A world of invisible things
You don't need a microscope to see what is there

The goal of this section is to help students construct the understanding of the internal structure of matter and be able to apply this understanding to explain real life phenomena. Many people heard the word "molecules". But what does this word mean? How do we know that there are these tiny particles inside things? It took science many centuries to devise the concept of the particle structure of matter, but now we can help students construct this understanding using simple household materials.

Development of this understanding follows the stages of a modified science learning cycle:

- observation (observation of a phenomenon – what happened?),
- concept construction (devising possible explanations of the phenomenon – why did it happen?),
- concept testing (experimental testing of suggested explanations - how do we know if our explanation works?), can serve as a new observation,
- concept application (can we use our concept to predict how real life phenomena will occur?).

At the stage of observation students observe physical phenomena selected by the teacher and record their observations using pictures, graphs or words.
At the stage of concept construction students devise possible explanations for the phenomenon that they observed and make a list of possible explanations.
At the stage of concept testing students either design experiments to test their explanations or use the explanations to predict an outcome of a new experiment designed by the teacher. Predictions are recorded before the testing experiment is done, and later revised based on the experience.
At the application stage students use the concept that they have tested to explain real life phenomena suggested by the teacher. They can also make a list of phenomena that can be explained using the new concept.

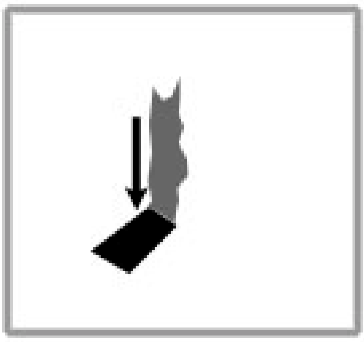
Prerequisite knowledge and skills:
Understanding of the concept of volume, ability to measure volume of liquids in ml (Section 2.1).
Materials:
Beakers, transparent plastic cups, graduated cylinders, rubbing alcohol, sponges, , food coloring, tea bags, sponges, CD exp.1.

1.1. Observation

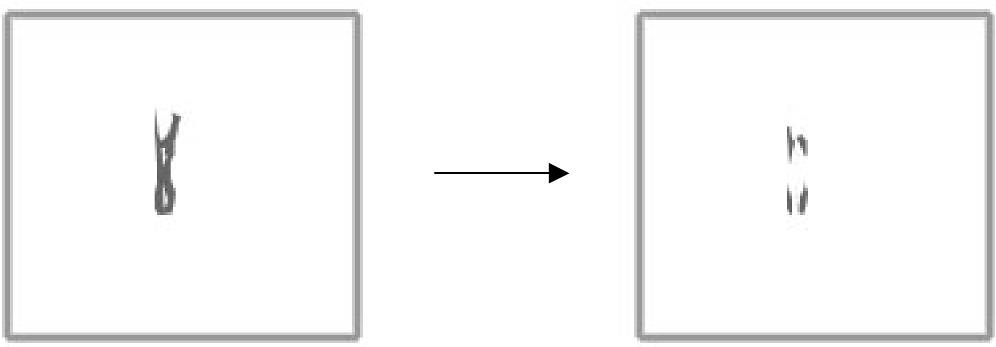
Procedure:

1. Ask students to observe the liquid you will put on the chalkboard. Ask them to draw pictures of their observations.

2. Apply a sponge soaked in rubbing alcohol to a clean section of chalkboard, making a long streak:



3. After the streak disappears, ask the students to describe what they observed. Did the liquid disappear gradually or all at once?



Concept construction

At this stage students are asked to offer possible explanations (concepts) that they construct during the discussion after the experiment, when they try to find out why the phenomenon occurred the way it did.

Conventional concept (explanation):
As we saw the liquid disappearing gradually we can say that it is made of small parts that left the board and went into the air.
These parts should be in motion and be able to separate otherwise the liquid would not be able to disappear gradually, it would disappear all at once.

Also, students can come up with alternative concepts (explanations), such as the liquid going into the board or that air somehow was responsible for the whole process by removing the alcohol from the board.

