Creating Science – States of Matter

Meet the 4 naturally occurring states of matter and experience air pressure. ***#CreatingSciencePuffCup***

Suggested outcomes

(NOTE: This is by no means an exhaustive list of possible outcomes, neither is it intended that ONLY these outcomes can or should be met. Science is a deeply interrelated activity, and you may find cross curriculum links you can and should use.)

Science understanding

- Chemical science 5: Solids, liquids and gases have different observable properties and behave in different ways.
- Chemical sciences 8: The properties of the different states of matter can be explained in terms of the motion and arrangement of particles.
- Chemical science 3: A change of state between solid and liquid can be caused by adding or removing heat.

Extra outcomes

- Chemical science 6: Changes to materials can be reversible, such as melting, freezing, evaporating; or irreversible, such as burning and rusting.

Science inquiry skills

- Planning and conducting F: Participate in guided investigations and make observations using the senses (ACSIS011)

Science as a human endeavour

- Nature and development of science 9-10: Scientific understanding, including models and theories, are contestable and are refined over time through a process of review by the scientific community.

Science vocabulary words

Tier 1 (Everyday words) solid, liquid, gas, plasma.

Tier 2 (Dual meaning)

- Plasma – the word also refers to the colourless part of blood, lymph, milk, etc. It is the part the other chemicals are suspended in. It is NOT the same thing as plasma below.

Tier 3 (Specialised vocabulary)

- Plasma – In this context plasma is similar to a gas, however, gasses are great insulators. When they become hot enough they will usually glow, and the electrons break free of the atoms allowing electricity to flow. Gases do not conduct electricity, plasma does.

Warning

- We will be using hot water today. BE EXTREMELY CAREFUL!

Preparation

- Balloons
- Hot water (Take all appropriate caution and keep well away from children!!!)
- Room temperature water
- Two clear cups or bowls
- Food colouring

Suggestions for other year levels

As always, more material is presented here than can be used by the average class during the average lesson time. However, since the student's questions can and should guide student learning, more material is presented for your convenience.

Younger:

Children at this age can have difficulty with focus. Avoid tangents if you're attempting to make a key point.

Middle:

This activity is well suited to this age group.

Teen:

This activity is a little below this group, and will need further extending.

Engage

[younger groups] Ask – can you name some things that are hot? What makes them hot?

Ask – what is heat?

Explain – Hundreds of years ago, 'What is heat?' was a scientific question many scientists were asking themselves. One theory that worked quite well for a long time, was that 'heat' was an invisible fluid that concentrated in hot things and flowed away over time, making them seem colder. This theory was known as Caloric, an idea published by French nobleman and chemist Antoine Lavoisier in 1783. This theory helped to explain:

- Why things go cold – caloric must be self-repelling
- Why gasses get larger when hot (i.e. a hot air balloon) - because the caloric is taking up space
- Pierre-Simon Laplace was even able to improve Sir Isaac Newton's calculation of the speed of sound using caloric theory!

The theory worked, and what did scientists do? They used it, of course!

But there were problems…

- In 1798, American born British physicist Count Rumford from showed that cannons being drilled out get *hotter*, not *colder*. How can that be explained if the caloric was being removed?
- In order to work, the theory had to ascribe some unusual properties to caloric, for example: weightlessness, elasticity greater than that of all other substances, and an ability to penetrate and expand even the tiniest pores of objects. It was beginning to seem pretty unreal, even magical.

So a new theory was needed. Caloric theory was so successful that the new theory was *over a hundred years old* before it became commonly accepted among scientists!

Explore

Blow up a balloon.

Ask how the air is keeping the balloon blown up. Explain that one theory is that air is made up of billions of invisible, tiny particles. These particles of air in the balloon aren't just sitting there, they're whizzing around at great speed! Even though they're too small to hear, see, or feel, there are billions of them, and whenever they hit something they give it a teeny tiny push. But since there's so many of them, all together they can give things an ENORMOUS PUSH!

⇨ Try squashing a soft drink bottle with the lid on and nothing but air inside. Is it possible? Not easy? – could it be because air is pushing!

Now measure the size of the balloon by tying a string around it.

⇨ Now put the balloon in the freezer for an hour. Have students predict what they think will happen.

