Creating Science – Breathing Fire, Deflagration, and Surface Area

With safety and preparation, anything can burn under the right conditions. #CreatingScienceBreathingFire

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 content

- Chemical sciences 3: A change of state between solid and liquid can be caused by adding or removing heat (ACSSU046)
- Physical sciences 3: Heat can be produced in many ways and can move from one object to another (ACSSU049)
- Chemical sciences 5: Solids, liquids and gases have different observable properties and behave in different ways (ACSSU077)

Science inquiry skills

- Questioning and predicting 3:With guidance, identify questions in familiar contexts that can be investigated scientifically and make predictions based on prior knowledge (ACSIS053)
- Planning and conducting 3: With guidance, plan and conduct scientific investigations to find answers to questions, considering the safe use of appropriate materials and equipment (ACSIS054)

Science as a human endeavour

- Nature and development of science 3: Science involves making predictions and describing patterns and relationships (ACSHE050)
- Use and influence of science 3: Science knowledge helps people to understand the effect of their actions (ACSHE051)
- Use and influence of science 5: Scientific knowledge is used to solve problems and inform personal and community decisions (ACSHE083)

Science vocabulary words

Tier 1 (Everyday words)

- **Fire.** Most common fires convert airborne oxygen and the fuel into water (steam) and carbon dioxide gas. This process releases so much heat it makes those products and the nearby air glow. Since hot air rises it tends to push itself upwards through the surrounding air. As the fire rises, the cooler air surrounding the base of the fire is then pushed into the fire. This helps to keep the fire burning as new oxygen is constantly replacing the old oxygen. Fires are around 1000^{o}C, and are dangerous to human touch!

- **Burning** is a chemical change (while melting is a physical change). In burning, atoms are rearranged to produce new chemicals, and so much heat is released that the nearby air (often made up of those new chemicals) glows. In a normal fire, the fuel is converted into carbon dioxide and water (the complete opposite of photosynthesis). Johnson (2002) believed that burning 'must be regarded as one of the last things we should expect [primary] students to understand'.

Tier 3 (Specialised vocabulary)

- Chemical kinetics – the study of how fast, or slow, a chemical reaction can be made to happen. Today, we use **surface area**.
- **Surface area** – the part of a material that is in direct contact with other materials. The surface of the water in contact with the air, for instance, is called the water's surface area. Today's example involves increasing the surface area of a solid by breaking it up into a very fine powder.
- **Surface area to volume ratio** – the relationship between how much the inside compares to the outside. Spheres have the lowest surface area to volume of any solid since they have the largest inside of any shape compared to their outside space. Since only the outsides of a material can react with other chemicals (remember the insides are covered up), fire and other chemical changes often rely on having a low surface area to volume ratio. One way to lower the ratio is to break things up into smaller and smaller pieces, thus increasing the amount of outside while decreasing the amount inside. Fire and chemical changes are sped up by having a low surface area to volume ratio, that is, by having lots of outside for every piece still inside.
- **Deflagration**. Explosions are sometimes organised into two kinds. Those that happen faster than the speed of sound are called detonations. Those that happen slower than the speed of sound are deflagration. In detonations, a shockwave results and hot material spread very quickly. In deflagration the explosion spreads by normal heat transfer.

Warning

- FIRE! All appropriate safety gear is required. Younger groups should have several responsible grownups or older children to help.
- FOOD ALERGY WARNING – while it is not expected that any of the powders today will be invested, be sure let families know in the case of extreme sensitivity. For example, you may want to include gluten free flour.

NOTE: most fireballs created today are so short lived they will not burn human skin. They will, however, set fire to highly flammable materials such as oil, gas, finely sized tissue paper, or curtains with lots of thin threads. Hair will usually just curl up, but the hair products such as hairspray are occasionally flammable. Be careful – you have been warned.

- DO NOT let your students make fireballs near flammable objects, such as curtains, paper, or other children. REMEMBER – fires tend to go UP, watch out for things above the fire.

