Health and Safety

Handling liquid nitrogen:

Liquid nitrogen can be used to deliver a host of exciting and thought-provoking demonstrations. When a user is trained and confident in handling it, this material can be happily and safely used. However there are a number of hazards that all users should be aware of.

Do not ever be tempted to try other demonstrations seen on the internet, such as putting liquid nitrogen into your mouth. It can be very harmful, result in injury and cause death.

Hazards:

Liquid nitrogen is an unreactive, colourless, odourless cryogenic substance, stored at - 196 °C. This leads to a number of hazards, some of them obvious, others less so:

1. Asphyxiation: Nitrogen can displace oxygen in air to levels that can kill people. The inhalation of excessive amounts can cause dizziness, unconsciousness and death. A very low oxygen concentration could happen in seconds. Victims will be unaware of this happening, and could become unconscious quickly. Taking precautions to avoid this is easy.

2. Intense cold: Risk of cold burns, frostbite and other cold-related injuries from direct or indirect contact (e.g. from metal cooled down by liquid nitrogen).

3. Fire: Liquid nitrogen may condense oxygen out of the air, especially when drawing or condensing air in tubes or other vessels. The oxygen could then enrich the surrounding environment, intensifying fires.

4. Explosion: If stored incorrectly liquid nitrogen may over-pressurise the vessel it is in, which could cause it to explode. Never ever put liquid nitrogen in a screw top thermos, always use an appropriate vented container.

5. Manual handling: Storage Dewars containing over 25 L of liquid nitrogen are heavy, and will represent a manual handling hazard.

Safety Precautions:

Asphyxiation: Liquid nitrogen should only ever be used and/or stored in areas with good ventilation. If there is a spill in a confined space then the room should be evacuated immediately. Always have two people collecting liquid nitrogen from your storage area (one collecting it, the other supervising from a distance). If someone is suffering from asphyxiation remove them to a well-ventilated area, and call an ambulance. Apply artificial respiration if breathing has stopped. Do not enter areas you suspect to have low oxygen concentrations. Remember cold nitrogen gas will be at highest concentration near the ground.

Intense cold: Always wear appropriate personal protective equipment (PPE) when handling liquid nitrogen. Eye protection must always be worn (ideally goggles or a face shield), and always wear cryogenic gloves. Open topped shoes must never be worn. Be vigilant to ensure there is no risk of liquid nitrogen getting trapped in gloves, clothing or against skin. Presenters should be aware that any item exposed to liquid nitrogen will also be very cold and should be extra careful with rubber tubing, tongs, balloons and gas traps.

In case of frostbite, spray with tepid water for at least 15 minutes, apply a sterile dressing and seek medical attention immediately.

Fire: Liquid nitrogen may condense oxygen out of the air (this is the intended outcome of some of the activities in this handbook). As long as you are working with small amounts of liquid nitrogen (e.g. two litres) there is little risk of significant oxygen enrichment. Never leave a test tube or other air-filled vessel in liquid nitrogen for long periods of time and keep away from sources of ignition or flammable materials.

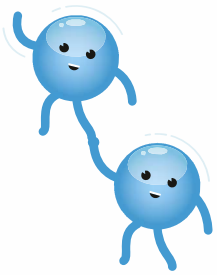
Explosion: Only ever use specifically designed liquid nitrogen Dewars for the use, storage and transport of liquid nitrogen. Open vessels are not suitable as there is a risk of splashing or spillage and since liquid nitrogen is cold, it may condense and form a water ice plug on top of the vessel. Never ever use 'thermos flasks' or any other sealable vessels, as two litres of liquid nitrogen will become 1366 litres of gaseous nitrogen, leading to an explosion. This has been linked to at least two incidents in schools. Only vented Dewars with pressure relief valves should be used.

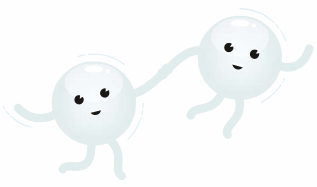
Storage

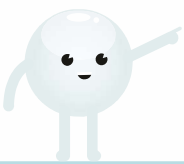
Dos and Don'ts:

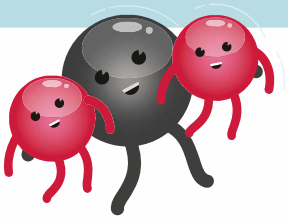
1. Never travel in a lift or small enclosed space with liquid nitrogen.

2. Never transport liquid nitrogen by car or other unsuitable vehicle. It should not be used or transported at all in a small, enclosed space with any person or animal due to the asphyxiation risk. Always mark a room where liquid nitrogen is stored.









