Chemistry
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14
ACTIVITY

Chemistry is fun!

a demonstration of solids, liquids and gases

age group 5-10

1 HR

120 STUDENTS

30 STUDENTS PER GROUP

1 SUPERVISOR

£50

background

The world we live in is made up of solids, liquids and gases and many of our everyday events involve a changing of state between two of them. For example when we make a cup of tea we boil the liquid and produce a gas and when we make an ice-lolly we freeze the liquid to produce a solid. Children are familiar with seeing these processes but often struggle to remember the correct terminology for what is happening.
This demonstration lecture is designed to illustrate the changes of state that occur when we move from one phase to another in a fun, exciting and truly memorable way, and is an excellent vehicle for teaching children the correct terminology for these processes.

pre-planning required

weeks before
Purchase liquid nitrogen and solid carbon dioxide (cardice). Order methylene blue, potassium hydroxide, Universal indicator, D-glucose and arrange for the glassware and equipment you need to be available.

days before
Purchase balloons, Pringles®, flowers, rubber tubing, eggs and a banana.

facilities required

A suitable classroom, lecture theatre or assembly hall.

materials required

- 2L measuring cylinder (plastic or glass)
- 5L conical flask with a bung (plastic or glass)
- large plastic bowl
- dewer for liquid nitrogen
- gloves for handling liquid nitrogen
- safety spectacles
- hammer
- eppendorf tube or film canister
- large spoon for handling cardice

Suggested timings for the day

This is a one hour event. A 45 minute demonstration with time allowed at the end for questions.

Suggested format of the demonstration with accompanying questions

The demonstrator carries out the experiments while asking the students questions and encouraging them to take part in some simulations. The students are not involved in the experiments themselves.

Introduction

The students will have done, or are about to do, the part of the curriculum that covers solids, liquids and gases. The demonstrator should prepare for the demonstration by becoming familiar with the content of this part of the National Curriculum or equivalent in other parts of the UK.

This activity is based on a demonstration done by Dr Sarah Heath, University of Manchester.

SAFETY
A risk assessment must be done for this activity.

Possible opening questions

This gets the students involved immediately and gives the demonstrator an idea of the students' knowledge.

- Who can tell me the name of a liquid?
  (Answer will usually be water)
- What is water called when it is solid?
  (Ice)
- What is this process called?
  (Freezing)
- At what temperature does this happen?
  (0 ºC)
- What is water called when it is a gas?
  (Steam, not vapour)
- What is this process called?
  (Boiling)
- At what temperature does this happen?
  (100 ºC)

Other liquids

1 Liquid nitrogen

Show the students that it is like water but it boils at -196 ºC i.e. it is very cold. Nowhere on Earth is that cold. The coldest temperature ever recorded on Earth is -89 ºC at the Russian Vostok Station in Antarctica.

Liquid nitrogen can burn the skin and as it is so cold it can freeze things. As a gas nitrogen is in the air around us.

2 Pour liquid nitrogen onto the floor

Who knows what other gases are in the air we breathe? The main gases in the air are nitrogen (78%), oxygen (21%) and others (1%). Among the others are carbon dioxide (0.03%), noble gases (0.9%) and varying amounts of water vapour depending on the weather.

Let's look at some other gases that are in the air.

3 Methylene blue and oxygen

This reaction is sometimes called the blue bottle reaction essentially because the clear solution in the bottle turns blue when shaken, then back to clear, then blue when shaken again etc.

These reactions involve the following chemicals:

- KOH (potassium hydroxide)
- glucose (a type of sugar – formula $C_6H_{12}O_6$)
- methylene blue (a type of indicator)
- water
- oxygen (from the atmosphere)

First, glucose reacts with hydroxide ion to form glucoside (glucoside is formed when glucose reacts to form it's acetal). The hydroxide ion comes from potassium hydroxide (KOH) that has dissolved in water.

When you first shake the solution, oxygen from the air is dissolved into the solution (just like oxygen is dissolved into a fish tank by pumping air into the water). This oxygen combines with methylene blue (in it's reduced form) to produce the blue colour of the solution (the methylene blue has been oxidised).

The glucoside formed in the first step now reacts with the oxidised methylene blue to produce colourless methylene blue (the same colourless reduced form that we started out with) and the OH- ion, both of which are free to react again if the solution is shaken to introduce more oxygen.