- GREAT BALLS OF FIRE – this activity will teach kids how to make fireballs at will. It is wise to expect they will do so at every available opportunity from now on. Have a fire at school camp, with chocolate powder and drinking straws, and you will soon also have fireballs. Teach all appropriate safety instructions, and teach students to teach *others* how to be safe – IF you feel they can handle this knowledge responsibly. Learning how to deal safely with fire, as with life, is a necessary skill for young kids to have. This is only possible once students gain a reasonable understanding of the risks.

Preparation

For the demo you will need:

- A steel nail.
- Some steel wool.
- Tongs to hold the above, and a ceramic plate to hold it over.
- A fire source, a fire lighter will usually do.

For the activity on flammability you will need:

- Aluminium foil to put the fire on.
- Some plates to set the very hot aluminium foil on, plastic is fine, ceramic also.
- Several firelighters, one for each group.
- Some powders, namely;
    - Normal sugar
    - Icing sugar
    - Bicarb
    - Chocolate powder
    - Corn flour
    - Wheat flour
    - Other powders as you desire.

For the activity on burning and surface area you will need all the above, as well as:

- A very wide mat to catch all spills and flying powers.
- Straws. Wider the better, and clear ones are ideal, though almost any will do.
- The fire source, see images (we use a small metal milk flavouring can, filled with towelling and soaked with Metho. The lid can be replaced to suffocate the flames. This makes it resistant to spilling if it falls over, however, do not invert).

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 students questions can and should guide student learning, more material is presented for you convenience. Remember, it is not uncommon for students to only remember those points which answered their personal questions.

Younger:

Through this activity the concept that spread out things will react faster is intuitively obvious to most learners even at this level.

Children at this age sometimes have difficulty with focus. Avoid tangents into interesting side tracts if you're attempting to make a key point – such as safety point. Reiterate often and repeatedly.

We had parents hold and manage all fire sources and fire lighters at all stages of the activity.

Middle:

This activity is well suited to this group, if you trust them with fire. We suggest you put the fire on a table to avoid it going up pant leg and lab coat tails, and having strict rules about where students are allowed to stand in order to participate.

Teen:

Try to develop an ideal powder amount relative to heat generated. Is more always better?

Learning Intent (student friendly)

'We are learning to' (WALT). Appreciate that the rate of chemical reactions can depend on the amount of surface area available. We are also learning to burn things safely.

Success criteria

'What I'm looking for' (WILF). Safe handling of equipment, as well as an understanding that all the powders used today are flammable, but lack surface area.

Student learning goals

Help students make a self-monitored learning goal for this lesson.

Evidence of learning

How will you know when the learning goal is achieved? What EVIDENCE do you have that your students have met or exceeded the learning expectations?

They can successfully deflagrate the powders used today.

Engage

- ⇨ Note the Learning Intention of this lesson for students.
- ⇨ Make sure all students write down any questions they may have generated during this phase regarding the topic for today.

Try to set fire to a steel nail using a lighter or match. It won't burn. (Use caution and tongs; heat can travel down the nail and burn you!)

Now set fire to some steel wool using a match.

Ask: Why does it burn? It's the same stuff!

Explore

⇨ Encourage and validate student explanations of this phenomenon. You may like to ask students to write or draw their explanation personally to avoid embarrassment to students unfamiliar with this material. Remember, 'I don't know' is a valid explanation in science – it is the beginning of learning new things!

Perform the activity in the appendix "Breathing Fire".[1]

Explain

Compare student predictions with results. What things burnt, and what did not?

Here are some typical results. **Remember** they are not the "right" results. We also have included some suggested explanations for your consideration. ***<u>Remember</u>*** they aren't the "right" explanations – we certainly don't have time to test them today. What do your students think?

