4.1 Observing changes in water

At the end of this activity students will be able to:

- explain that substances can change state when they are heated or cooled.
- explain that a change in state does not produce a new chemical substance.
- interpret a graph documenting the change in temperature of water is it is heated and changes state.

What ideas might your students already have?

Students, along with most of the general public, will confuse water vapour and steam. Even the Oxford Dictionary refers to both an 'invisible vapour' and to a 'white mist' when defining steam. Students may also find it difficult to explain where condensed water comes from, or where the water goes when a surface dries.

Equipment list

Each GROUP will require:

- 250 mL beaker, half filled with crushed ice
- thermometer (-10 – 110^{o}C) or digital thermometer
- retort stand and clamp
- stirring rod
- Bunsen burner, tripod, gauze mat and safety mat
- stopwatch
- access to **Student Digital.**

Each STUDENT will require:

- *Science by Doing* ***Notebook***
- Safety glasses
- Graph paper

Things to consider and hints for success

Preliminary discussion with the class about what happens when water boils is important in this activity. It may be useful to explain directly that water vapour (i.e. the gas form) is an invisible and odourless gas.

When groups are formed, it is important to allocate students roles as timer, temperature reader and recorder. Make sure timers don't stop the stopwatch after recording each temperature in order to record later temperature changes on the minute. If it is too difficult to record each minute, the group should take a reading every two minutes.

Teacher content information

Most of us will refer to the white mist coming out of a boiling kettle as 'steam' in some contexts. However, it is important to keep in mind that from a scientific perspective it is important to distinguish clearly between the vapour state of water and the white mist formed from droplets of liquid water (or ice crystals in some situations).

This activity also introduces the concept of a 'physical change'. This is a problematic concept. A lot of time and effort is often devoted to teaching students some distinction between chemical and physical changes to little educational effect. Change of state is usually given as one example of a physical rather than a chemical change, and is reasonably clear cut as an example. Other examples, however, are not so clear. For example, dissolving of salts in water is sometimes described as a physical change but also qualifies as a chemical change according to common definitions, since ionic bonds are clearly broken. In this case the dissolving of non-ionic compounds, such as sugar, in water is sometimes referred to as an example of a physical change, but this distinction is unlikely to help clarify the concept for students. Alloys (covered in **Activity 3.3**) are considered to be mixtures, and yet the structure of most alloys involves metallic bonding between the different metal atoms, so that the creation of an alloy could also be considered to be chemical in nature.

Other physical changes, such as bursting a balloon, tearing paper, breaking an egg are clearly macroscopic in nature and provide fairly trivial examples of the concept and do not help students understand what is happening in other situations at a molecular and atomic level. This activity focusses on change of state since this is an important phenomenon to understand in its own right, and not just as an example of a physical change.

Student graphs should look similar to the one shown below. Due to experimental error (inaccurate thermometer and students' recordings) graphs may not be exactly as shown, but should identify changes in state.

A-B temperature of icy is rising – solid

B-C temperature remains constant at around 0^{o}C as solid becomes liquid (latent heat of fusion)

C-D temperature of liquid rises – liquid

D-E temperature remains constant at around 100^{o}C as liquid becomes gas (latent heat of vaporization)

E-F temperature of steam rises – gas (this section will not be observable in this activity since the gas disperses and re-condenses into mist).

Lesson plan

Step 1: Discuss the phenomenon of a boiling kettle with the class. Explain that water can exist as a vapour, but that this is a colourless and odourless gas.

Step 2: Groups form to conduct the experiment, collect results and answer Discussion questions.

Step 3: Students complete the Digital activity and the ***e-Notebook*** activity.

Step 4: Students complete the Summary, individually or in groups.

Discussion Questions

1. At what temperature did the ice start to melt?
2. At what temperature did the water start to boil?
3. On your graph label when the water was a solid, liquid, or a gas.

Further optional question (depending on whether it is appropriate for your class at this stage).

4. At the points on your graph where the graph was flat, the water was still being 'heated'. What do you think was happening to all that heat energy at these points?

4.2 Ice play

At the end of this activity students will be able to:

- explain how salt was used to lower the freezing point of water.