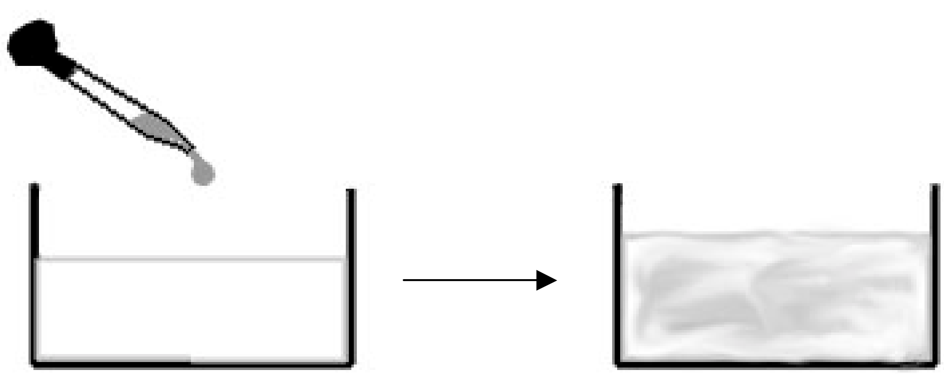
Concepts to Test

Liquid on the board disappeared because liquids are made up of small parts; these parts are in motion and can separate from each other, these parts went into the air.
Liquid went into the board part by part that is why it disappeared.
Air removed the liquid from the board part by part.
All of these explanations have one idea in common: whenever these small parts went, they are really small and should be able to break apart, so the liquid can disappear gradually.

1.2 Concepts testing

Procedure:

1. To test if the idea of liquid going into the board is correct, use a piece of paper instead of the board. Ask students to predict what will happen if you wet it with alcohol. According to this concept, it should not leave the paper, and the paper should stay wet and continue to smell alcohol. An actual observation disproves this idea.
2. To test if the idea that air is responsible for the disappearance, you can use a vacuum jar with a wet paper inside (CD exp. 1). Ask students to predict what will happen if you pump the air out. According to this idea, the paper should dry slower or may be stay wet. Again, the actual experiment disproves this idea.
3. To test if the liquid went gradually into the air because its parts break up and move, ask students to predict what will happen based on their explanations to the liquid in the container when you add a droplet of dye to a container of water. Ask them to justify their prediction. After they stated their predictions based on the idea that liquids are made of small parts that can break apart, let them observe the experiment to see if their predictions matched the outcome of the experiment.
4. Add one drop of dye, do not stir. Let students observe the dye spreading slowly in the water, so that in several minutes the water has a uniform color. Ask them to record their observations every 2 minutes.



After the dye mixes well, ask the students to revise their prediction if necessary. Ask questions such as, “Did he dye and water mix together or stay separate?” (mixed together) , “Did they mix all at once or over time? (over time) , Why?” (probably because the liquid and the dye both are made of parts that can break apart and move). “What additional assumption about the internal structure of liquids do we need to make in order to explain the mixing?” (we need to assume that there are empty spaces between the moving parts otherwise, the dye parts would not be able to move between water parts and vice versa). This is a new concept that needs to be tested.
At this stage the teacher can give a name to these small parts (a word “particle” is the best, but “molecule” is acceptable too)

Concept Application

1. Open a container with perfume near one of the students and ask her/him to describe what she is feeling. Ask other students to explain why she can smell perfume after several minutes using the concept constructed before. A possible explanation can be: if we assume that perfume is made of small particles that move and can leave the container, then these particles move out, and somehow reach our nose to produce the sensation of perfume smell.
At this point some students might ask a question about the air: what is it made of if particles of perfume can travel in it? Is it also made of something or it is empty? The idea that air is not empty can be tested by predicting what will happen if somebody was put in the room with no air (student experience with science fiction movies will help then to predict the result). Another test is that when we blow air into a balloon it expands.
2. Ask students to describe what happens when you leave wet clothes on a couch (at first the couch becomes wet under the clothes, then both dry out but it takes longer for the couch). Ask students to explain why they think these phenomena might occur.

