PROPERTIES OF CO₂

This demonstration has two aims: firstly, to show that carbon dioxide gas is denser than air; secondly, to show that carbon dioxide will not support combustion.

- **EQUIPMENT** a large glass tank
 - 3 candles of varying heights
 - Erlenmeyer flask with side-arm
 - rubber tubing
 - glass tubing with an elbow near the end of the tube
 - dry ice, solid CO_2 (40 g)
 - matches
- **PROCEDURE** Assemble apparatus as shown in the diagram.
 - Dim the lecture theatre lights.

RESULTS Carbon dioxide, being denser than air, first sinks to cover the bottom of the tank. All of the candles continue to burn. As the carbon dioxide level rises, the shortest candle is extinguished, followed by the middle then the tallest candle.

CAUTION

Solid CO, sublimes at -78°C and can cause frostbite.





ILLUSTRATING BOYLE'S LAW

The relationship between the pressure and volume of a fixed amount of air at constant temperature is investigated by measuring its volume while varying the pressure.

EQUIPMENT

- large cylinder with plunger (apparatus illustrated in diagram)
- weights: 4 kilogram or more
- glycerine
- metre rule
- PROCEDURE
- Lubricate the plunger with glycerine and fill the cylinder with a set volume of air.
- Seal the outlet.
- Record the volume of air below the plunger.
- Balance one weight on the plunger and gently press down, and let the plunger spring back up.
- Record the height of the plunger and the weight.
- Calculate the volume of gas by using $V = \pi r^2 h$.
- Add a second, third, etc. weight and calculate the volume of gas and the weight.
- Remove the weights one at a time, again calculating the volume.



- Average the volumes obtained as the weights were removed with those obtained as the weights were added.
- Plot a graph of 1/(average volume) against weight.
- **RESULTS** The graph of 1/volume against weight should be a straight line (within experimental error). It shows that the volume of gas is inversely proportional to the weight and hence to pressure, since the pressure equals mass per unit area.

Note: With zero weight added, the pressure on the plunger is atmospheric pressure.

ILLUSTRATING CHARLES' LAW

This demonstration illustrates the effects of temperature on a volume of gas at a fixed pressure.

EQUIPMENT • liquid nitrogen

- boiling water
- 3 round balloons (red, purple and blue if possible)
- 2 x 2 L beakers

PROCEDURE • Inflate the balloons to an equal size.

- Immerse the blue balloon in a beaker of liquid nitrogen. Notice that it shrinks as the air inside cools.
- Remove the balloon from the liquid nitrogen and the balloon expands to its original size as the air inside warms up again.
- Compare the diameter of the shrunken balloon with the purple balloon at room temperature.
- Immerse the red balloon into the beaker of boiling water and notice that the balloon expands as the air inside it heats up.
- Remove the balloon from the boiling water and the balloon contracts down to its original size.
- Compare the size of the expanded balloon with the balloon at room temperature.
- Immerse a single balloon in liquid nitrogen (-196°C) and quickly measure its diameter.
- Allow the balloon to warm up to ambient temperature and measure its diameter.
- Finally repeat the measurement using hot water.
- Calculate the volume of the balloon assuming it to be spherical. Volume is $1/6\pi d^3$ where d is the diameter of the balloon.
- Plot a graph of volume against temperature.

RESULTS

A plot of volume against temperature should be linear.

CAUTION • Liquid nitrogen has a boiling point of –196°C and can cause frostbite.

High Risk Demonstration:

- Refer to HIRAC
- Set up in Red Tray

THE "HYDROGEN FOUNTAIN": EFFUSION

Hydrogen gas effuses more rapidly than air through a porous cup forcing the water in an attached conical flask out through a thin glass tube. The demonstration is repeated with other gases, for example helium, methane and carbon dioxide. The relative rates of gas flow cause liquid to be forced from the flask, or air to be drawn into the flask.

EQUIPMENT

hydrogen, helium and natural gas cylinders with regulators

- dry ice, solid CO_2 (5 g)
- rubber hose
- 800 mL beaker
- tall porous pot with rubber stopper
- 1 L conical flask with rubber stopper
- glass tubing
- retort stand with 2 boss heads and clamps
- water, coloured with fluorescein

PROCEDURE • Construct the apparatus as shown in the diagram.

- Hold the beaker upside down over the end of the hose and allow it to fill with hydrogen gas.
- Keeping the beaker inverted, place it over the pot.
- Repeat the demonstration using helium, natural gas and carbon dioxide instead of hydrogen gas.

CAUTION Water may be ejected from the nozzle for a considerable distance. Protect surroundings from water damage.

RESULTS The low molecular weight gases flow more rapidly through the porous cup than heavier gases. Hydrogen, effusing into the porous pot faster than air, will cause excess pressure inside the pot. This will transmit to the flask and cause water to be forced out of the jet tube. The lighter the gas, the greater the force on the liquid. Removal of the beaker or filling it with CO₂, will cause the reverse phenomenon: air will be "sucked" into the flask and appear as bubbles in the water.



