Liquid Crystals

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Subject: Chemistry

Grade Level: K-2 & 3-5

Standards: Next Generation Science Standards (www.nextgenscience.org)

2-PS1-1 Plan and conduct an investigation to describe and classify different kinds of materials by their observable properties.

4-PS3-2 Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

Schedule: 2 to 3-40 minute lessons

CCMR Lending Library Connected Activities:

<table>
<tr>
<td><u>Objectives:</u>
Students will observe how liquid paper can detect temperature changes. They will use this to find out that water changes state due to the gain or loss of energy.

Upper elementary students will also use the liquid crystal papers to look into the transfer of heat by conduction and tie this in with specific changes of state during the water cycle (evaporation, condensation).</td>
<td><u>Vocabulary:</u>
Matter — Gas
Atoms — Liquid
Molecule — Solid
Liquid Crystal — Temperature

Additional Vocab for 3-5:
Conduction — Insulator
Evaporation — Conductor
Condensation</td>
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<td><u>Students Will:</u>

Observe the behavior of liquid crystal paper and try to infer how it changes.

Students will learn that atoms are the basic building blocks of matter and that you make molecules by combining atoms.

Students will learn about the atoms that make up a water molecule and construct a model.

Students will measure the temperature of water at different states and try to infer what is causing the change.

Students will model how the atoms/molecules change state.

Students will explore how heat is transferred by conduction during the processes of evaporation and condensation.</td>
<td><u>Materials:</u>

For Each Pair:
Liquid Crystal Paper
Activity Sheet
Liquid Crystal Thermometer
2 Red and 1 Blue Lego Bricks
Sandwich Bag

For Upper Elementary Activity:
Eyedropper
Aluminum Foil

Provided by Teacher:
Colored Pencils or Crayons
Electric Kettle
Ice</td>
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<tr>
<td>Safety</td>
<td>Students should be watched when using the electric kettle.</td>
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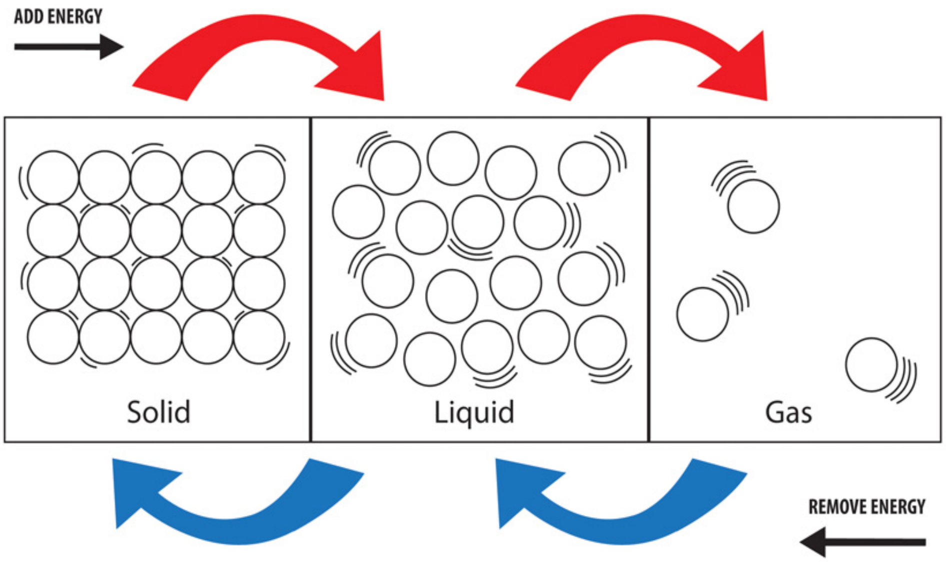
Science Content for the Teacher:

States of Matter:

We experience 3 states of matter on a daily basis: solid, liquid, gas (Figure below). All matter can change to and from these states by adding or taking away energy. This causes the atoms/molecules to move closer or further apart, which changes their density. Depending on the class, you can also introduce the students to the terms for each change of state (Melting, Freezing, Evaporation, Condensation).[1]



Heat transport:

Temperature is a measure of thermal energy contained in the object. The thermal energy is contained in the movement and mutual interactions of molecules in the object. In hotter bodies molecules move faster than in colder bodies. A common way of changing temperature is to allow the object to exchange heat with surroundings or another object. Heat is a form of energy. There are three ways for heat to be delivered to (or be taken away from) some place in an object: conduction, convection and radiation.