New Concept Construction

The small particles that liquids are made of, not only move and can separate from each other, but also have spaces between them, allowing liquids to mix. Two things can mix because their particles move into the empty spaces between each other.

Concepts to test:
There are empty spaces between particles.
When two liquids mix, particles of one liquid move into the spaces between the particles of the other liquid and vice versa.
Consequence: when you mix two different liquids the total volume might be less that the sum of the volumes of the liquids before mixing.
Alternative idea: the space between particles is filled with air.

1.3 Concepts testing

Procedure:

1. Ask students to observe the volumes of the two medium containers full of liquids: one water, one alcohol. Measure the volume of each in front of the students and have helpers write the values on the board (it is better to have at least 50 ml of each). Ask the class to predict what- if anything- will be different between the volume of the two liquids mixed together versus the sum of the volumes of the two separate liquids using the concept that they just constructed (particles have spaces between them) and provide reasoning for their prediction.

2. Mix the two containers of liquids together into a large container and ask the students to observe the new volume. (It will be less than the total of the two medium containers)

3. Ask the students to revise their answers if necessary after you measure the volume of the mixture. Ask questions such as, “Are the total volume and the final volume the same value?” (no, final should be slightly less) , “Why not?” (liquids mixed, taking up space between their parts, further proving that liquid is made of parts) , “Can we mix with things?” (yes, we mix well with air, water…) , "How about with solids?" (but not solids like the desk) , “Place these in order of which has the least amount of empty space between their molecules- solid, liquid, and gas.” (Usually solid has the least, followed by liquid and then gas. Water vs. ice is an exception.) “So do you think solid objects like a desk or a rock have empty spaces between their parts?” (Yes.)
4. To test if spaces between particles are filled with air or are real empty spaces, students can use any transparent container filled with water. Ask them to predict what will happen if they insert in water a small transparent container upside down, so that its bottom is completely submerged. If the idea that empty spaces between particles are filled with air is true, then water will go into the container the same way it mixed with food coloring. The experiment shows the water does not enter the container. It means that if empty spaces between particles of water were filled with air, then water and dye would not mix.

Observation 1.5.

1. Prepare two identical transparent containers (as a demonstration or for each group of students), containers with cold and hot water, and a container with dye (food coloring).
2. Ask students to observe and record what happens if they pour the same amount of hot and cold water in two transparent containers and then insert a drop of food coloring in it.
3. Students will observe that the drop of dye in hot water spread much quicker than in cold water.
4. Ask students to devise explanations of what they observed. Possible questions might be: “How can you use the concept of moving particles to explain the results of the experiment?” “What new assumptions do you need to make to explain why dye dissolved in hot water much faster?”

Concept construction

Students can give different explanations for the observed phenomenon. Some of the explanations can be:

1. In hot water particles move faster and thus mix faster.
2. In hot water spaces between particles are bigger thus it is easier for them to mix.

Both of these explanations allow testable predictions (we suggest that the students design testing experiments themselves, the following are examples of possible testing experiments):
Concept 1. If in hot water particles move faster, then if we take very-very cold water, the particles should move slower and dye will spread much slower.
Or: if in hot liquids particles move faster, then hot liquids should evaporate faster.
Concept 2. If we take a narrow tube filled with water (1/2) and place it first in hot and then in cold water we should see the water level in the narrow tube rise and fall.

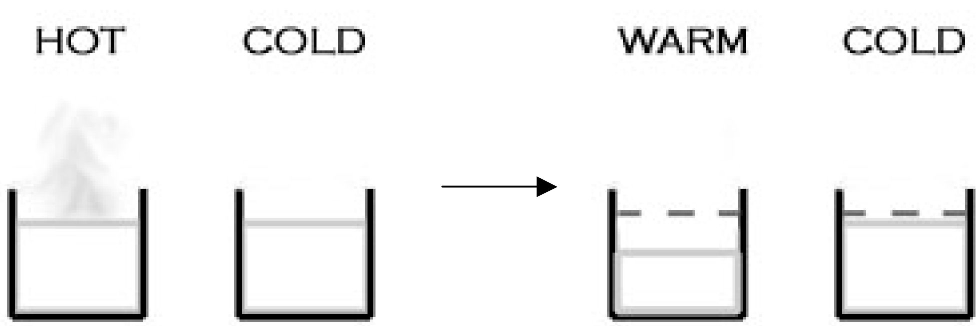
Some of the testing experiments are described below.