The general reactions are:

1. $KOH\ (\text{dissolved in water}) \rightarrow K^+ + OH^-$
2. $\text{glucose} + OH^- \rightarrow \text{glucoside}$
3. $\underset{\text{in air}}{\text{oxygen}} + \underset{\text{colourless}}{\text{methylene blue}} \rightarrow \underset{\text{blue}}{\text{oxidised methylene blue}}$
4. $\underset{\text{blue}}{\text{glucoside}} + \text{methylene blue} \rightarrow \underset{\text{colourless}}{\text{methylene blue}} + OH^-$

4 The evolution of oxygen from hydrogen peroxide (H_2O_2) and potassium iodide (KI)

Put H_2O_2 in a measuring cylinder and add some fairy liquid. The students see that nothing happens. Add the KI which acts as the catalyst.
The students also see I^- going to iodine and some of the foam goes yellow/brown.
$H_2O_2 + I^- \rightarrow IO^- + H_2O$
$H_2O_2 + IO^- \rightarrow O_2 + H_2O + I$

5 Special gas – carbon dioxide (CO_2)

Explain that we breathe it out. You may want to expand on this.

6 Compare to ice – solid to gas (sublimation)

Blow on the solid CO_2 – warming it up, showing that it doesn't turn to a liquid. Melt ice so that the students can see it turns to water.

7 CO_2 in a measuring cylinder

The basic solution in the measuring cylinder is coloured with Universal indicator. Add dry ice and the colour changes with the evolution and dissolution of CO_2. The resulting solution in the measuring cylinder is weakly acidic and is comparable in pH to Coca Cola®.

8 CO_2 in a plastic bottle

There are three main ingredients in fizzy drinks – water, syrup and CO_2 gas. It is the carbon dioxide gas that makes them fizzy. When the ingredients are combined, the CO_2, syrup and water form a solution. The ingredients are mixed in a container and the empty space at the top of the container is filled with CO_2. The bottle is then sealed. The CO_2 at the top of the container is under pressure and prevents any of the dissolved CO_2 from coming out of the solution. When the bottle is opened, a hiss is heard and the CO_2 in the top of the bottle is released. The dissolved CO_2 can now come out solution resulting in a bubbling carbonated drink.

9 CO_2 in Eppendorf tube and glove

Put a small pellet of CO_2 in an Eppendorf tube and seal it. (Eppendorf tubes are small, cylindrical plastic containers with conical bottoms and an integral snap cap). Put it in the far corner of the room. When the CO_2 turns into a gas the top pops off the Eppendorf.
Use this to illustrate that gases take up more space than solids. Do the same with the glove – but don't let it pop! What's happening? Explain that gases fill the space they are in more than solids. What about liquids and solids? You can demonstrate this with groups of students. There are three states of matter, solids, liquids and gases which surround us every day.

10 Liquid N_2 in a Pringles® container

This demonstration shows that liquids take up less space than gases. Put a small amount of liquid N_2 in the tin and show the students it isn't full – then put the lid on. The top pops off due to the pressure of the gas. The tin also gets condensation on it from the air so this is a good point to talk about.

11 A balloon full of air in liquid N_2

What's happening? When the liquid N_2 cools down the air in the balloon changes from a gas into a liquid and we've already seen that liquids take up less space than gases so the balloon deflates.

12 A balloon full of air over a boiling-tube of liquid N_2

Blow up a balloon and then put it over a large boiling tube. Put the boiling tube into a beaker that's full of liquid N_2. The gas in the balloon cools and the balloon deflates – when you take the boiling tube out of the beaker you can see the 'liquid air' in the bottom. This starts to boil and the balloon reinflates. The boiling tube also gets condensation on it from the air when you lift it out. This is another good point to talk about.