⇨ Then remove the balloon and measure it as soon as you can. What has happened? (In most cases the difference in size should be apparent to the eye. You can even blow up two balloons at the start to exactly the same size and compare them after one has been in the freezer. But you'll need to be quick because as soon as you remove the freezer balloon it will warm up and increase in size. Sometimes you can get the same effect placing the balloon in a bowl of ice water instead of a freezer.)

Challenge students to explain what has happened.

Explain

Ask – Did the balloon get smaller because all the caloric was taken out?

Explain – Another theory to explain heat was invented 1798 by Sir Benjamin Thompson, better known as Count Rumford and developed more thoroughly in 1824 by the French physicist Sadi Carnot. They explained heat as being the random movement of particles, and not as an entirely different 'invisible fluid'. Thus:

- Everything is made up of particles. These particles are always moving. The more they move, the 'hotter' a substance feels.
- Depending on the substance:
  - At a certain temperature those particles will have so little movement energy that they cannot break away from each other. We call that a solid, i.e. bricks and poles.
  - When those particles are moving enough to slide over each other, but still not enough to break away entirely, we call that a liquid, i.e. juice and blood.
  - When those particles are moving enough so that they break away entirely and fly around the room, we call that a gas. I.e., air such as clouds or flatulence.
  - When those particles are moving around so much that when they hit each other they begin to break apart, we call that a plasma. I.e. lightning and the sun.

Elaborate

Have students explain the following;

- Hold some ice.
  - When you touch a cold object, some of your heat energy transfers to the ice, making it melt. You, on the other hand, get cold, which can be very bad news since you can get frost bite if you hold on for too long!
  - When you touch a hot object, the bouncing particles begin to smack into the particles that make up your skin. If they have too much heat energy, the particles in your skin can be wacked right off! This can be very dangerous to you too as it will burn.
- Place a drop of food colouring into two cups of water, one with hot water and the other with room temperature water. What happens? [you can use this to illustrate fair testing by insisting on using one colour for hot and cold, since if you use different colours to represent hot and cold, then what are you really testing – temperature, or how fast different colours mix around?]
  - The hot water will mix up the food colouring quicker because the particles are moving around more. You may even see millions of them leaving and forming quickly together to form drops you can see – i.e., steam. (Be careful – it's hot!)
  - Remember, there are no liquids without air pressure! Take away the air above, and all liquids will boil away!
- Place a balloon in the freezer, what happens?
  - As the air gets colder, the particles slow down, pushing less hard on the sides of the balloon. Thus, the entire balloon will shrink.

- View lightning or a plasma ball.
    - This is a demonstration of plasma, caused as electricity makes the air so hot that it rips the particles apart, just a little. (The atoms themselves aren't split, but the particles can split into atoms and electrons, as long as there is an equal amount of positive and negative change.) Note that you cannot see the electricity, as it is invisible. Neither can you see the surrounding air. All you see is the air glowing as it is turned into plasma by the invisible electricity passing through it.
    - Technically, the sun is a ball of plasma, not a ball of gas!

⇨ Build a puff cup (see appendix) to help experience and explain air pressure.

Evaluate

⇨ Review with students what they felt they learnt from this lesson. Did they have any questions at the start that they feel were answered?

Success criteria

⇨ Review the Learning Intentions of this lesson with students. Was it met?

At the end of each class, review the learning objective and see how we did. Ask:

⇨ Did you achieve your learning goal?
⇨ What did You learn?
⇨ What worked to help you achieve it?
⇨ What might you do better next time?
⇨ (If needed) where can you go for extra help or information?

Assessment

Prior learning:

Find out what students think heat is during the engage phase. You may find it useful to bring along or refer to several objects used for making and storing heat, such as ovens, fridges, coffee flasks, etc.

Formative:

As students are learning, help them self-monitor their own learning and achievements.

Find out if students are appreciating the important concepts of this unit (i.e., the concept of heat and the history of how we got that concept) by asking students to explain the concepts back to you. You may also want to ask:

- What might have happened if a scientist other than Count Rumford came up with the kinetic model of heat?

- Why didn't Lavoisier come up with the kinetic theory of heat? [Could it be he didn't want to, as he was trying to prove the effectiveness of the caloric theory?]
- What was the final experiment that convinced people about kinetic theory of heat? [There were many, including Einstein's description of Brownian motion – the jiggling of poppy seeds under a microscope. Also (English) chemist Humphrey Davy, inspired no doubt by his teacher Robert Dunkin, who demonstrated that two pieces of ice rubbed together even in a fridge could still melt - strong support for the kinetic theory and refutation of the caloric theory.]