Equipment list

Each GROUP will require:

- 1 cup milk (or ½ cup of cream and ½ cup milk)
- 2 tablespoons sugar
- 1/4 teaspoon vanilla
- 6 cups of ice cubes (crushed)
- ½ cup table salt
- 1 small ziplock bag
- 1 large ziplock bag
- clean spoon for each student

Each STUDENT will require:

- *Science by Doing* ***Notebook***

Things to consider and hints for success

It is pretty important that students are able to taste the ice cream they produce, so only standard and clean kitchen equipment should be used.

Teacher content information

Sodium chloride can depress the freezing point of water to around -21^{o}C. Radiator water in cars, at least where they operate in cold climates, often has ethylene glycol added to the water. This can depress the freezing point to below -30^{o}C. In the northern hemisphere the use of salt on roads in winter was often used lower the freezing point of ice on the roads. It is used less today because of the rusting effect on cars and adverse environmental effects.

Lesson plan

Step 1: Students follow the recipe for making ice cream. During the activity encourage conversations about changes of state, and what effect the salt is having on the melting point of ice.

4.3 Can matter skip states?

At the end of this activity students will be able to:

- give examples and uses of sublimation.

What ideas might your students already have?

Students will not be aware that there is a change of state other than the usual ones.

Key vocabulary:

Sublimation

Equipment list

Each GROUP will require:

- access to **Student Digital**

Each STUDENT will require:

- *Science by Doing* ***Notebook***

Things to consider and hints for success

This activity relies on videos to provide experience of sublimation. Most substances used to demonstrate sublimation, such as dry ice, iodine and mothballs (naphthalene) and not able to be used by students at this level. You may choose to show some of these through a teacher demonstration.

Teacher content information

Whether or not sublimation occurs depends on a substance's triple point, the conditions of temperature and pressure at which the substance can coexist as solid, liquid and gas. Interestingly under very low pressure, for example, in outer space water ice will also sublime rather than melt.

Lesson plan

Step 1: Students complete the Digital activity and complete the **e-Notebook** questions.

4.4 Detecting an invisible gas

At the end of this activity students will be able to:

- explain how carbon dioxide gas can be detected through its ability to smother a flame
- identify a range of gases and describe their properties.

What ideas might your students already have?

Students have difficulty recognizing gases as chemical substances. This is compounded by the fact that most gases that we might come across in our lives are colourless and odourless. They will also tend to classify gases as either 'air' (good) and 'gases' (bad).

Equipment list

Each GROUP will require:

- 1 large beaker
- 1 small beaker
- sodium bicarbonate
- hydrochloric acid (0.1 M)
- tea light candle
- spatula

Each STUDENT will require:

- *Science by Doing* ***Notebook***

Things to consider and hints for success

Remember that iodine is used not only because it provides an example of sublimation, but also because it is one of the few gases that we can see, allowing us to identify some of its physical gaseous properties.

Teacher content information

The **Student Digital** activity introduces nine gases that students may come across during their lives. It is notable that every one of them is colourless and odourless, properties that make it difficult for students to develop a meaningful concept of what a gas actually is or to recognize their existence in the first place. These gases, however, have a wide range of chemical properties rendering some of them innocuous and other highly toxic. This raises considerable safety issues around their use.

Lesson plan

Step 1: Students complete the hands-on activity and answer the questions in their ***Notebook***.

As an extension you could discuss with the class why this property of carbon dioxide (heavier than air) makes it dangerous in certain situations. Depending on the level of the class you could also discuss the reaction that occurred in more detail.

Step 2: Students complete the **Digital** activity and answer questions in the **e-Notebook**.

4.5 What is happening to me?

At the end of this activity students will be able to:

- describe what happens to particles when heated and cooled.
- use correct terminology for what takes place when matter changes state.

Key vocabulary:

Melting, boiling, evaporation, condensation, freezing.

Equipment list

Each GROUP will require:

- a tray of sand
- polystyrene or plastic cups
- digital scales

Each STUDENT will require:

- *Science by Doing* ***Notebook***

Things to consider and hints for success

This task can be used as a **formative** or **summative assessment**. To assist students, especially those with low literacy, you could distribute a spelling list.

Lesson plan

Step 1: Students describe what happens to a water molecule in an ice block left in the sun. Encourage them to be creative – write a story, draw a comic strip, make a poster etc.

You could allow students to use the information in their ***Notebooks***, depending on the type of assessment you are undertaking. This could be a homework task.