Testing Experiment 1.6

Procedure:

1. Ask students to observe the volumes of the two medium containers full of liquid- one hot water, one cold water. Ask them to predict which- if any- container will have a higher volume than the other if you were to let the containers sit in the front of the room for the duration of the class using the concepts that they want to test. Ask them to explain their predictions so they can see how they are using a newly constructed concept.

2. Leave the two containers of liquids side by side for an hour or so, then measure the volumes of the liquids again. The "hot" container will contain less liquid than the "cold" container:



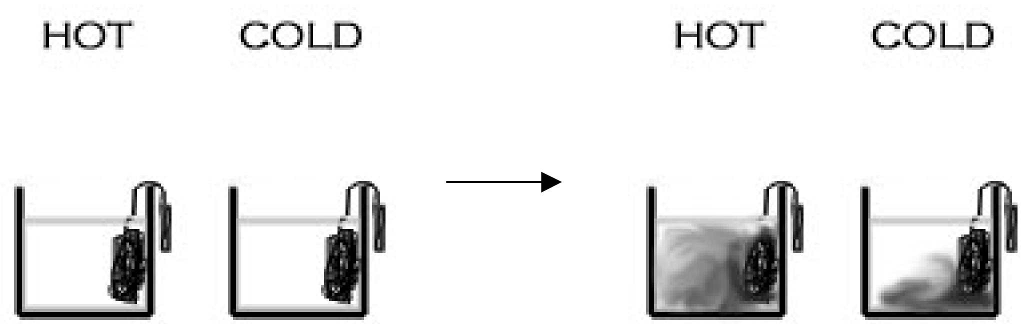
3. Ask the students if their predictions match the observations. Ask questions such as, “Which one is less than the other?” (hot water has a lower volume) , “Why?” (hot

water particles (molecules) evaporated into the air more quickly than the cold water particles because they move faster and this leave liquid more often.)

Testing Experiment 1.7

1. Ask students to observe two medium containers full of liquids- one hot water, one cold water. Have the students predict what will happen when to the liquid in each container if you were to put a tea bag in each one using the concept that they want to test.

2. Put a tea bag in each one, at the same time. Let them sit for a couple of minutes, then ask the students to observe the containers and revise their predictions:



3. Ask the students to explain, using questions like, “Which one mixed better than the other?” (hot water mixed better with the tea) , “Why?” (hot water particles (molecules) moved- and therefore mixed with tea particles more quickly than the cold water particles.)

The following questions will help students see how the concepts that they have constructed help them to understand real life phenomena:

1. Why does sugar dissolve in hot tea faster than in cold tea?
2. Why does hot soup smell more than cold soup?
3. How can we smell somebody’s perfume?
4. Why does perfume wear out after some time?
5. Why is there more human odor in a hot room than in a cold room?
6. Why do we keep a lid on a pot of boiling water?
7. Why does a football look deflated when you take it outside in the winter?
8. Why if you wear hiking boots on a hot day they feel tight?
9. Why do power line wires look loose in the summer and tight in the winter?
10. Will water shrink when cooling? Design an experiment to test your answer.

Section 2.2 concepts:

Most things we encounter are made up of small parts called particles (sometimes they are molecules). These particles are in constant motion.

Particles are too small for us to see.

These particles have empty spaces between them, allowing them to mix with parts from other things.

If two things can mix so their particles take up the empty spaces between them, then the sum of the volumes of two things is more then the volume measured when they're mixed together.

In warmer liquids particles move faster and they have bigger spaces between them. That is why in warmer liquids mixing and evaporation happens faster than in cooler liquids, and they expand when heated.