Under the 'Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations' liquid nitrogen may only be transported if:

i. All drivers are suitably trained.
ii. Dewars are transported separately from drivers or passengers.
iii. Flat-back pick-ups or vehicles fitted with a separating bulkhead should be used.
iv. Dewars are transported in such a way that it cannot fall over or spill.

3. Remember: Even the vapours from liquid nitrogen can cause cold-burns or frostbite.

4. Do keep a minimum audience exclusion distance of 2 m from liquid nitrogen demonstrations.

5. Do point all tubes put into liquid nitrogen away from any persons.

6. We recommend not to invite volunteers up to interact with the liquid nitrogen.

7. Never leave liquid nitrogen unattended or in a place where non-users may gain access to it. Always mark where it is stored with appropriate signage.

8. Under no circumstances swallow or put in mouth, ever.

Handling solid carbon dioxide (dry ice)

Solid carbon dioxide is a great, versatile substance which can be used in a large number of demonstrations. It is easier to handle than liquid nitrogen, although still has some significant hazards.

Hazards:

1. Asphyxiation: Carbon dioxide can displace oxygen in air to levels that could kill people. Inhaling low concentrations can cause increased respiration and headaches. Inhaling high concentrations can cause loss of mobility, unconsciousness and death with victims unaware of asphyxiation.

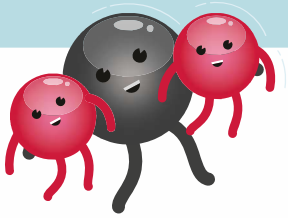
2. Intense cold: Risk of cold burns, frostbite and other cold-related injuries from direct or indirect contact (e.g. from metal cooled down by solid carbon dioxide). Solid carbon dioxide is - 78 °C.

3. Explosion: If stored incorrectly solid carbon dioxide may become a gas, and over-pressurise the vessel it is in which could cause it to explode.

Safety Precautions:

Intense cold: Never handle solid carbon dioxide with your bare hands, wear cryogenic gloves or transfer using a thermally insulated cup (polystyrene drinking cups work well). Be aware that any material in close contact with solid carbon dioxide will also be very cold and so should not be directly handled. There is a risk during some of the demonstrations in this handbook that small bits of solid carbon dioxide may spit out and land on your skin if incorrectly carried out. Ensure solid carbon dioxide is never trapped between skin and clothing and always wear closed shoes.

In case of frostbite, spray with tepid water for at least 15 minutes, apply a sterile dressing and seek medical attention immediately.



Asphyxiation: Solid carbon dioxide sublimes (changes from a solid to a gas) at a much slower rate than liquid nitrogen boils off, but this is still a very real danger. Ensure it is always stored and demonstrated in a well-ventilated space. When added to warm water its rate of sublimation rapidly increases. Carbon dioxide is denser than air so will build up near the ground. Make sure you do not carry out demonstrations with very small children or assistance dogs nearby who may be sitting at ground level.

If someone is suffering from asphyxiation remove them to a well-ventilated area, and call an ambulance. Apply artificial respiration if breathing has stopped. Do not enter areas you suspect to have low high carbon dioxide concentrations.

Explosion: Solid carbon dioxide will sublime and build up pressure if put into a sealed container and eventually explode. It should only ever be stored in polystyrene boxes (allowing carbon dioxide to diffuse through its structure) or appropriate vented vessels. Most suppliers of solid carbon dioxide will provide it in polystyrene boxes.

Dos and Don'ts:

1. Never travel in a lift or small enclosed space with solid carbon dioxide, if travelling between floor, take the stairs.

2. Solid carbon dioxide is not covered by the 'Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations' but it is recommended that the same process as for liquid nitrogen is observed for its transport in a vehicle.

3. Never leave solid carbon dioxide unattended or in a place where non-users may gain access to it.

Under no circumstances swallow, put in mouth, or in any drinks.

Handling hydrogen balloons:

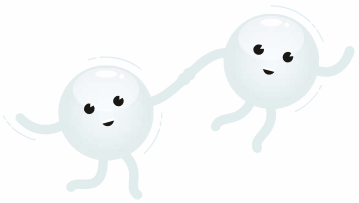
These will be generated as part of the show, resulting in balloons containing hydrogen gas.

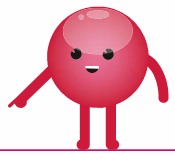
Hazards:

1. Explosion: Hydrogen can explode when mixed with the air. Hydrogen and air mixtures are particularly explosive when the ratio of hydrogen: air is between 4% and 74%. At these concentrations, this mixture will ignite below 500°C. The fireball produced will be approximately three times the size of the balloon and accompanied with a shock wave which can damage hearing.

Safety Precautions:

Never generate or have hydrogen present when there are sources of ignition. Remove all ignition sources and only generate in a well-ventilated area. Ensure you have a fire blanket nearby in case of accidental detonation to smother any burning debris.