Also

- Rather than give the explanation for each of the observations during the Explain and Evaluate phase, allow students to provide their theories (explanations) of what unseen processes are happening here.

Summative:

Help students consider ways they can communicate their new understanding to others, just as scientists need to do.

- Have students present a report on how the theory of heat changed over time.
- Have students explain to an imaginary friend or class puppet the molecular processes of going from a solid, to a liquid, to a gas, to a plasma.

So what?

- People from all over the world, including England, America, Britain, France all contributed to the modern theory of heat (Ok, they're all 'western' society, but I hope it helps to validate a point)
- Scientific theories change as new evidence comes to light or as old evidence is reinterpreted in the light of a more effective theory. Ie, Rumford's cannons.
- Heat can now be thought of as the motion of particles: more motion, more heat!
- Chemical facts:
    - The word chemical in science means 'material' or matter. So even air, water and skin are all made up of chemicals.
    - There are no innately dangerous (or safe) whats??

Creating science

Science understanding

As we explored solids, liquids, gasses and plasmas we saw that;

- Chemical science 5: Solids, liquids and gases have different observable properties and behave in different ways.
- Chemical sciences 8: The properties of the different states of matter can be explained in terms of the motion and arrangement of particles.
- Chemical science 3: A change of state between solid and liquid can be caused by adding or removing heat.

Science inquiry skills

As we built and played with the puff cup, we were;

- Planning and conducting F: Participate in guided investigations and make observations using the senses (ACSIS011)

Science as a human endeavour

As we explored the history of air pressure as an idea, appreciating that it was many scientists over many years, we learned that;

- Nature and development of science 9-10: Scientific understanding, including models and theories, are contestable and are refined over time through a process of review by the scientific community.

Tips from the Masters to make it work:

some grownup help may be helpful.

a hole may be placed in the bottom of the cup

Easy, easy, easy! And apart from the sticky tape this can be made out of completely recycled materials the next time you have a picnic!

Appendix: Pressure cups

How to make a pressure cup

All you'll need is A) a large, firm cup, B) a sheet of thickish plastic or a small, firm plastic bag, and c) loads of sticky tape!

Push the plastic into the cup, leaving a large rim on the outside of the cup

Tape down the rim to the outside of the cup – be thorough, aim for air tight! And don't forget a label.

Tips 1/ To make sure your plastic is large enough, line three cups up along the centre line, marking off the edges. Repeat in several directions until you have a very large circle.

2/ The plastic needs to be nearly air tight. Use loads of sticky tape and make sure you go above and below where your rim ends several times. Of course, if your cup is completely air tight you'll have to rip the plastic to pull it out (or back in) so some small holes are acceptable.

How to work it:

1/ Push the plastic into the cup, yet it resists… why?

2/ Now pull the plastic out of the cup, again it resists … why?

(Remember – air never sucks! It only ever pushes!)

How it works

Air has pressure: every single particle of air is moving around, and when a little particle hits something, it gives it a little push. Now even though those little pushes are soooo teeeeny tiny that you cannot see, hear or feel them individually, there are actually soooo many particles of air that all tighter they can give even a very small thing a very large push!

Further explanation and label:

Air Bottle

Push in the plastic – why is it so difficult?

Perhaps because the air pressure in the bottle is pushing the plastic back out?

Pull out the plastic – why is it so difficult?

There's air in the bottle, and air in the room. Both have pressure because the air particles are bouncing around. Perhaps it is difficult to pull the plastic out because the air pressure in the *room* is now pushing the plastic back in!

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1/ When you are trying to push the plastic into the cup, the air inside the cup now has more pressure than the air outside the cup – that is, because you're squeezing down on them the particles inside the cup tend to press against the plastic just a little more often than the air outside the cup. You experience this as a push. So the air inside the cup is pushing out, making it hard to get the plastic in. That's not so hard, eh?

2/ Where people get stuck is in trying to understand why it's hard to pull the plastic back out again, especially since air never sucks. The visual explanation is that as you try to pull the plastic out, the *air in the room* is now pushing against the plastic harder than the air in the cup. This means you're trying to pull not only the tiny, insignificant weight of the plastic, but the enormous, significant pressure of the air touching the plastic as well. And as we know; air is always pushing in all directions all the time … *very* powerfully!