Cold reactions

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Acknowledgements

This resource was originally developed by the University of Reading to support outreach work delivered as part of the Chemistry for All project.

To find out more about the project, and get more resources to help widen participation, visit our Outreach resources hub: rsc.li/3CJX7M3.

Guidance notes

This session should take approximately two hours to complete in full. It was initially created for 11–14 year-old learners but can be adapted for other age groups.

Download the PowerPoint presentation, technician notes and student workbook that accompany this resource at rsc.li/3aJIqPc.

Read our health & safety guidance, available from rsc.li/3IAmFA0, and carry out a risk assessment before running any live practical.

The safety equipment suggested is in line with CLEAPSS requirements. For non-hazardous substances, wearing lab coats can help to protect clothes. The safety rules might be different where you live so it is worth checking local and school guidance.

Learning objectives

- Explain what is meant by ‘cold’.
- Describe some practical applications of reactions that give a temperature decrease.

Introduction to ‘cold’

Slide 3 of the PowerPoint asks the question ‘What is cold?’ Give learners two minutes to discuss this question in pairs before sharing their answers as a class.

Slide 4 then gives learners six different situations and asks them to put them in order of their temperatures from coldest to hottest. Give learners two minutes to do this in pairs, asking them to write their answers down on mini whiteboards or paper.

Use **slide 5** to go through the answers as a class.

Order of coldest to hottest: answers

Coldest

- Liquid nitrogen: –196°C
- The surface of the moon: –153°C (in the shade)
- A domestic freezer: –18°C
- The North Pole during the day: 0°C
- The bottom of the ocean: 3°C
- The Sahara Desert at night: 15°C

Hottest

Use **slide 6** of the PowerPoint to introduce endothermic reactions.

Career link

Consumer products technician

Use **slide 7** to introduce learners to Robert, a consumer products technician, by watching his job profile (also available from rsc.li/3HR7C31). He studies the behaviour of different materials to develop and improve the properties of products, such as cold packs used to treat sports injuries.

Activity 1: cold packs

Use **slide 9** to introduce the practical activity that learners will be completing. This activity will be familiar to many as a slightly cruder version of 'coffee cup calorimetry', where the enthalpy of a reaction is measured by calculating the energy transferred to an amount of water when a reaction takes place within an insulated vessel. This experiment is a lot simpler, but it should still be obvious which chemicals work best.

Find the method in the student workbook. Learners will work in pairs or groups of three. They will investigate which of the six different compounds (ammonium nitrate, sodium chloride, sodium hydrogen carbonate, citric acid, calcium chloride and calcium sulfate) will produce the best cooling effect and therefore be the best to use in a cold pack. They will add 5 g of the solid to 50 cm^3 water and monitor the temperature of the resultant solution over a period of three minutes. Learners should record all measurements taken and answer the questions individually in their student workbooks.

Depending on time, the pairs or groups could test all six compounds or could be allocated two or three different compounds to investigate. The class could pool their data at the end of the activity. If time allows, learners could repeat their tests.

Encourage the learners to work scientifically by adding the same amount of water and solid to the beaker each time. Discuss why this is done and anything else that makes this a fair test. If there is time, ask the learners how they might improve the experiment.

Disposal

Please check the technician notes for CLEAPSS hazard information.

Instruct learners to dispose of their solutions by emptying the contents of their beakers into the correctly labelled collection vessel for the technician to dispose of appropriately. Dispose of ammonium sulfate, calcium nitrate, calcium chloride and sodium chloride solutions down a foul-water drain after treatment/dilution.

Neutralise and dilute sodium hydrogen carbonate and citric acid solutions before disposing of them down the foul-water drain.

Throw calcium sulfate (plaster of Paris) in the general waste after decanting the water for collection by a registered waste carrier.

Answers

Go through the answers as a class using **slide 10** of the PowerPoint.

Some compounds, such as sodium chloride, will have almost no effect on the temperature change.

Ammonium nitrate should give a significant temperature decrease as this is used in commercial cold packs.

Calcium sulfate is also known as plaster of Paris. This reaction is exothermic (meaning it gives out thermal energy) and the calcium sulfate may start to solidify in the beaker of water.

Activity 2: citric acid and sodium hydrogen carbonate

Use **slide 12** to introduce the activity and tell learners that they will mix solutions of citric acid and sodium hydrogen carbonate and measure the temperature of the resultant solution over three minutes.