Other chemical handling health and safety

The United Nations developed the Globally Harmonised System (GHS): a standardised system to classify and label chemicals. Hazards are described with statements identified with a code (H + 3 digits). Precautionary statements (identified with P + 3 digits) describe recommended measures that minimise harm from exposure to hazardous chemicals. Always use the full statements on risk assessments. The P-codes and H codes for chemicals encountered in the family show are listed below:

Potassium chlorate	**H271:** May cause fire or explosion; strong oxidiser. **H332:** Harmful if inhaled. **H302:** Harmful if swallowed. **H411:** Toxic to aquatic life with long lasting effects.	**P210:** Keep away from heat/sparks/open flames/ hot surfaces. No smoking. **P221:** Take any precaution to avoid mixing with combustibles. **P273:** avoid release to environment.
Hydrogen peroxide (30 %)	**H302:** Harmful if swallowed. **H318:** Causes serious eye damage. **H412:** Harmful to aquatic life with long lasting effects.	**P280:** Wear protective gloves/lab coat/ eye protection. **P301** + **P330:** IF SWALLOWED: Rinse mouth. **P305** + **P351** + **P338** + **P310**: IF IN EYES: Immediately call a poison centre or doctor, rinse cautiously with water for several minutes, remove contact lenses if present and easy to do so, continue rinsing.
Sodium hydroxide	**H290:** May be corrosive to metals. **H314:** Causes severe skin burns and eye damage.	**P280:** Wear protective gloves/lab coat/ eye protection. **P301** + **P330** + **P331:** IF SWALLOWED: Rinse mouth. Do NOT induce vomiting. **P305** + **P351** + **P338:** IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. **P308** + **P310:** IF exposed or concerned: immediately call a POISON CENTER or doctor/ physician.
Universal Indicator	**H226:** Flammable liquid and vapour. **H319:** Causes serious eye irritation.	**P210:** Keep away from heat. **P305** + **P351** + **P338:** IF IN EYES: Rinse cautiously with water for several minutes.

Hydrochloric acid (2 M)	Low hazard, may still irritate if in eyes or broken skin.	Wear gloves/eye protection.
Magnesium ribbon	**H228:** Flammable solid. **H260:** In contact with water releases flammable gases which may ignite spontaneously.	**P210:** Keep away from heat/sparks/open flames. No smoking. **P223:** Keep away from contact from water, because of violent reaction and possible flash fire. **P232:** Protect from moisture. **P370** + **P378:** In case of fire use a type 1 Class D extinguisher.
Manganese dioxide	**H302:** Harmful if swallowed **H322:** Harmful if inhaled.	Wear gloves/eye protection.

Storage:

Ensure you follow your Centre's chemical storage protocol, for example storing flammable liquids like universal indicator in metal, lockable cupboards separate from oxidising agents such as potassium chlorate.

Disposal:

Ensure you follow your local disposal policy, check the material safety data sheets for full disposal procedures.

General do's and don'ts for chemical safety:

Always wear eye protection.

Always label your bottles/containers with paper labels, date the label and write all details about the chemical inside.

Always wash your glassware in a non-food sink after use, and set up a clean/dirty system of where glassware lives. If in doubt, assume the glassware is dirty.

Never use gloves on communal surfaces, if they are contaminated you will contaminate handles/other places that people without gloves might handle.

Always wash your hands immediately after carrying out any preparation work.

Never prepare chemicals in a place where food or drink may be consumed.

Remember gloves are not indestructible, if you spill anything on your gloves, remove them immediately and dispose of them appropriately.

References:

1. BCGA Code of Practice CP30 The Safe Use of Liquid Nitrogen Dewars up to 50 litres: Revision 1 (British Compressed Gases Association, 2008).

2. CLEAPSS advice on handling liquid nitrogen in schools

3. www.sigmaaldrich.com (accessed 23/10/17)

Kit List

Overview

At the core of this project is the set of project equipment. This equipment is intended to be flexible. It can be used by your staff, and the scientists and engineers you work with, for a host of activities and demonstrations.

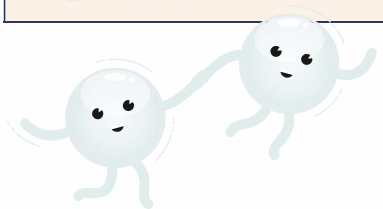
Standard equipment list:

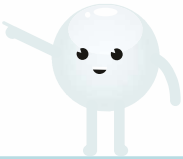
Item	Activity(ies)	Supplier or notes
One bingo machine and set of balls	1	Supplier: Bingo Bingo Supplies Ltd and The Precision Plastic Ball Company Ltd.
Standard balloons (white, red, blue and black)	2, 5, 8, 9	Balloons supplied from Amazon, or BOC 18 inch latex balloons.
Metal tongs with rubber handles	2	Insulated handles for handling balloons in liquid nitrogen: from general scientific equipment supplier.
Sausage balloons	2, 3	Balloons supplied from Amazon or BOC, 18 inch latex balloons.
B34 quick-fit borosilicate tube	3, 5	B34 refers to the size of the neck, quick-fit is a special type of neck on the tube. From general scientific equipment supplier.
B19 to B34 borosilicate adapters x 2	3, 5	Two adapters required to connect 18 inch balloon to B34 quick-fit borosilicate tube. From general scientific equipment supplier.
B34, B24 quick-fit clips x 2	3, 5	Clips to maintain quick-fit joints.
Elastic bands	3, 5	To attach balloons to glassware.
Rubber tubing (4 x 1 m)	4	From general scientific equipment supplier.

Funnel	5	For use in pouring liquid nitrogen into borosilicate tube.
Plastic jars (x 2)	6	Jars supplied from Amazon.
Wide neck quick-fit 500 mL round bottom flask (RBF)	7	Should be wide-neck to lower speed of exhaust, from general scientific equipment supplier.
Retort stand	7	Heavy based metal stand.
Boss	7	A double ended clamp for attaching clamps to retort stand, from general scientific equipment supplier.
Clamp	7	A long armed clamp with screw to close jaws, should be bare metal, from general scientific equipment supplier.
Heat proof mat (x 4)	7	From general scientific equipment supplier.
Portable Bunsen burner	7	From general scientific equipment supplier.
Safety screen	7	From general scientific equipment supplier.
Long-handled spoon	7	From general scientific equipment supplier.
250 mL conical flask with B19 quick-fit neck (x 2)	8, 13	From general scientific equipment supplier.
Balloon clip (x 2)	8, 9	Units supplied from Amazon.
USB cup warmer	10	Units supplied from Amazon.
Balloon pump	10	Units supplied from Amazon.
Glass jug	11	Must have a good spout for pouring and be at least 2 L.
Tea lights	11	General supplies.
Cling film	11	General supplies.
Plastic tub (35 L)	11	Clear sides are a must.
Polystyrene cups	11	Used for safely handling solid carbon dioxide.
2 L glass measuring cylinder	12	From general scientific equipment supplier.
Metal spoon-end spatula	12	From general scientific equipment supplier.
Hydrostik	14	Supplied by Arcola Energy.

Hydrogen experiments:

Item	Activity(ies)	Supplier or notes
Remote control bus	16	Supplied by Arcola Energy.
Hydrogen fuel cell (x 4)	16, 18	For both bus and house, supplied by Arcola Energy.
Arduino controller (x 2)	16, 18	For both bus and house, supplied by Arcola Energy.
Arcola fuel cell controller (x 2)	16, 18	For both bus and house, supplied by Arcola Energy.
Balloon valve (x 2)	16, 18	For both bus and house, supplied by Arcola Energy.
Hydrostik valve (x 2)	16, 18	For both bus and house, supplied by Arcola Energy.
Car chassis	17	Supplied by Horizon Education.
Solar panel charging kit	17	Supplied by Horizon Education.
Battery pack	17	Supplied by Horizon Education.
Reversible hydrogen fuel cell	17	Supplied by Horizon Education.
Electrolysis tanks and tubes	17	Supplied by Horizon Education.
Fan(s)	18	Supplied by Arcola Energy.
RGB LED strips	18	Supplied by Arcola Energy.
Micro-servos	18	Supplied by Arcola Energy.
On/off switch	18	Supplied by Arcola Energy.
Indicator LEDs	18	Supplied by Arcola Energy.
Dolls House	18	Supplied by Arcola Energy.





Consumables and PPE

Item	Activity(ies)	Supplier or notes
Liquid nitrogen	16	Supplied by BOC.
Apples	16, 18	General supplies.
Potassium chlorate	16, 18	General chemical supplies.
Wotsits®	7	General supplies.
Hydrogen peroxide (30 %)	16, 18	General chemical supplies.
Manganese dioxide	16, 18	General chemical supplies.
Diet coke (2 L)	17	General supplies.
Mentos	17	Should be original only, general supplies.
Solid carbon dioxide	17	General chemical supplies.
Bubble mixture	17	General supplies.
Sodium hydroxide	12	General chemical supplies.
Universal Indicator	12	General chemical supplies.
Hydrochloric acid (2 M)	13	General chemical supplies.
Magnesium ribbon	13	General chemical supplies.
Cryogenic gloves	1, 2, 3, 4, 5, 11, 12	From general scientific equipment supplier.
Face shield	General use	From general scientific equipment supplier.
Goggles	General use	From general scientific equipment supplier.
Lab coat	General use	Supplied by ASDC
Nitrile gloves	General use	From general scientific equipment supplier.

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