Suggestions and Information for Using the Water Kit

Note:

* sections written in blue are primarily ‘teacher background information’
* this handout is online at: <http://blogs.sd41.bc.ca/science/dlrc/>

Main Ideas

* Atoms are a ‘basic building block’ of matter.
* Atoms can bond together to form molecules
* A water molecule is made up of 2 hydrogen atoms and 1 oxygen atom.
* A water molecule is incredibly small.
* Water molecules are *polar* (‘hydrogen side’ of the molecule is slightly positively charged and the ‘oxygen side’ is slightly negatively charged ( due to the way the electrons are ‘shared unequally’ when hydrogen and oxygen atoms bond ).
* The solid, liquid and gas states of matter can be better understood by discussing molecules.
* Water has many unusual properties that are important for sustaining life.

<http://ngm.nationalgeographic.com/ngm/0405/resources_who.html>

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* Models help us understand but have limitations.
* atoms were first philosophized by Democritus in approx. 400 BC
* experimental evidence in early 1800’s verified existence of atoms
* scientists have since learned atoms are made of smaller particles
* particles that scientists have not ‘broken down’ are called fundamental (or elementary) particles – currently, the electron is considered a fundamental particle but a proton is not

<http://www.iflscience.com/physics/what-are-fundamental-particles/>

* ‘images of atoms’ are possible using technology such as Scanning Tunneling Microscopy (STM) or Atomic Force Microscopy (AFM)

<http://www.differencebetween.net/technology/difference-between-afm-and-stm/>

More Ideas

* hydrogen and oxygen are examples of elements
* elements 🡪 matter made of only one type of atom – the periodic table lists all the known elements – all other matter is made of molecules that are combinations of the atoms listed in the periodic table

<http://www.rsc.org/periodic-table>

* Intramolecular bond – attraction holding atoms together within a molecule
* Intermolecular bond – attraction *between molecules* – not as strong as intramolecular bonds

[*https://www.khanacademy.org/test-prep/mcat/chemical-processes/covalent-bonds/a/intramolecular-and-intermolecular-forces*](https://www.khanacademy.org/test-prep/mcat/chemical-processes/covalent-bonds/a/intramolecular-and-intermolecular-forces)

* the attraction in intramolecular and intermolecular bonds is due to electrostatic attraction

In water:

Covalent bonds occur within each water molecule – covalent bonds are a type of intramolecular bond involving *electrons being shared between oxygen and hydrogen*

Hydrogen bonds occur between water molecules – hydrogen bonds are a type of intermolecular bond and occur because of the polar nature of each molecule – the hydrogen from one molecule is ‘partially positive’ and is attracted to the oxygen on another molecule which is ‘partially negative’

Suggested outline for lesson(s)

a) show video of a drop of water at 10000 frames per second

* video at: <http://blogs.sd41.bc.ca/science/dlrc/>
* Video acts as a ‘hook’ (perhaps there is more to water than meets the eye)
* Pause video at 30 second mark (just before drop hits water) and ask students to predict what they will see
* Could use Bill Bryson excerpt as another ‘hook’ – his book is in DLRC (there is also a children’s version which has pictures and simpler text)

b) show a single water molecule from kit to the class (remind them this is a model)

* ask students to estimate ‘how many water molecules are in a drop of water?’

( write ‘300 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_’ and ask ‘how many more zeros?’ )

* the answer is approx. 3 x 1021 so 21 zeros are needed after the 3 (‘yikes’)
* if actual water molecules were the same size as the model, then a drop of water would be bigger than the earth (‘wow’)

c) give each student three water molecules

**What do you notice?** (give students a bit of play time)

 Some examples of what students might notice:

1. each molecule has two white and one red teacher 🡪 model shows us each molecule is made of 2 hydrogen and 1 oxygen atom 🡪 H20 (the atoms that make up the water molecule are bonded strongly together – it is called covalent bonding ( type of intramolecular bonding – electrons are shared – electrons are a type of subatomic particle that make up atoms)
2. there is an attraction between molecules teacher 🡪 model helps us understand the bonding between water molecules – the oxygen (red) on one molecule is bonded with hydrogen (white) on another molecule - this is called hydrogen bonding (type of intermolecular bonding)
* have students rub the three molecules back and forth in their hands
* rub hands lightly so **bonds are constantly forming and breaking** - this action models what is happening in the **liquid** phase of water - molecules are close together, moving around and often hitting each other – bonds form and break very quickly (approximately every picosecond 0.000000000001 seconds) – in the liquid phase at any instant in time, the average water molecule is bounded to approximately 3 other molecules (i.e. forming a small group of 4 molecules briefly bonded together)
* rub more quickly – more energy added to the system - **molecules separate** (and would continue to move far apart if you had longer hands) – this models what happens in the **gas** phase – molecules moving more quickly and farther apart than in liquid phase
1. now have students ‘physically model’ molecules in water in a gas phase:
* start with about 6 people in a fairly large open area (approx. 4 m x 4 m)
* predict how they think molecules will move and then act it out
* now with teacher’s help, **adjust** the first attempt of the student model by considering the following questions:

Do water molecules . . .

i ) move along curved paths or lines? 🡪 molecules moves in lines until hit something (ex. another molecule, wall of container)

ii) move in all 3 dimensions? 🡪 yes, but this is a bit tricky to model since the students can only move easily along one plane – if students are walking along the floor they are only moving ‘north, south, east, west’ (2d) and they are not moving up/down (in the 3rd dimension) so the ‘student model’ is limited to 2d motion

iii) move all at same speed? 🡪 no, molecules move at a variety of speeds

iv) change direction and speed when hit? 🡪 yes (can discuss pool balls to help students visualize how the direction and speed change)

v) occupy more or less space than modelled by the 6 students? 🡪 need less students - in gas phase, the percentage of space occupied by water molecules in a container is only about 0.1% so the molecules are very far apart

* percentage varies with temperature and pressure
* to visualize a 0.1% occupation of space, imagine a **cube** 4m x 4m x 4m
* within this cube, imagine spheres with diameter 30 cm representing water molecules
* for the spheres to occupy about 0.1% of the 4m x 4m x 4m cube, there would be about 3 spheres in this cube
* when using students to model the molecules, reducing the number of students to **2** people on the 4m x 4m floor area provides a ‘reasonable visual’ for a 0.1% occupancy of space (the students are not spherical and the motion is 2d, so using 2 people will provide a ‘reasonable approximation’)
1. now have students physically model molecules in water in a liquid phase

– in liquid phase, **about 70% of space is occupied by molecules** – need whole class to help out - pretend each person is standing in a square enclosing their feet – with this in mind, you will need **about** 3 students in every 4 adjoining squares - some movement is possible but molecules/students are mostly just bouncing back and forth (caution students to not be rough as they ‘bounce around’) – notice that the bonds are constantly forming and breaking (recall how molecules moved back and forth in hands earlier in the lesson)

1. now have students model the solid phase

– molecules are just vibrating – not moving in linear paths

note: for water, there is a particular way the molecules bond together as a solid and surprisingly, it creates slightly more open space than the liquid phase – can investigate this molecular arrangement with the water kit later in the lesson

1. show animation: <http://blogs.sd41.bc.ca/science/dlrc/> 🡪 ‘Structure of Water’
* can use parts of the animation to reinforce many ideas of the lesson

( do not need to discuss the entire animation )

1. now use water kit to model arrangement(s) in ice (solid phase of water)
* scientists have identified up to 16 different lattice structures in which ice can form depending upon temperature and pressure

(a lattice is simply an arrangement of molecules in a regular pattern)

<http://www.differencebetween.com/difference-between-lattice-and-vs-crystal/>

* almost all ice on earth’s surface and in its atmosphere has a hexagonal form (called Ice 1h )

- see 3D Molecular Designs Basic Lesson Plans (page 25 or 26) for directions on how to construct this Ice 1h lattice <http://www.3dmoleculardesigns.com/Teacher-Resources/Water-Kit/Basic-Lesson-Plans.htm>

optional – build large models of snowflakes – see page 27 (very fun)

optional – very small traces of ice in earth’s atmosphere have a lattice form called Ice 1c - see 3D Molecular Designs Basic Lesson Plans (page 23 or 24) for directions on how to construct Ice 1c