Tell learners 'As you mix these two solutions, consider why the reaction can't be used in cold packs'.

Your learners may already have one or both of these solutions made up from Activity 1. If not, they will have to follow the instructions from Activity 1 to make these solutions.

Find the method in the student workbook. Learners should record all measurements taken and answer the questions individually in their student workbooks.

Answers

Use **slide 13** to explain why this reaction is not suitable for cold packs. Tell learners that although mixing these two solutions gives a large temperature decrease, it can't be used in cold packs as it gives off carbon dioxide gas.

The reaction between citric acid and sodium hydrogen carbonate produces sodium citrate, water and carbon dioxide. The equation for this reaction is:

$$3NaHCO_3 + C_6H_8O_7 \rightarrow Na_3C_6H_5O_7 + 3H_2O + 3CO_2$$

Activity 3: making ice cream

Career link

Use **slide 15** of the PowerPoint to introduce your learners to Claire, a flavourist and innovation director. Watch her job profile, also available from rsc.li/40V9mkh, to learn how she applies her chemistry knowledge and understanding to create new flavours, find raw materials and develop technologies.

The method for this activity is in the student workbook. You can project it on the board using **slide 16** of the PowerPoint too. Provide the method separately if you do not give each learner a copy of the student workbook during the session.

For use in the lab, do not use sugar or flavouring. This emphasises that this ‘ice cream’ can’t be eaten due to the lab setting.

Although the method instructs the learners to measure out 150 cm^3 of milk, this does not have to be exact as the method works with volumes up to 200 cm^3.

As the learners must shake the bag for 10 minutes, encourage them to work together on this step, passing the bag to their partner when they get too tired.

As the learners are shaking the bags, ask them to think about the reasons why we added the salt to the ice. Give them a few minutes to discuss their ideas in pairs/groups before sharing their thoughts as a class.

Go through the answer in a class discussion using **slide 17** of the PowerPoint.

At the end of the time get the learners to remove the bags with the ice cream inside. They can touch it and press it but **must not eat it**.

You could set Activity 3 as homework, where the learners can try the method again at home using sugar and flavouring.

Dispose of the ice and ice cream down the sink.

Answer

Adding salt to ice lowers the melting to around −5°C. This encourages the ice to melt, forming a very cold slush, which is cold enough to freeze milk and make ice cream.

You can also point out that the water rearranges itself around the salt when it dissolves, driving the reaction. The melting point is reduced to around −5°C, which is why we grit roads if the weather is really cold.

Demonstration: glow sticks

In this demonstration you will link the rate of a chemical reaction to the temperature of the surroundings. The effect of heating or cooling the glow sticks can be assessed by the brightness of the light given out. The brighter the light emitted, the higher the rate of reaction.

Method

1. Fill four measuring cylinders with hot water, water at room temperature, iced water, and ice and salt water.
2. Break the four glow sticks.
3. Ask the learners to write down their predictions about how the appearance of the glow sticks will vary.
4. Place the glow sticks in the measuring cylinders one at a time and discuss the differences in the appearances of the glow sticks in each of the four different temperatures of water.
5. Ask the learners to predict what would happen if you moved a glow stick from one measuring cylinder into another.

This is a great demonstration of the concept of ‘rate of reaction’. The higher the rate of reaction, the brighter the glow stick.

Ask learners why this kind of knowledge might be useful. In a chemistry context, controlling temperature is incredibly important. This is especially true when dealing with very reactive chemicals. If the temperature gets too high, you can end up with a runaway thermal reaction which could explode.

Share the answers to questions using **slide 20**.

Answers

(a) The learners should expect the glow sticks to shine most brightly in the hot water and least brightly in the ice and salt water.

(b) The learners should expect the glow sticks to shine more brightly when moved into hotter water and less brightly when moved into colder water.

Challenge

When applying this knowledge to health we have learned about various techniques using cold. Use **slide 21** to discuss how in the last 10 years there have been huge leaps in cooling the body down to preserve it and make survival from surgery more likely.

If you have time, you can use **slide 22** of the PowerPoint to mention cryonics (also known as cryogenic freezing), where someone can be frozen so they can potentially be revived in the future. Science fact or science fiction? Let the learners discuss this, as there really isn't a clear answer. Task your learners to research the technique to find out more.