Handwarmer science

Help your students explore an exothermic reaction using the real-world example of a self-heating patch.

Image courtesy of Nicola Graf

By Manfred Eusterholz, Andreas Böhm, Andy Bindl and Gregor von Borstel

Self-heating patches that can be worn on the skin for hours are becoming increasingly popular as a method of pain relief, and the same technology can also keep your hands warm on cold days. But how do these patches heat up? This activity allows your students can investigate this in a lesson.

Start by introducing your students to a hypothetical scenario in which they work for a scientific magazine. A letter to the editor arrives and it is your students' job to answer it.

Dear Madam,

I often suffer from painful shoulders and neck because of my job, so I'm thinking of trying self-heating patches that I can wear during the day to reduce the pain. I am curious as to how exactly they work and if they are reusable.

The information on the packaging claims that they are simply activated by air. Is this true? Are they harmless or could they cause any problems or side effects?

Thank you in advance for your help.

Susanne Musterfrau, Cologne

The challenge

Explain to your students that their task is to examine the functionality of the self-heating patches and provide an answer to the letter writer's question. They should:

1. Write down questions that they need to answer in order to explain how the self-heating products work.
   For example, they could consider the term 'air-activated'. Could just one of the main components of air activate the self-heating patches?
2. Use the materials provided to find answers to their questions, and document their process.
   The experiment described below can be used to test the reaction in small volumes.
3. Write a brief reply to the letter writer, in which they explain the functionality of the self-heating patches in a way that readers with some knowledge of chemistry will understand.

Image courtesy of Gregor von Borstel

Introducing the activity

Materials

Each group of students will need:

- Self-heating patch or body-warmer pack
- Kitchen roll or fillable teabags
- Spatula
- Oxygen
- Nitrogen
- Two 50 ml syringes
- Stoppers for the syringes
- Three-way valve
- Length of foam pipe insulation
- Temperature sensor or thermometer
- Scissors

Procedure

1. Open the patch or pack and remove two spatulas full of the filling, wrapping it in a paper towel or putting it in the teabag.
2. Remove the plunger from one of the syringes and place this wrapped material in the body of the syringe. Replace the plunger.
3. Seal the tip of the syringe.
4. Place a temperature sensor on the side of the syringe and wrap both the syringe and the sensor in pipe insulation.
5. Observe the set-up for a few minutes. Does the temperature change?

Putting the material in a syringe

Adding a gas with another syringe

Watching what happens to the plunger

Measuring the temperature at the start of the reaction

Measuring the temperature during the reaction

All images courtesy of Gregor von Borstel

Image courtesy of Gregor von Borstel

After the reaction you can see the red of rust.

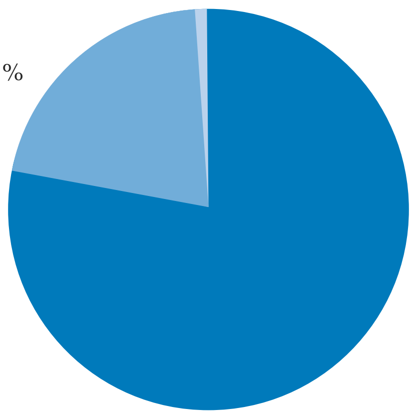
6. What happens to the plunger of the syringe?
7. Unseal the syringe and depress the plunger fully.
8. Fill a second syringe with nitrogen.
9. Connect the two syringes using the three-way valve and depress the plunger of the second syringe to transfer the nitrogen to the first syringe.
10. Observe the set-up for a few minutes. Does the temperature in the first syringe change? What happens to the plunger of the first syringe?
11. Repeat steps 8–10 with oxygen instead of nitrogen.

About what happens

You will have noticed that the material from the self-heating patch releases heat when exposed to air and even more heat when exposed to pure oxygen. As the gas is used up in the reaction, the pressure in the syringe is reduced and the plunger moves down inside the syringe. The material doesn't react with nitrogen, so there is no heat or movement of the plunger. This is because the heat pack works by the oxidation of iron:

$$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$$

This is an exothermic reaction: it releases heat. If you examine the contents of the syringe at the end of the experiment, you will see that they include flecks of red (rust).



Air is mostly nitrogen (N) and oxygen (O)

Image courtesy of Nicola Graf

What about the carbon and salt that are also present? Rusting is a redox reaction, with the iron being oxidised to ferric ions:

$$4Fe \rightarrow 4Fe^{3+} + 12e^-$$

and the oxygen being reduced:

$$12e^- + 3O_2 \rightarrow 6O^{2-}.$$

The salt and the carbon are not used up but act as electrolytes, helping the electrons to flow between the elements.

Further discussion

The syringes can be used to measure exactly how much oxygen is consumed in the reaction, and you could use this information to work out the rate of reaction. Perhaps you could discuss with your students other ways to increase this rate and other exothermic reactions that could be used to make a warming pad.

References

Howes L (2015) Science teaching in the spotlight. *Science in School* **33**: 30-33. www.scienceinschool.org/2015/issue33/Scionstage

Rau M (2011) The heat is on: heating food and drinks with chemical energy. *Science in School* **18**: 46 -51. www.scienceinschool.org/2011/issue18/lncu

Web reference

w1 Learn more about *Lebensnaher Chemieunterricht* and find more of their activities. See: www.lncu.de

Manfred Eusterholz, Andreas Böhm, Gregor von Borstel and Andy Bindl are all German chemistry teachers who work together as part of *Lebensnaher Chemieunterricht*[w1] (real-life chemistry education; Rau, 2011). In 2015, they travelled to London, UK, for the Science on Stage Europe festival, where they won a European Science Teacher Award for their work (Howes, 2015).

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