DIY Science – Hot Crystals

A challenging activity to turn sodium acetate trihydrate from a liquid to a solid in an instant.

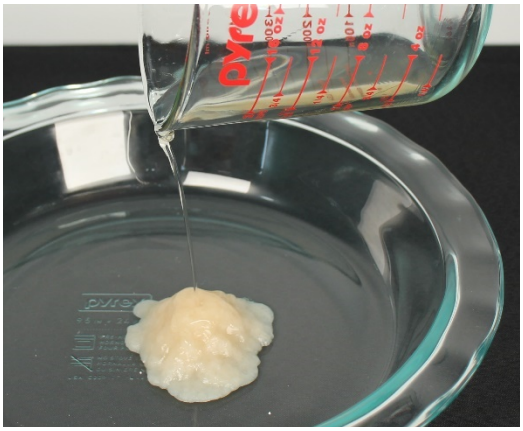
Safety

An adult must supervise and assist with steps that use a stove or hotplate. Never leave the boiling solution unattended. Avoid skin contact with chemicals as they may cause irritation. Wear safety goggles to avoid eye contact with chemicals. The crystallisation process produces heat – avoid touching the hot crystals.

What you need

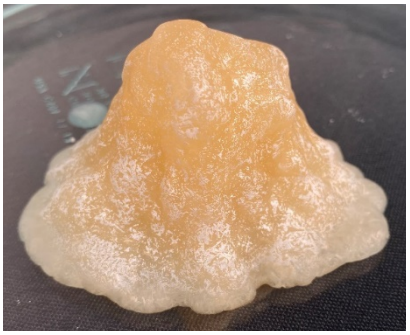
Patience! This is a tricky activity and may not work the first time.
4 cups (1 litre) white vinegar, 3 tablespoons sodium bicarbonate (bicarb), large bowl, measuring cup and tablespoon, large metal spoon for stirring, medium saucepan, stove or hotplate, heat-proof jug, plastic wrap or lid to cover the heat-proof jug, plate

What to do



1. Add 3 tablespoons of bicarb to the large bowl.
2. Slowly add 2 cups (500 mL) of vinegar to the bicarb, adding about half a cup of vinegar at a time. There will be a lot of fizzing as the bicarb reacts with the vinegar. Stir thoroughly and wait for the fizzing to stop between each addition before adding more vinegar.
3. Stir the mixture in the bowl and then let it sit until most of the bubbles have disappeared from the surface.
4. Add another 50 ml vinegar to the bowl and watch to see if there is still some fizzing.
5. If there is still some fizzing, stir and wait for most of the bubbles to disappear again before repeating Step 4.
6. Continue to repeat Steps 4 and 5 until there is no fizzing. This is the point where all of the sodium bicarbonate has reacted with the vinegar. Do not add too much vinegar or the activity will not work. We used 800 ml vinegar before the fizzing stopped, but different brands of white vinegar may require different amounts.
7. Pour the vinegar and bicarb mixture into the saucepan and heat the liquid on the stove or hotplate. When the liquid starts to boil, turn down the heat to a gentle simmer. Do not boil the liquid too quickly.
8. Simmer the liquid for about 1 hour to boil off most of the water from the liquid. 1 litre will reduce down to about 100 mL. Keep a close eye on the saucepan, especially at the end of the hour. The liquid is ready when a thin film of crystals starts to form on the surface of the liquid.
9. Pour the hot liquid into the heat-proof jug and cover immediately with plastic wrap or a lid to prevent any further evaporation. There should be no crystals in the jug. If you see some crystals, swirl the jug to melt the crystals, or pour the liquid back into the saucepan and add a small amount of water. Re-heat the liquid and simmer again until the thin film of crystals is only just forming.
10. Allow the liquid in the jug to cool to room temperature, either by leaving it on a bench, or placing it in a refrigerator. Handle the jug with care to avoid starting the crystallisation process too soon.
11. There should be some white crystals left in the saucepan. Use a dry spoon to transfer some of the crystals to the plate. These will act as 'seed' crystals to kick-start the crystallisation process.

12. When the liquid in the jug has cooled, slowly pour the liquid over the seed crystals on the plate. The liquid should start to crystallise. Keep pouring to create a tower of hot crystals.
Carefully feel underneath the plate with your hand – does it feel hot?



Watch a video of the activity in action: https://youtu.be/HAqjyo0aLIM

What's happening?

White vinegar is a solution of acetic acid in water. Adding sodium bicarbonate to vinegar creates fizzing due to an acid-base reaction between acetic acid and sodium bicarbonate. The fizzing is caused by bubbles of carbon dioxide gas, and another product of the reaction is a type of salt called 'sodium acetate'.

acetic acid + sodium bicarbonate -> carbon dioxide + water + sodium acetate

$CH_3COOH + NaHCO_3 \rightarrow CO_2 + H_2O + CH_3COONa$

The sodium acetate solution is boiled to reduce the amount of water, leaving behind 'sodium acetate trihydrate', which is a chemical made up of one molecule of sodium acetate for every three molecules of water. As the liquid cools, it becomes a 'supercooled' liquid, which means that it remains a liquid even though the temperature has dropped below the freezing point of the chemical. The freezing point of sodium acetate trihydrate is around 60°C, but the supercooled liquid tends to stay in its liquid state unless it has a starting point for the crystallisation process.

When the supercooled liquid is poured over a seed crystal, the seed crystal provides a regular structure on which the crystals can start to grow. Once this starts, the entire volume of liquid will crystallise in seconds. The crystallisation process is 'exothermic' which means it releases heat energy. Crystals of pure sodium acetate trihydrate are white, but impurities from the kitchen ingredients and equipment may cause the hot crystals in this activity to be slightly yellow.

Results

If the activity didn't work the first time, try again by reheating the sodium acetate trihydrate in the saucepan. You can try adding a little more water and boiling down the solution until the thin film of crystals starts to form. When it does work, the solid sodium acetate trihydrate can be re-heated and used again and again! One way of gently re-melting the crystals is by using a water bath or double saucepan. Try making a video recording of your successful experiment. Can you think of other ways to start the crystallisation process? What would happen if you dropped a seed crystal into the jug of cooled liquid?

Did you know?

Instant heat packs contain supercooled sodium acetate trihydrate, inside a sealed pouch. Instead of a seed crystal, there is a metal disc. When the metal disc is pressed to make it click, the crystallisation process starts at the site of the disc, and the liquid quickly turns into a solid crystal. To re-use the heat pack, the pouch can be heated in boiling water until the contents melt back into the liquid state.

Find out more

- Discover how to make supercooled water at home and learn more about the science behind supercooled liquids in a video from Veritasium: https://youtu.be/ph8xusY3GTM
- Explore the icy hazards in aviation created by supercooled water droplets in clouds, with the Bureau of Meteorology: http://www.bom.gov.au/aviation/data/education/icing.pdf
- Find out how Antarctic fish have adapted to live in sub-zero sea water without freezing to death, with PBS Learning Media (video includes a fish dissection): https://bit.ly/3wIP1QP