Lesson plan: Chemistry of water and its effects on pond ecology

Main activity: The properties of water

This activity focuses on the main properties of water, includes a range of demonstrations and asks students to consider how the properties of water contribute to life in ponds.

It is useful for students if they are aware of hydrogen bonding before beginning this practical. The activities outlined below will provide a more visual representation of hydrogen bonding and how this contributes to the various properties of water.

Students will be aware of some aspects of these properties as they will have come across them throughout their science education.

A circus of activities is set up that demonstrates each property.

The abstract nature of hydrogen bonding requires some discussion of the various properties of water.

Students should be encouraged to develop their own ideas to explain their observations.

Activity 1: Demonstrating surface tension

Hydrogen bonding, Van der Waals Forces, the impact of detergents on aquatic environments

Activity 2: Demonstrating capillary action

Cohesion, adhesion, meniscus

Activity 3: Water as a temperature buffer

Specific heat capacity, Latent heat of vaporisation, heat of fusion

Activity 1: Floating a needle on water

Requires: Petri dish filled with distilled water,
Small needle,
Detergent

Distilled water
Students should first attempt to float a needle on distilled water; this should be a relatively easy task although they will need to think about how they manage this. There are a variety of methods but delicacy is the key!

Distilled water will have limited impurities, thus the hydrogen bonding and Van der Waals forces between water molecules will be strong and the surface tension high. Small objects can float on this even if technically they are denser than water.

Detergent

With the needle remaining floating a drop of detergent can be gently added to the water just behind the needle. The needle will immediately speed off away from where the detergent has just been added

Adding detergent to the water breaks the hydrogen bonding, significantly reducing the surface tension, initially this causes the needle to be pulled away by the remaining hydrogen bonds, eventually the majority of bonds break and the needle sinks. Students will not be able to get the needle floating on the water surface again

This can be used to model the impact of pollutants on the properties of water

Discussion points:

Mobility
Organisms such as Pond Skaters use the surface tension to allow them to move across the surface of the water. They are able to hunt for food (dead and dying animals) on the surface of the water.

Note: Pond skaters also have hairs on their feet and waxy cuticle making their legs hydrophobic as an additional adaptation to allow them to walk on the water surface

Interesting facts:

The bigger the organism, the bigger the surface area required for them to be able to walk on water…… If we were to be able to walk on water, our feet would need to be about 1.5 miles long.

Jet Propulsion? Some members of the Stenus species (Rove beetle) are able to secrete a chemical molecule reducing surface tension locally and therefore creating asymmetrical forces that cause them to move forwards with considerable greater speed as demonstrated by adding the detergent behind a floating needle

The molecule could be mimicked to spread on mosiquito infested waters (see below)

Respiration
A key adaptation to life in water is to find ways of breathing air by using snorkel like structures which mean submerged organisms can access the air above. Organisms such as mosquito larvae rely on this surface tension as a way of anchoring themselves to the underside of the water surface. This anchorage allows them to access the air for gaseous exchange with minimum effort. Reducing the surface tension reduces the ability of the organisms to remain at the surface and would cause suffocation

Additional resources for younger students:

http://www.stanford.edu/group/henrysplace/Activities/fall/2_Surface_Tension.doc

Activity 2: Capillary action as a result of Cohesion and Adhesion

Requires: Water (with food colouring added for visual impact if required),
Measuring cylinders of decreasing diameters,
Capillary tubes,
Mercury thermometer or barometer if available

Demonstrating the meniscus

All students will be familiar with the concept of the meniscus in a measuring cylinder where water forms a concave surface. Comparing this to the mercury in a thermometer or barometer they will notice that mercury forms a convex surface.

Students should compare the meniscus in decreasing measuring cylinders to determine if the radius of the container has any effect.

Capillary action
Placing a clean capillary tube in water, students will notice that the water appears to rise in the tube. The narrower the tube, the greater the height difference between the reservoir at the bottom and the height to which the water rises is likely to be.

Straws can be used to demonstrate drinking and also transpiration in plants as water is very easily drawn up through the straw.

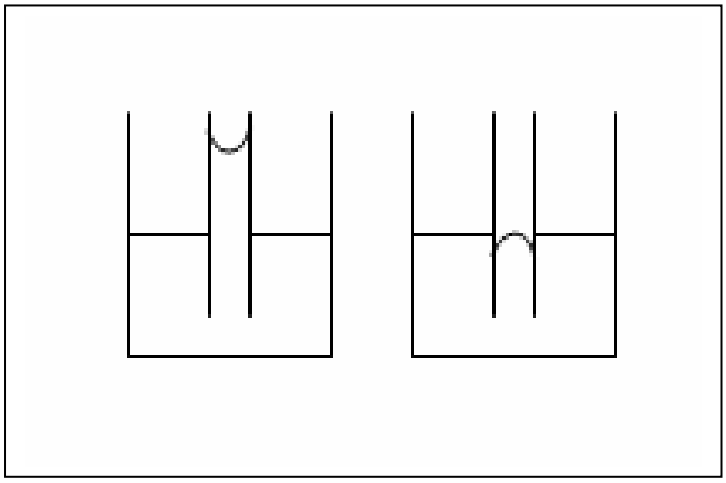
A subjective assessment can be made quickly between straws of varying diameter.