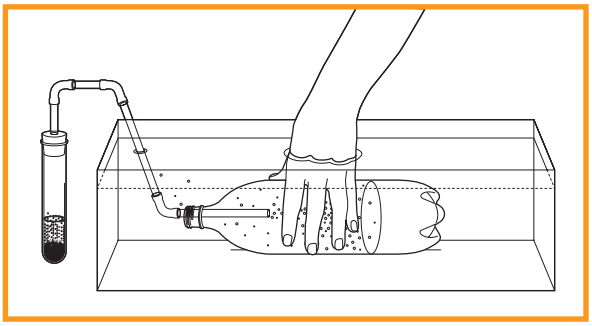
13 Fill two balloons – one with N_2 and one with CO_2

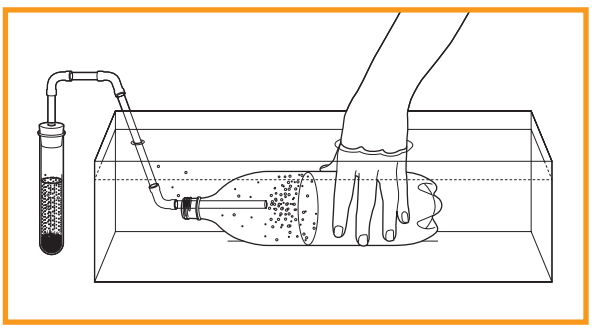
What happens when you drop them? CO_2 wins, but why? CO_2 is 1.57 times heavier than N_2.

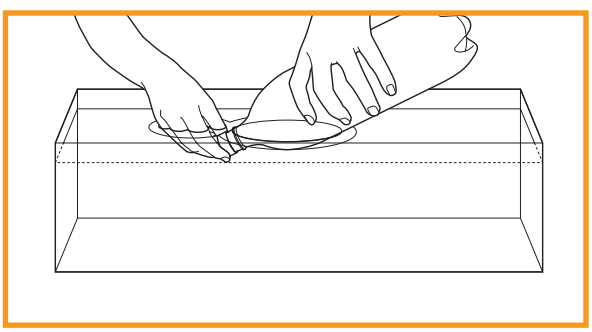
14 Making things cold

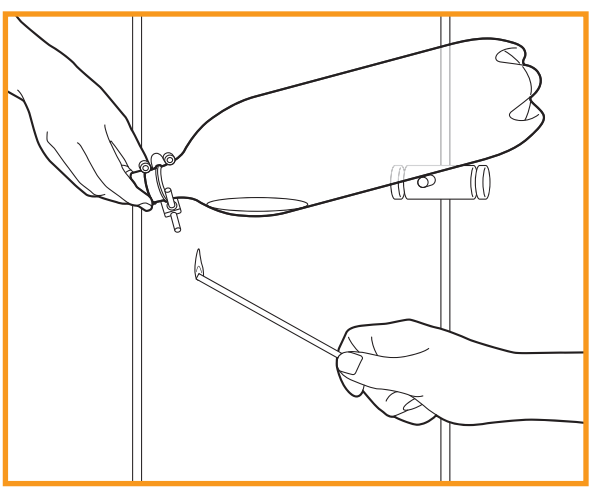
Dip a series of objects into liquid N_2 to show the effects of making things cold. You might like to try flowers, rubber, eggs, bananas etc. You might like to finish the demonstration by looking at a gas the students haven't seen yet – hydrogen (H_2).
If H_2 and O_2 are mixed in the right amounts we can make rocket fuel.

In the US Space Shuttle the large External Tank (ET) contains a liquid hydrogen fuel and liquid oxygen oxidiser and supplies them under pressure to the three Space Shuttle main engines during lift-off.









15 Hydrogen rockets

Finish with a bang! Tell the students that they are going to use a gas you haven't talked about yet – H_2. Pre-fill a plastic bottle with $^1/_3$ H_2 and $^2/_3$ water. Tell the students that to power rockets it is very important that the fuel mixture is correct – $^1/_3$ H_2 to $^2/_3$ air is okay and the fuel will burn. However, $^1/_2$ H_2 to $^1/_2$ air will cause the rocket to explode. Let the water out of the bottle – put the bottle on a launcher.

Tell the students to plug their ears and then set light to the gases at the neck of the bottle. The rocket flies across the room. Get someone to fetch the bottle and ask them how it feels – it should be warm. Explain that hot gases need even more space than cold gases, so when the gases burn they expand and fly out of the neck of the bottle propelling the rocket.

SAFETY

Wear eye protection and ensure that the clamp is only 'loosely' holding the neck of the bottle prior to ignition. Ask students to stand well back. It may be sensible to warn others within ear shot that loud bangs are likely.