Heat conduction involves fast-jiggling molecules located in a hotter place shaking up their neighboring molecules, which then shake up their neighbors, and so on, leading to transport of thermal energy towards a colder place. Conduction is most important between solids that touch, and through solids, since the molecules cannot stray away from their positions.

In Activities 1,2,3 for young kids, you can limit the time of touching the paper with hand, so to limit the transfer of heat to the paper. With a smaller amount of heat transferred to the paper, its temperature (and color) will change less.

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[1] "Middle School Chemistry | Download Free Science Activities ..." 2006. 27 Jan. 2015 <http://www.middleschoolchemistry.com/>

In Activities 1 for older kids --- you might observe this also in Activity 4 for young kids --- the plastic of Lego blocks is bad at conducting heat. You need to hold the block for a while before it warms up, and when you put the block down it takes longer for it to heat up the LC paper. At first the block leaves a sharp color pattern were it touches the paper, since the heat is slowly transferring and heating the paper only at the point of contact. After a while enough heat is transferred to warm up a larger area of the paper. In Activity 2 for older kids the plastic bag slows down the conduction of heat from the block to the paper. The paper below the plastic warms up less in the same time compared to the part of paper in direct contact with the Lego block. Metals, such as aluminum, on the other hand are very good conductors of heat. The color change of the paper below a warm Lego block will depend on the amount of heat conducted to the paper in the given time. When we use the folded aluminum foil, it quickly conducts heat away from the block and throughout the foil, and then conducts it to the paper below. If the foil is not neatly folded and gently pressed down by the block, there is a lot of air trapped between the layers of the foil. Air is very poor at conducting heat and can block the heat conduction from block to paper. You can introduce the concept of insulation in clothes, homes, etc.

At this point you can apply the conclusions to the question of why metals feel cold to touch. Our body heat is quickly conducted away from point of touch, flowing away through the metal. This effect is very apparent compared to touching wood or plastic, which conduct heat poorly. Wood, plastic and metal sitting in the room for a while will all be exactly at room temperature (can be checked by thermometer or LC paper), yet this “cooling” effect on touch is obvious.

Change of state:

Older kids using this kit can explore changes of state, and the water cycle. All matter can change to and from different states by adding or taking away thermal energy. A liquid can change into gas by either boiling (when it’s at the boiling temperature) or by **evaporation** (at any temperature). In either case, the change of liquid to gas requires addition of energy, called the **latent heat** (“hidden heat”). Considering an evaporating droplet of water, even if the water in the droplet and the water vapor leaving it are both at exactly the same temperature, heat needs to be added for the evaporation to happen. This added heat, the latent heat, is used by the water molecules to break away from the surface of the droplet, instead of being used to raise their temperature.

Water has a relatively large value of latent heat, so we can observe it using the kit in Activity 3 for older kids. The cup with warm water will typically turn the LC paper blue, showing that the water is at room temperature. Once we put a thin layer of water on the paper directly, the water rapidly evaporates. The evaporating water takes the latent heat from its surroundings, the paper and air. The paper will turn dark brown as the evaporation continues, since the paper cools down quickly by giving heat to the evaporating water. This process is everywhere: cooling us down when we perspire, occurring with water in environment, etc. The effect of evaporative cooling is also used in homes, and even in advanced laboratories for achieving low temperatures.

In Activity 4 for older kids evaporation and latent heat are explored in more detail by observing water droplets on the paper. Within seconds of creating a droplet, the paper below it turns blue, showing the temperature of the water. After that, the paper below and around the droplet slowly changes towards dark brown as it cools down. It cools down due to giving away heat for the latent heat of water evaporation.

One general principle at work here is that the total amount of latent heat necessary for evaporation is proportional to the amount (mass) of evaporated liquid. Bigger droplets will therefore leave bigger dark spots on the paper, having extracted more heat. Note that in contrast to the latent heat (necessary for change of state), the temperature does not depend on the amount of matter.

The second principle is that the total evaporation rate is higher if the droplet's surface is bigger. This is due to the fact that evaporation happens only at the water surface where the molecules are escaping it. However, this higher evaporation rate cannot match the increase in the mass of a bigger droplet, so bigger droplets need longer time to evaporate.