Discussion points

Both phenomena can be explained by cohesion and adhesion.

Cohesion is a measure of the ability of molecules within a liquid to bond (via hydrogen bonds) to each other where as adhesion refers to the bonding between the molecules in a liquid and an external substance (in this case, the sides of the measuring cylinder/thermometer/capillary tube)

When the forces of adhesion are stronger than the cohesion within the liquid a concave meniscus is formed. The water molecules are “sticking” more strongly to the surface of the container than they are to each other. If the sides of the measuring cylinder are greased, this adhesion is reduced and it’s possible to see a much reduced concave meniscus and even possible to observe a convex meniscus which is lower than that of the surrounding water



The concave and convex meniscus formed as a result of the varying forces of cohesion and adhesion

A convex meniscus occurs because the forces of cohesion between the molecules within the liquid are stronger than the adhesive forces of the liquid with the container sides

Cohesion and adhesion in ecology

Cohesion and adhesion help to explain why water moves up through the soil on dry land and contribute to the flow of water through the xylem vessels in plants.

The majority of aquatic organisms need to ensure that they reduce the adhesive properties of any structures which are in contact with the water, usually through production of waxy cuticles or production of oils to coat skin, fur and feathers.

Note: Oil pollution should based on the theory above reduce the adhesive properties actually damages the natural mechanism of such organisms in a number of ways thereby increasing the adhesion.

If you have access to feathers a good demonstration of the impact of oil on birds feathers can be found at http://www.biologycorner.com/worksheets/oilspill.htm

Activity 3: Water as a temperature buffer

Requires: Water,
Alcohol,
Hot lamp,
Thermometer/temperature probes,
Warmed tile

Observing specific heat capacity

Specific heat capacity can be measured in any number of ways, a good example can be found at http://timjoh.com/specific-heat-capacity-of-water-h2o/ should you wish to carry out a more detailed practical.

A simple and quick demonstration however that highlights the principle allows students to compare the temperature rises in water, alcohol and air under a simple heat lamp.

Three test tubes filled with air, alcohol and water should be left under a hot lamp, their temperature recorded at regular intervals

Care should be taken with the alcohol to monitor its temperature carefully and avoid accidental overheating

Heat of fusion

The practical above can also be carried out in reverse, with the water; alcohol and air cooled in beakers of ice or kept in a freezer compartment.

Latent heat capacity

The latent heat capacity can also be demonstrated by placing a single drop of alcohol and water onto a warmed tile. The alcohol will evaporate very quickly and the water much more slowly. On hot sunny days, a warmed tile is not necessarily required.

Discussion points

The practical ideas here demonstrate the transfer of energy between ponds and the environment, comparing water to the rates of transfer for air and alcohol.

It takes significantly more energy to heat water than other liquids or air. The Earth which already has a limited temperature range due to the unique nature of the atmosphere has and due to the high specific heat capacity of water an even more limited temperature range in its aquatic environments.

Reducing the effect of temperature rises

The high specific heat capacity means that the temperature in ponds on hot sunny days tends not to rise significantly, an almost constant temperature is maintained. The advantage of this is that the effect of temperature on respiratory, photosynthetic and gaseous exchange rates from air to water and water to air is avoided, i.e rising water temperatures often reduces oxygen concentration in water causing respiratory challenges for aquatic organisms.

Surviving the winter freeze

The heat of fusion in winter means that ponds are less likely to freeze. Due to the density of water when freezing occurs, ice floats on the surface and aquatic organisms can survive under the surface over winter

Ponds can freeze over, although they do not freeze completely. Pond organisms are moiré likely to be troubled by the reduced oxygen content of water during a winter freeze than the colder temperatures.

Surviving and adapting to summer droughts

The high latent heat of vaporisation means that the volume of water can remain reasonably constant and ponds tend not to dry out in hot summers however some ponds can and do dry out and in some cases the local ecology is highly dependant on this annual drying out. Temporary or seasonal ponds are an important and also threatened habitat often containing rare species, especially amphibian and invertebrate species. Such organisms prefer temporary ponds because the seasonal drying out kills off fish, their main predator.