging

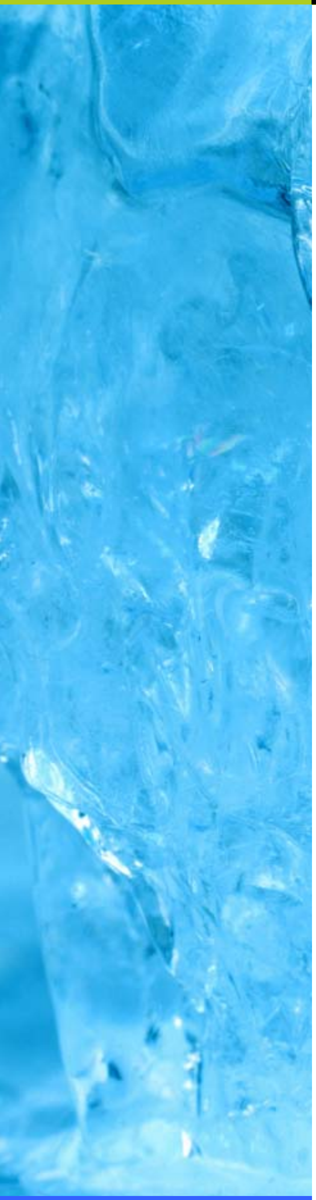
- Students recognize that H_2O expresses the molecular structure of water and ice.
- Students observe representations of H_2O.
- Students pose basic science questions drawn from observing pictures and models of the molecular structure of water and ice.
- Students write and/or illustrate a description of the molecular structure, H_2O, sharing it with both a small group and the whole group.
- Students construct their own models of H_2O, using a variety of ways to represent H_2O.

Students ask a rich range of questions about the meaning of H_2O.

Students make speculations about possible implications of the structure, H_2O.

Formative

- Students recognize that H_2O expresses the molecular structure of water and ice.
- Students identify the basic parts of a water molecule (atoms of hydrogen and oxygen, bonded together).
- Students pose science questions drawn out of the context of viewing pictures and models of H_2O.
- Students construct their own models of H_2O.



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RESOURCES

N. H. Fletcher. The Chemical Physics of Ice. Cambridge University Press. Cambridge, 1970. (An intermediate to advanced text that illustrates many aspects of solid-state physics using ice as an example.)

Michael Faraday Lectures
Eliot, Charles W. (ed.) (1910). Scientific Papers: Physics, Chemistry, Astronomy, Geology, Vol. 30. New York: P.F. Collier & Son.

Modeling the Water molecule: (well-explained and illustrated)

http://snobear.colorado.edu/Markw/SnowHydro/mol.html
Mark Williams, Department of Geography and Institute of Arctic and Alpine Research University of Colorado at Boulder, Course on Snow Hydrology

http://micro.magnet.fsu.edu/primer/java/fuelcell/index.html
Using a fuel cell to put Hydrogen and Oxygen together to produce water (interactive java tutorial)

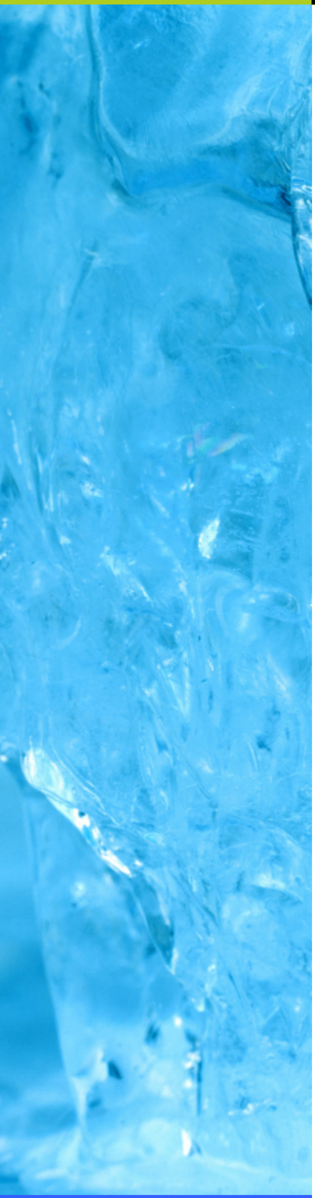
http://www.sbu.ac.uk/water/molecule.html
H_2O structure

http://www.sbu.ac.uk/water/hbond.html
Hydrogen Bonding

http://www.sbu.ac.uk/water/vibrat.html
Molecular Vibration

http://www.sbu.ac.uk/water/ice1h.html
Hexagonal Ice

http://www.nyu.edu/pages/mathmol/library/
3-D Molecular models



PRINT

Electrolysis

http://www.du.edu/~jcalvert/phys/elechem.htm
Nicholson & Carlisle Experiment, 1801

http://snobear.colorado.edu/Markw/SnowHydro/mol.html#uniqu
Ice physics

X-ray Crystallography

http://www.stolaf.edu/people/hansonr/mo/x-ray.html
Introductory college-level explanation

http://www.uni-wuerzburg.de/mineralogie/crystal/teaching/teaching.html
Interactive college-level tutorial (build your own molecule)

http://www.eserc.stonybrook.edu/ProjectJava/Bragg
Bragg's Law: How waves reveal the atomic structure of crystals

http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/bragg.html
Bragg's Law

Bonding

http://polymer.bu.edu/Wasser/robert/work/node4.html
Hydrogen Bond explained and illustrated

Water Concepts

http://www.nyu.edu/pages/mathmol/modules/water/info_water.html
Water Molecule

http://www.shorstmeyer.com/wxfaqs/float/watermolec.html
Looking at the Water Molecule

http://www.longwood.k12.ny.us/wmi/wq/lombardi2
Teacher Designed Lesson on The Journey of a Water Molecule

http://www.concord.org/~barbara/workbench_web/unitIII_mini/index.html
Water and Life

http://www.fcwa.org/story_of_water/html/molecule.htm
The story of drinking water

http://wps.prenhall.com/wps/media/objects/476/488316/ch12.html
Introductory chemistry of water

Images

Link to image gallery