Your students might observe that the liquid crystal paper changes color most rapidly right below the edge of the evaporating drop. Please refer to the next section if you wish to discuss this effect.

In Activity 5 for older kids, water first evaporates from droplets on the paper, then water vapor condenses on the paper above the kettle, and finally evaporates again from the paper. During condensation a given mass of water vapor releases exactly the same amount of latent heat that it absorbed during evaporation. The total energy is always conserved. The total mass of water molecules is also conserved. In the water cycle in Nature these processes continuously occur.

Using the above concepts, you can also discuss the melting and freezing of water. There is also latent heat in the melting process. However, the temperature of ice is too low to observe the process on the liquid crystal paper.

Additional information about an evaporating droplet:

The rate of evaporation, i.e., how much water evaporates in a given time, is the highest at the edge of the droplet. You will observe that the paper color indeed changes the fastest right below the edge of the droplet. This happens due to two effects: (1) The evaporation happens at the droplet surface, and the surface near the droplet edge is positioned closest to the paper. The heat is conducted to it through the paper more quickly than the heat conducted through the air to other parts of the droplet surface; (2) Water vapor needs to flow away from the droplet to allow continued evaporation. (This is why moist objects dry more quickly when we blow over them, for instance we cool soup in this way.) The water vapor near the edge of the droplet can flow away more efficiently than it can near the top of the droplet (water molecules leaving the droplet near the edge are more likely to proceed to air or hit the paper than hit the droplet surface and get absorbed). This enhances the evaporation near the droplet edge.

Another physical effect you can explore is the change in the shape of the evaporating droplet. In general, droplets have two ways of evaporating. One is by keeping the droplet edge at a fixed position and flattening the droplet shape as the liquid evaporates. The other is by retaining the round droplet shape but shrinking the edge as the droplet shrinks. Properties of the paper surface determine how the drop will behave. In the first case, as the edge remains fixed, there needs to be a flow of water inside the droplet, from the center towards the edge, to replenish the evaporated water near the edge. This flow inside the droplet carries with it any material dissolved in the water. That is why in dried coffee stains you can easily find dark brown shading at the stain edges, where the dissolved coffee particles were carried to and deposited during evaporation.

****This is not part of the lessons, but is merely for anyone interested****

How liquid crystal paper works:

In a solid the particles (atoms, ions or molecules...) arrange in space in an ordered pattern (Figure 1). In liquid matter, the particles keep close to each other, but do not form any ordered structure since they move freely and randomly throughout space (Figure above).

Liquid Crystals (LC) do not fit into this conventional list of states of matter. Most known LCs flow just as normal liquids flow. However, LCs contain molecules with complicated shapes or complicated interactions, which make these molecules arrange in certain patterns, similarly to what happens in solids. An example of a LC we will consider is depicted in Figure 2.

Figure 2 shows a few vertically stacked layers of molecules in the LC. Orientation of molecules twists from one layer to the next. Many such layers are stacked from the top to the bottom surface of the LC paper. The **pitch** is the vertical distance after which the molecules twist a full circle. Layers in left figure make a half of the pitch.