- Normal sugar - does not burn very well. The crystals are quite large and even as an airborne powder, not enough heat is generated to set fire to them all.
- Icing sugar – burns quite well. Its' small, and it is a good fuel for our bodies which means it's also a pretty good fuel for fire. It won't burn long, but it will burn brightly.
- Bicarb - does not burn… or, rather, it does, but it produces a lot of carbon dioxide, which actually helps put out the fire. It also turns into sodium carbonate, which looks just like sodium bicarbonate. So things are happening, but we cannot easily see them.
- Chocolate powder – Often one of the best to burn, made of food with very small particles. Chocolate is food too!
- Corn flour – tends to burn really, really well. It's a happy mix of something that is really, really tiny and very, very burnable.
- Wheat flour – burns quite well. So well, in fact, that any process making flour has to be very, very careful of making too much powder and risking an explosion!

What makes things burn?

There are many other fine answers to the question 'what makes things burn', what do you think?

In order for atoms to join together, they usually need energy. Sometimes they can get this energy lying around, sometimes they need it to be added.

So, naturally, when atoms break away from each other they usually release energy as well, usually as heat. Sometimes this heat is so much that it can make the nearby atoms glow.

[1] We are indebted to *Jim Dash* for thinking of the straw based technique for deflagration, rather than huge hoses or breathing directly out of student's mouths, and thus have named this technique after him.

We see this glow as fire, and say the material is burning. Remember the atoms are just rearranging, they're **not** disappearing at all. A normal fire is a little like the complete reverse of photosynthesis. Fuel and oxygen go together to make carbon-dioxide, water, and excess energy.

What makes things burn better?

The inside of a material cannot burn – for example, only those atoms at the outside of the fuel can react with the oxygen in the air. Thus, increasing the surface area can dramatically speed up a reaction.

From https://en.wikipedia.org/wiki/Chemical_kinetics#Surface_area_of_solids 30 may 18. Surface area of solids:

In a solid, only those particles that are at the surface can be involved in a reaction. Crushing a solid into smaller parts means that more particles are present at the surface, and the frequency of collisions between these and reactant particles increases, and so reaction occurs more rapidly. For example, Sherbet (powder) is a mixture of very fine powder of malic acid (a weak organic acid) and sodium hydrogen carbonate. On contact with the saliva in the mouth, these chemicals quickly dissolve and react, releasing carbon dioxide and providing for the fizzy sensation. Also, fireworks manufacturers modify the surface area of solid reactants to control the rate at which the fuels in fireworks are oxidised, using this to create different effects. For example, finely divided aluminium confined in a shell explodes violently. If larger pieces of aluminium are used, the reaction is slower and sparks are seen as pieces of burning metal are ejected.

Chemical kinematics is the study of the reaction rate of chemical changes.

A dust explosion

Diagram showing the five requirements for a dust explosion:

There are five necessary conditions for a dust explosion:[1]

- A combustible dust
- The dust is suspended in the air at a sufficiently high concentration
- There is an oxidant (typically atmospheric oxygen)
- There is an ignition source
- The area is confined - a building can be considered an enclosure

Taken 13 june 2018 from https://en.wikipedia.org/wiki/Dust_explosion

Elaborate

⇨ Ask students if they can design new ways to test this explanation, is it really sufficient? Can they think of further or better explanations, and the experiments needed to test them?

In real life

Huge explosions have been recorded due to the kinematics of having a high surface area. Even things that normally don't burn can become *veritable besoms of destruction* once conditions are right.

- Coal plants often dampen down the coal dust, as a single spark can set a whole mountain ablaze.
- Flour mills must be careful of their conditions or explosions can rock the whole city.
- Sugar factors can get in terrible trouble if they don't take care of their dust.
- Paper mills can sometimes get in situations they cannot control.
- Even metals such as titanium can cause a dust explosion in the right conditions!

Part of the danger can be that a powerful dust explosion can shake the area so much that it releases more combustible dust.

Of course, we sometimes put this to good use.