* ice floats – water is less dense in the solid phase than the liquid phase

 - use the model to show water molecules require more space in solid phase than liquid phase – this is an unusual property compared to other matter (once you build the ‘ice structure’ of 12 molecules you can see there is physically room for a 13th water molecule to fit inside the structure - try adding a 13th molecule to confirm this – because of this ‘extra space’ in ice, water molecules occupy more space in the solid phase than in the liquid phase which leads to ice having a lower density)

Optional – form several lattice structures (each with 12 molecules) and stack them inside a cylindrical container (the container should have a diameter that allows for the lattices to packed tightly in the container - see page 17 in 3D Molecular Designs Basic Lesson Plans)

– measure height of the stacked ‘ice pile’ in the container – gently push down on molecules to break the hydrogen bonds until all the molecules are at bottom of container – measure height of the resulting ‘liquid pile’ 🡪 compare volume of solid vs liquid water

* optional – compare Ice1h and Ice 1c using 3D Molecular Designs handout

<http://www.3dmoleculardesigns.com/3DMD-Files/Water-Kit/PDFs/PatternsinCrystalStructures_water-TeacherNotes1.pdf>

1. you may wish to continue discussing molecules and explore other ideas (ionic bonds, solubility) by using the NaCl kit at the DLRC <http://blogs.sd41.bc.ca/science/dlrc/nacl-info/>

At some point, discuss the limitations/benefits of the water kit model

For example:

Limitations:

* atoms are not red and white
* molecular bonds are not magnetic
* atoms are mostly space – if an atom were size of a large cathedral, the nucleus would be about the size of a fly
* atoms have subatomic components not shown in the model

The model supports the following:

* there is an attraction between hydrogen and oxygen from different water molecules
* in water, the covalent bond (intramolecular) is stronger than the hydrogen bond (intermolecular) by about 20 times
* the hydrogen and oxygen atoms in a water molecule are arranged in a ‘Mickey Mouse shape’
* analyzing ice lattices

FYI

Which is stronger, covalent or ionic bonding?

🡪 it depends upon the elements involved

Can you ‘see’ an atom?

🡪 Technically, you cannot ‘see’ anything smaller than the shortest wavelength of light that you can see it with. The shortest wavelength violet light is 4 x 10-7 meters. An atom is about 10-11 meter. So an atom is 4 x 104 or 40,000 times too small to be seen.  But there are ways to "visualize" it, like Atomic Force Microscopy (AFM) or Scanning Tunneling Microscopy (STM). But these are all just measurements converted to computer images, and are not in any real sense "seeing" the atom.

Atoms look like very, very tiny spheres (or more like cones when on a surface), although there is no way to see this with a kind of *optical microscope*. However, there are imaging techniques that allow you to see the shapes of atoms. The shape of the atom is determined only by the shape of the *electron cloud* surrounding it. Using STM, you can map out the shape of the electron cloud by using a metallic tip that interacts with the electrons in the atom, allowing you to see where they are. As the tip moves over the sample, a current, called a tunneling current, is passing from the atoms to the metallic tip. The amount of current is extremely sensitive to the distance from the atom to the tip. So, as you move the tip around over the atoms, you can map out the shape and size of atoms.

Another technique is called AFM, for atomic force microscopy. This also uses a metallic tip, but instead of interacting with the electrons directly, it vibrates at a certain frequency, and when it approaches an atom, the frequency changes. If you monitor the frequency as you move the tip, you can map out the shape of atoms.

Other things to perhaps introduce to students:

* Cohesion, adhesion, capillary action and surface tension

<https://water.usgs.gov/edu/adhesion.html>

<https://water.usgs.gov/edu/capillaryaction.html>

* see 3D Molecular Designs Basic Lesson Plans (pages 12-15) <http://www.3dmoleculardesigns.com/Teacher-Resources/Water-Kit/Basic-Lesson-Plans.htm>
* Osmosis

<http://encyclopedia.kids.net.au/page/os/Osmosis>

<http://www.science-sparks.com/2011/08/29/shrinking-eggs/>

<http://www.3dmoleculardesigns.com/3DMD-Files/Water-Kit/PDFs/OsmosisLesson-StudentHandout1.pdf>

* Ethane and ethanol molecules
* See 3D Molecular Designs Basic Lesson Plans (page 9-11)