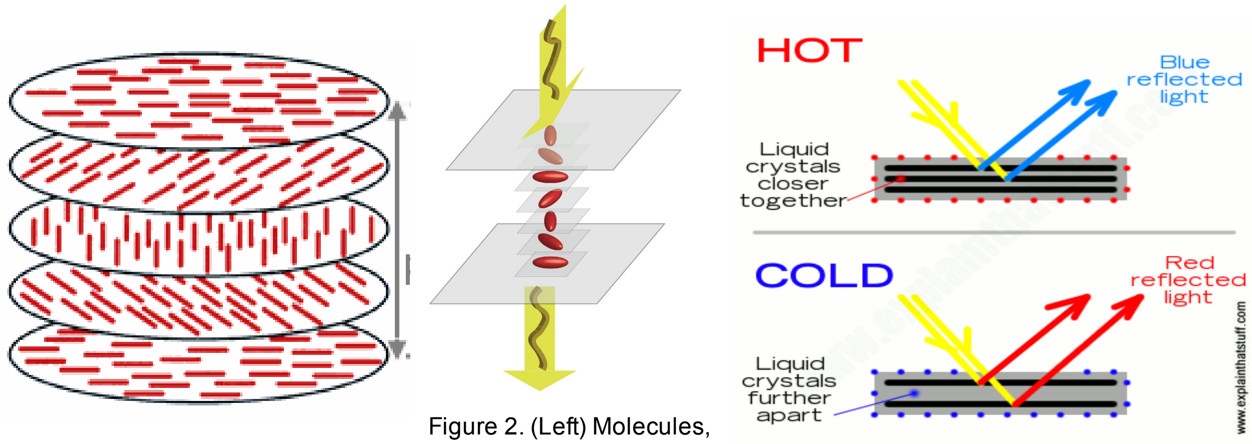

Figure 2. (Left) Molecules, shown as red elongated particles, move freely within horizontal layers and maintain the same orientation in a layer. Shown layers cover half the pitch since molecules twist half a circle. (Middle) Light enters the LC paper (top and bottom surfaces shown) from above and follows the twist in molecule orientation. (Right) Heating shrinks the pitch (marked by black lines).

Light follows the twist of molecules as it travels through the LC (Figure 2, middle). Light having **wavelength** equal to the **pitch** gets reflected by this arrangement of LC molecules. This reflected light gives the color of LC we see.

When **heated**, the LC pitch contracts so the wavelength of reflected light shrinks (Figure 2, right). The shrinking wavelength takes the LC color from reddish-brown, through green, to blue.

Colors in this kit:
The liquid crystal **paper** square changes colors in the temperature range
23 - 27 ºC. From cold to hot the colors continuously change: dark brown, brown, red, orange, yellow, green, blue, dark blue.
The liquid crystal **thermometer** shows three colors if temperature is within its range:
The green (middle) marking is closest to measured temperature.
The brownish (upper) marking is just above the measured temperature.
The blue (lower) marking is just below the measured temperature.

Weblinks with information on Liquid Crystals:
"Thermochromic materials - Explain that stuff!." 2011. 25 Nov. 2014
<http://www.explainthatstuff.com/thermochromic-materials.html>
Structure of Liquid crystals:
<http://www-g.eng.cam.ac.uk/CMMPE/lcintro1.html>
Liquid crystals and light:
<http://www.mc2.chalmers.se/pl/lc/engelska/tutorial/tutframe.html>

Classroom Procedure:

K-2 Activity, but older students might find this useful to begin:

Explore:
Activities 1-4 :Hands
Give students a handout with a hand prints on it. Have one of them put their hand on the square, hold it, and take it off. Have them color in their hand print with what they observe. Ask them why they think this happened. Have students warm their hands (rubbing) and cool their hands (ice), then place them on the square. Have them color in and note any changes. See if they can figure out what is causing the paper to change color. What could we use this for? Depending on the level of your students, you can have them read this and answer on their own or ask the questions to the students and have them explain their observations and inferences.

Explain:
What is this paper? How does it work?
Have the students share their observations and inferences. This can be done by them writing on their own or by having a group/class discussion. How does this paper work? What does it do? What causes it to change color. Be sure to have them use their observations to back up any inferences they make. Wrap up by making sure they understand that the temperature of there hand changes the color of the paper. Blue means the temperature is warm. Brown/Black means it is cold. It is up to your discretion to decide how much you want to explain to them how the paper actually works. Explain that one way we use liquid crystal is with thermometers. Show them a thermometer that they will be using. Computers and cell phones also use liquid crystals in their displays.

What is an atom? How can we make molecules?
Give each student a Lego brick. Tell them this represents an atom. Atoms are the building blocks of everything. We are made up of atoms, but we can't see them.There are different kinds of atoms. See if they can think of any (oxygen, carbon, gold, silver . .)

Give the students another brick and have them put the two "atoms" together. They have now made a molecule. Molecules are made when atoms join together.

Give each student 1 brick of one color (red) and two bricks of another color (blue). Tell them they are going to build a very important molecule. Have them take the red brick (oxygen) and connect the other two blue bricks (Hydrogen) on each side of the oxygen. See if they might know what this molecule is? Water!

Show them some water and have them imagine millions of these molecules in there. Tell them they are now going to do an experiment to find out some things about water.

Experiment:
Have the students look at the thermometers to see how they work and how you can read them.
The liquid crystal thermometer shows three colors if temperature is within its range:
The green (middle) marking is closest to measured temperature.
The brownish (upper) marking is just above the measured temperature.
The blue (lower) marking is just below the measured temperature.