GRAHAM'S LAW OF DIFFUSION AMMONIA AND HYDROGEN CHLORIDE

Graham's Law of diffusion is illustrated using the vapours from concentrated hydrochloric acid and ammonia.

EQUIPMENT • 2 syringes

- 2 cotton balls
- glass tube
- ruler

REAGENTS • hydrochloric acid, HCl (10 M, 20 mL)

• ammonia, NH_3 (6 M, 20 mL)

PROCEDURE



- Place a ball of cotton wool into each end of a glass tube.
- Seal the ends with glad wrap.
- At one end inject 20 mL of concentrated hydrochloric acid.
- At the other inject 20 mL of ammonia solution.
- After several seconds, note the position of the white ring of NH₄Cl formed where the NH₃ and the HCl gases meet.
- Measure the distance from each cotton ball to the centre of the white ring.

RESULTS



where d represents distance from the cotton ball, r represents the rate of diffusion and M represents the molecular mass of the gas.

This suggests that ammonia molecules should travel 1.46 times as far as hydrogen chloride molecules in a given amount of time. Thus, the ring of ammonium chloride should form 1.46 times as far from the ammonia end of the tube as from the hydrogen chloride end. The usual result is 1.27. This result represents the ratio of diffusion coefficients rather than the ratio of diffusion rates. The deviation from Graham's Law is because the process occurring is not a simple diffusion process; there are 3 gases involved: ammonia, hydrogen chloride, and air.

High Risk Demonstration: 1- Refer to HIRAC 2- Set up in Red Tray

DEMONSTRATION 2.6 (older version)

PARAMAGNETISM OF OXYGEN

An empty test tube is lowered into a Dewar filled with liquid nitrogen. However, when it is removed it contains a small amount of liquid oxygen. The oxygen can then be tested in a magnetic field.

EQUIPMENT

- large horse-shoe magnet on sliding base
- large test tube
- Dewar flask
- cotton thread
- retort stand
- boss head and rod or clamp
- rubber tubing and pasteur pipette (optional)
- oxygen cylinder (optional)

REAGENTS liquid nitrogen, N₂

PREPARATION Prepare liquid oxygen as follows:

- Suspend the test tube by a length of thread from the retort stand.
- Fill the Dewar flask with liquid nitrogen.
- Immerse the empty test tube in the liquid. Ensure that the nitrogen does not enter the tube.
- After approximately one hour sufficient liquid oxygen should have collected in the tube for the demonstration to take place. Optional: In order to speed up the process, and to increase the yield, oxygen gas may be fed into the tube.
- Attach the rubber hose to the cylinder.
- Insert the pipette into the free end of the hose and feed a *gentle*, steady stream of oxygen into the test tube. (This process will shorten collection time to approximately 20 minutes).
- Set up the retort stand with the test tube still suspended from it.
- Place the horse-shoe magnet so that the test tube will later be able to hang freely between the pole pieces of the magnet.
- Return the test tube to the Dewar flask until the demonstration is about to take place.

PROCEDURE • Take the test tube from the Dewar flask and allow it to hang still.

- Slowly slide the magnet towards the test tube until the pole pieces are on either side of it.
- **RESULTS** The test tube will undergo a deflection in the magnetic field.

CAUTION

Liquid oxygen in the presence of organic material is explosive. Extreme care should be taken when handling it.

Liquid nitrogen boils at -196°C and can cause frostbite.

High Risk Demonstration: 1- Refer to HIRAC 2- Set up in Red Tray

DEMONSTRATION 2.6 (New Version)

PARAMAGNETISM OF OXYGEN

A test tube with an oxygen filled balloon attached is lowered into a Dewar filled with liquid nitrogen. When the test tube is removed it contains a small amount of liquid oxygen. The liquid oxygen can then be tested in a magnetic field.

- EQUIPMENT large balloons
 - long test tube
 - Dewar flask
 - Oxygen cylinder
 - Apparatus (please ask for assistance from the first year technical staff)
- **REAGENTS** liquid nitrogen, N₂

PREPARATION

Prepare liquid oxygen as follows:

- Fill the Dewar flask with liquid nitrogen
- Fill up two Balloons with oxygen gas from the cylinder.
- Attach each balloon to the rim of a large testtube.
- Immerse the test tube in the liquid nitrogen flask.
- Leave the test tubes in the liquid nitrogen to allow the pale blue liquid to be collected at the bottom.
- The pale blue liquid is liquid oxygen.
- **PROCEDURE** Place the magnet assembly in a white tray provided and place the tray onto the overhead projector. Take the test tube from the Dewar flask and remove the balloon. Pour the liquid oxygen over the aperture between the magnet arms. Observe the aperture carefully. Repeat the procedure using liquid nitrogen.
- **RESULTS** Liquid oxygen results in a white line between the magnet arms. There are no visible lines observed when using liquid nitrogen.

CAUTION Liquid oxygen in the presence of organic material is explosive. Extreme care should be taken when handling it.

Liquid nitrogen boils at -196°C and can cause frostbite.

High Risk Demonstration:

- 1- Refer to HIRAC
- 2- Set up in Red Tray