2. Shrinking balloons

Condensing the air inside a balloon into liquid air

Overview

Shrink air-filled balloons by using liquid nitrogen to condense some of the air to a liquid state.

What's happening?

When we immerse the balloon in liquid nitrogen, we see the balloon shrink. This is because the gases that make up the air inside the balloon undergo a change of state when cooled to -196 °C (the temperature of the liquid nitrogen). The molecules of the gases in the air inside the balloons lose energy to their surroundings and the amount they can move decreases. The molecules are the same in composition and number, but they have less energy and are far closer together, so take up a lot less space. This causes the balloon to shrink.

When we remove the balloon from the liquid nitrogen, it warms up. Inside the balloon, the liquid air is actually boiling. Gaseous air can take up about 750 times more volume than liquid air, which causes the balloon to re-inflate.

Why is this important?

This is a dramatic example of changing state, showing how the physical properties of a seemingly fixed volume of air changes with temperature. This reaction is completely reversible and is the grounding for understanding particle theory and changing states of matter. It should be linked with familiar changes of state such as solid ice to liquid water and into water vapour.

Liquid air would freeze at about -215 °C at atmospheric pressure. For real-world uses and applications of liquid air, please see the 'Liquid air' activity and 'Further Ideas and Information'.

> Liquid air would freeze at about -215 °C

The Activity

1. Take a single balloon, inflate (using lungs or pump) in front of audience and then, using tongs, submerge the balloon slowly in liquid nitrogen.

2. After the liquid nitrogen has stopped boiling, use the tongs to withdraw the balloon from the liquid nitrogen.

3. Allow the audience to watch the balloon. While the balloon is warming up, keep it moving to stop the liquid air from staying in one place for too long, this will reduce the chance of the balloon popping and show the rapid increase in volume as the balloon magically blows itself back up.

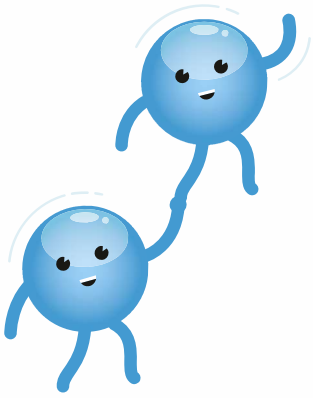
You can try using longer 'sausage' balloons for a more dramatic effect, but be warned, these balloons tend to burst as they warm up.

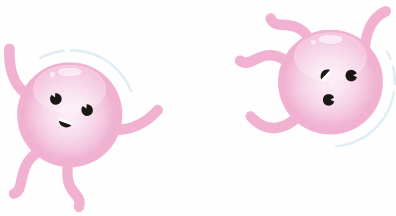
You can prepare several blown up balloons in advance. If you have a portable Dewar suitable for storing liquid nitrogen, you can place a large number of balloons inside this before the show and, after doing the demo with the single balloon, use tongs to pull out lots of apparently self inflating balloons. This is particularly effective when using balloons that you have made into small balloon animals!

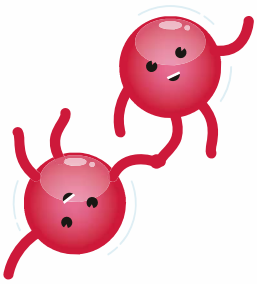
Troubleshooting

Use latex balloons, not foil balloons. Most party balloons are fine, but you will find that some larger balloons, thin or variable skinned balloons will pop more easily. We recommend helium-grade balloons and you can purchase good quality balloons from BOC.

Always have back-up balloons and be prepared for an unexpected pop! Even the best quality balloons can burst when they are removed from the liquid nitrogen.







Health and Safety

Every delivery centre must undertake their own risk assessments for the specific audiences, locations and conditions they are presenting in. Sample assessments are available on The Secret World of Gases website. Below is a guide to the key risks and hazards:

1. Please see risks associated with handling liquid nitrogen in 'Additional Resources'.

2. When the balloon first comes into contact with the liquid nitrogen, it is likely it will send liquid nitrogen boiling and spitting in all directions.

3. Use tongs when putting balloons into or removing them from the liquid nitrogen receptacle.

4. If using metal tongs they will get very cold, so ensure they have an insulating handle or you are using cryogenic gloves.

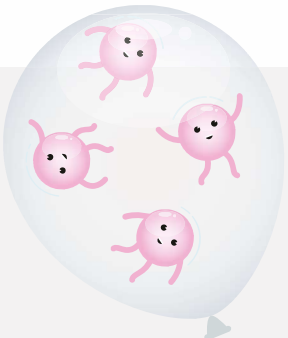
5. If you find using tongs is not practical (for example when using a sausage balloon) ensure you maintain a minimum 15 cm distance between your hand and the surface of the liquid nitrogen.

6. When the balloon is removed from the liquid nitrogen, it will continue to condense air around it and will drip liquid nitrogen and liquid air.

Hold the balloon away from your body and not above anything that could be damaged by cryogenic liquid.

7. There is always a chance the balloon will pop unexpectedly. Fragments of latex should warm rapidly, but to mitigate any potential risks the demonstration should be a minimum 2 metres away from the audience and the demonstrator should always wear lab glasses.

SECRET GAS FACT



If you try to shrink a helium balloon it will only shrink to about one quarter of its original size as the temperature of liquid nitrogen is not cold enough to condense the helium (helium changes into a liquid at - 268.9 °C). However, as the helium cools and the molecules come closer together, the balloon becomes too dense to float. It will then float again when it is warmed back up.