- An early car used coal dust as its main fuel source.
- The dramatic explosions in movies are usually actually two explosions – the first one turns the fuel into a wide dust (or drip) cloud, and the second explosion ignites it.
- Dissolving a chemical in a solution will potentially break it up into individual molecules and atoms – literally the largest surface area possible for that material. This is one reason why many chemical reactions, particularly in living creatures, rely on water to occur.

Some tragic examples of dust explosions.

- Mount Mulligan mine disaster in Australia 1921. Cable drums were blown 15 m from their foundations following a coal dust explosion.
- The Great Mill Disaster, in Minnesota USA on May 2, 1878, killing 14 workers at the Washburn A Mill and another four in nearby buildings.
- Imperial Sugar in Port Wentworth, Georgia, US, in 2008. Fourteen people were killed and forty injured.

Taken 16 jun 18 from https://en.wikipedia.org/wiki/Dust_explosion#/media/File:MountMulligan.jpg

What else burns?

The rapid increase in surface area can make even generally non-combustible materials burst into flames. You could try:

- Old dust from the laser printers, even though its mostly just clay.
- Sawdust.
- Pollen.

Deflagration

Sometimes explosions are organised into two kinds:

- Detonation is where the fire spreads faster than the speed of sound
- Deflagration is where the fire spreads by normal heat transfer, slower than sound.

To be more precise: (From https://en.wikipedia.org/wiki/Deflagration 30 may 18). Deflagration (Lat: de + flagrare, "to burn down") is subsonic combustion propagating through heat transfer; hot burning material heats the next layer of cold material and ignites it. Most "fires" found in daily life, from flames to explosions, are deflagrations. Deflagration is different from detonation, which propagates supersonically through shock waves. This means that when a substance detonates, it decomposes extremely quickly instead of deflagrates. Black powder is an example of a substance that deflagrates when it is ignited.

Deflagration is a kind of burning, and is the more technical name for the explosions we created today, if you wish to use the term.

Evaluate

⇨ Review with students what the 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:

- What did **You** learn?
- Did you achieve your learning goal?
- What worked to help you achieve it?
- What might you do better next time?

Assessment

Prior Learning:

Take time to focus on planned content material during the engage phase, for example,

- How does burning happen? What do we need to make things burn?
- What can burn?
- Where do we use burning to help us in society?

Focus on the outcomes – how can we create the BEST scientific knowledge?

Be sure to watch out for the following common alternative conceptions:

- Fire makes new chemicals – to be more precise, the fire is *made out of* those new chemicals. They float up all the way to the roof, but stop glowing long before then.
- Atoms are 'used up' by the fire. In every chemical reaction there are the same number of atoms before as after, but they might have new 'friends' to hang out with.

Formative:

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

Discuss:

- Why they think the powders don't burn with a fire lighter?
- Which powder burns the best – and can the answer that question fairly with only ONE test?
- What use could this knowledge be in real life?

Summative:

Do an oral presentation that explains the science of *fire*. Be sure to include an example of breathing fire, with all appropriate safety measures explained and demonstrated.

So what?

It is surprising, and maybe even a little terrifying, what can burn if you get conditions right.

Safely implemented and wisely handled, fireballs are fun!

Creating science

Science content

In working with fire, we saw that:

- Chemical sciences 3: A change of state between solid and liquid can be caused by adding or removing heat (ACSSU046)
- Physical sciences 3: Heat can be produced in many ways and can move from one object to another (ACSSU049)

In learning about deflagration, surface area, and carefully observing the behaviour of fire, we saw that:

- Chemical sciences 5: Solids, liquids and gases have different observable properties and behave in different ways (ACSSU077)

Science inquiry skills

As we explored that aerated powders burn far better than compressed powders, and tested those ideas, we experienced:

- Questioning and predicting 3:With guidance, identify questions in familiar contexts that can be investigated scientifically and make predictions based on prior knowledge (ACSIS053)
- Planning and conducting 3: With guidance, plan and conduct scientific investigations to find answers to questions, considering the safe use of appropriate materials and equipment (ACSIS054)

Science as a human endeavour

As we learned that aerated powders burn far better than compressed powders, we were:

- Nature and development of science 3: Science involves making predictions and describing patterns and relationships (ACSHE050)

As we learned that this knowledge of deflagration has been put to use in society (for example, preventing mining and flour mill explosions) we saw that:

- Use and influence of science 3: Science knowledge helps people to understand the effect of their actions (ACSHE051)
- Use and influence of science 5: Scientific knowledge is used to solve problems and inform personal and community decisions (ACSHE083)

Appendix: Breathing Fire

Questions

- What is fire? What is needed to make fire burn? What can burn?