Activity 5 - Ice
Give students an ice cube. Let them touch it. What is ice? Put the ice on the table. Have them draw the ice, then use a thermometer to find out the temperature. Have them write it down. They will need to move the thermometer along the ice to notice the color changing for the lower temps.

Activity 6 - Water
Give students a cup with water. What is different from the ice? Allow them to touch it. Put a small amount on the table. What does it do? Have them draw the water, then use a thermometer to find out the temperature. Have them write this down.

Activity 7 - Steam
Have an electric kettle with heated water. Have the students observe the steam coming out of the top. What is this? How is it different from the ice and water? Allow them to put their hand above the steam. Have them draw the steam, then use a thermometer to find out the temperature. Have them write this down. Move the thermometer up and down in the steam and observe what happens to it.

Activity 8 - States of Matter
Ask the students about the substance in the 3 activities. What was it? **Water.** What was different about each of them? **Temperature.** What does temperature measure? **How fast molecules are moving.** What were the 3 phases of the water? **Solid (Ice), Liquid (Water), and Gas (Steam)**

Have the students do a dance to model how water changes from a solid to a liquid to a gas. For the dance, their hands will be the molecules. Ask them what they they think the molecules look like when they are a solid (they are close together). How does ice melt to a liquid (add energy)? This causes the molecules to move a little bit apart so that they can now move around each other. Have the students do this. What would they need to do to change the liquid to a gas? (add more energy). This would cause the molecules to move a lot further apart and move very fast. Have the students do this. They can then go the other way by taking away energy and turning the molecules to a liquid and a solid. Once the students have this, you can get them to stand up and dance. They can move left or right depending on whether they are adding or taking away energy. Can you slow and fast music to represent energy.

Once they have done this, have them try to draw what the molecules look like for each state on their activity sheet.

Grade 3-5 Activities:
These activities have the students exploring how water interacts with the liquid crystal paper. The emphasis is on getting them to understand that something is moving between the two: heat.

Activity 1:
The ice will cause the paper to turn brown. The longer the contact time, the more outline of the brick you will see in brown. Heat is being taken from the paper and going to the block by the process of **conduction**. When they put the warmed LEGO on the paper, it will cause the colors to change to green/blue.

Activity 2:
This will show the kids that some materials are good insulators and some are good conductors of heat. The plastic bag will not allow heat to move easily between the objects. The aluminum foil is a good conductor or heat. The heat will get absorbed by the foil and will spread out before moving to the paper. The paper will have large random patterns instead of the block outline. You might have to vary the times for better results.

Activities 3 and 4:
This will allow the students to experiment and see the process of evaporation. The smaller the drops, the easier it will be to notice the water evaporating. The paper changing from a blue to black color will show the students that something is taking heat away.

Activity 5:
This will demonstrate condensation. They will feel the paper after it has been held above the steam and notice that water is on the paper. If they watch the paper for longer, they will notice that the paper cools and the water evaporates.

Assessment:

The following rubric can be used to assess students during each part of the activity. The term "expectations" here refers to the content, process and attitudinal goals for this activity. Evidence for understanding may be in the form of oral as well as written communication, both with the teacher as well as observed communication with other students. Specifics are listed in the table below.

1= exceeds expectations
2= meets expectations consistently
3= meets expectations occasionally
4= not meeting expectations

	Engage	Explore	Explain
1	Shows leadership in the discussion and activities, displays good understanding of a water molecule and how it changes state..	Completes work accurately while providing an explanation for what is observed. Works very well with partner.	Provides and in-depth explanation of findings. Makes excellent and thoughtful comparisons to everyday life. Fills out worksheet clearly.
2	Participates in the discussion and activities; shows an understanding of of a water molecule and how it changes state.	Completes work accurately and works cooperatively with partner.	Provides clear explanation of findings. Notes good correlations to everyday life. Fills out worksheet clearly.
3	Contributes to the discussion and activities, but shows little understanding of a water molecule and how it changes state..	Works cooperatively with partner, but makes some mistakes with the procedure.	Provides a limited explanation of findings. Struggles to make comparisons to everyday life. Fills out some of the worksheet.
4	Does not participate in discussion or activities.. Shows no understanding of of a water molecule and how it changes state..	Has trouble working with partner. Does little to complete the procedure.	Is not clear in explanation of findings. Does not fill out worksheet.