Activity 1 – Flammability

1. Safety first! Get your gear on, have fire safety measures on hand, and use a safe area.
2. Set out a large pinch of each of the materials in the table below.
3. Place a large pinch of the powder (1/4 teaspoon) onto some aluminium foil.
4. **Predict** – will it burn if you set fire to it with a lighter?
5. Experiment – find out if it burns using the lighter. Record your **result**.
6. **Conclude** – what did you learn? (Applause). Now CLEAN UP!

Substance	*Prediction*	*Result*
Normal sugar		
Icing sugar		
Bicarb		
Chocolate powder		
Corn flour		
Wheat flour		

Question 2

- Did the powders burn? Maybe they can in the right conditions – just add lots of air!

Activity 2 – Deflagration

1. Safety first! Get your gear on, have fire safety measures on hand, and use a safe area. Set your fire source on a flat, stable surface such as the floor. Have fire resistant mats down to catch any extra powder or spills. DO NOT stand where the fire will touch you or anything.
2. Fill a straw with 1-2cm of one of the powders, make sure it's nice and loose.
3. Put the fire source onto the plate, on the mat.
4. **Predict** – what will happen when you blow the power onto the flame?
5. Carefully puff the powder out through the flame – not too close or you'll blow the fire out, and not too far of you won't see any reaction. Blow the straw from the end that's full of the dust in order to give it plenty of time to mix with the air.
6. **Record** your results.
7. Conclude – what burning things this way any different?

Substance	*Prediction*	*Result*
Normal sugar		
Icing sugar		
Bicarb		
Chocolate powder		
Corn flour		
Wheat flour		

Appendix: Breathing Fire results

Aim: To see what burns if it is turned into a fine powder.

Scientist's Name:
Date of Experiment:

First! Predict:

Chemical	Prediction – what do you think will happen if you spray the dust into a fire?	Explanation (theory or hypothesis). WHY do you think it will happen?
Normal sugar		
Icing sugar		
Bicarb		
Chocolate powder		
Corn flour		
Wheat flour		

Now, Experiment:

Chemical	Prediction – what happened when you sprayed the dust into a fire?	Explanation (theory or hypothesis). Why do you think you got those results?
Normal sugar		
Icing sugar		
Bicarb		
Chocolate powder		
Corn flour		
Wheat flour		

Finally:

Explain your results and discuss them with others. What did you learn?

Tips to make it work from the Masters

Advice to get it going

- This activity requires AIR as well as DUST. Everyone forgets the air – you need to get those particles spread out. Try spreading the powder along the straw with a few careful taps first.
- Make sure you breathe into the straw from the end that's got the dust in it. It won't work well if you put the dust into the far end of the straw and blow it at the fire. More air is better!
- Try thicker straws.
- Make sure your fire is big enough.
- Blow *through* the fire, not *onto* the fire.
- *Listen* – the results are not only to be seen.
- Don't be too close, you need about a arm's reach distance from the fire.
- *Turn off the lights*.

Can you tell the difference between powder and a larger fire simply due to more air?

This is a really good example of where NOT TO STAND!!! Also note the girl is unbalanced and leaning too close to the fire. Thanks for the poses kids!

Notes glasses, gloves, careful standing back, and responsible adult helpers keeping flame safe.

References

Johnson, P. (2002) Children's understanding of substances. Part 2: explaining chemical change. International journal of science education, 24 (10), pp. 1037-54.