Teacher Demonstration 32

Imploding drum

Teaching solids, liquids and gases, changes of state or meteorology? In this spectacular demonstration, atmospheric pressure crushes a steel drum with an almighty bang. If time permits, a small scale version of this demonstration can be performed with an empty soft drink can first (see Procedure notes).

A small volume of water is boiled in an open steel drum or jerry can until steam replaces nearly all the air inside. When the heat is removed and the drum is sealed, the hot water vapour cools and condenses, causing the internal vapour pressure to fall. When the internal pressure becomes sufficiently low, atmospheric pressure crushes the drum instantaneously with a loud bang.

Two video clips of this demonstration can be viewed online at:

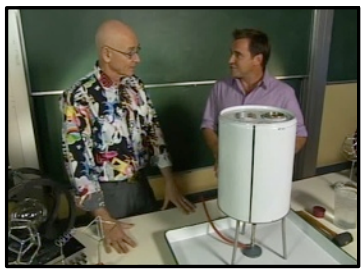
www.abc.net.au/science/surfingscientist/video

See: Imploding drum (Catalyst, 20 litre steel drum)
Imploding can (Roller Coaster, 5 litre steel jerry can)

Materials:

- Empty steel drum or jerry can (clean)[1]
- Gas heater or bunsen burner
- Tripod (not required for gas heater)
- Large shallow tray (optional)
- Water
- Large jug of cold water (icy if possible)
- Rubber bung and mallet (if using drum)
- Gloves

[1] Rinse used drum or jerry can thoroughly (with detergent if necessary) to remove original contents – use a tight rubber bung to seal drums



Bunsen burner setup:

Set the drum or jerry can on a large, stable tripod if using a Bunsen burner. If necessary, stand the tripod in a shallow tray to catch any spilt water in step 4. Keep the table clear of fragile props to avoid breakage if the drum falls off the tripod.

Camp stove burner setup:

Place the drum or jerry can directly on the camp stove burner. If necessary, place the burner in a shallow tray to catch any water spilled in step 4,

Procedure

If time permits, perform the small-scale version of this demonstration with an aluminium soft drink can first. Instructions can be downloaded at:

www.abc.net.au/science/surfingscientist/pdf/teachdemo18.pdf

Safety and risk assessment:

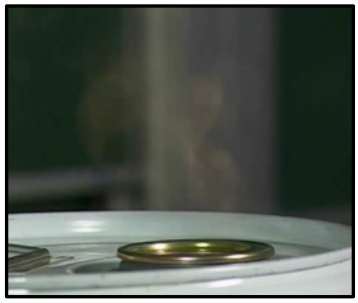
Conduct your own risk assessment before performing this demonstration ensuring that your equipment and materials are performing properly.

Keep bench or table clear of fragile items to avoid breakages if the drum or jerry can falls over after imploding.

Water will splash off the drum so keep the demostration clear of electrical outlets and equipment.

1. Pour a small volume of water into the drum or jerry can to a depth of one or two centimetres.

   Note: this demonstration also works with a standard 55 gallon drum (procedure is identical)



2. Ignite the Bunsen burner or camp stove and wait until the water is boiling audibly. Allow the water to keep boiling until you see condensed water vapour rising from the opening.

3. Switch the Bunsen burner or camp stove off and immediately screw the cap on tight for a jerry can, or if using a drum, insert the rubber bung and force it tight with a rubber mallet.

4. To accelerate condensation of the water vapour inside, pour several litres of cold water (icy if possible) over the top and sides of the drum or jerry can. Now wait until the drum implode

5. Several minutes may pass before the drum implodes so be patient. The time taken varies significantly and depends on the temperature and volume of water you used in step 5. Dints reduce the strength of cylindrical drums or jerry cans and may also reduce the time taken for an implosion to occur.

   NOTE: creaking and the sound of condensation droplets falling inside the drum are normal but a hissing noise usually indicates an air leak which will almost certainly prevent an implosion. If a leak occurs, remove and clean the bung or lid and start over.

6. The drum implodes suddenly and without warning. The water you poured on top of the drum in step 4 will splash in every direction.

7. Inspect the drum or jerry can – it will be crumpled and bent as though it was hit at full force by a large sledgehammer.

Teacher notes

When liquid water turns into steam at atmospheric pressure, its volume expands by a factor of 1700 times (see calculations on the next page). Boiling a small volume of water inside a drum displaces nearly all the air and replaces it with steam. When the heat is removed and the drum is sealed, the steam inside begins to condense back to the liquid state and the internal pressure rapidly falls.

Standard atmospheric pressure exerts 101.3 kilopascals in every direction, which is equivalent to 10,330 kilograms per square metre.

A 20 litre drum (28 centimetre diameter, 36 centimetres tall) has a total surface area of 0.44 metres^2.

Assuming all of the steam is condensed back into liquid water, the weight exerted on the drum's walls could reach 4544 kilograms (10,332 multiplied by 0.44) or nearly half a tonne. This pressure is more than sufficient to crush the drum, as is evident during the demonstration.

The cylinder implodes rapidly due to the considerable strength of a cylinder. A rectangular drum or jerry can crumples sooner but more slowly.

Volume of steam calculation:

The degree to which a given volume of water at room temperature expands when converted to steam can be calculated from the ideal gas law.

Ideal gas law:

$$P\,V = nRT$$

If the temperature T of the steam is assumed to be just above the boiling point of water at atmospheric pressure (ie100^{0}C), then for one mole of water:

Pressure	P = 101325 Pascals	*(atmospheric pressure)*
Temperature	T = 373 K	*(100^{0}C at atmospheric pressure)*
Ideal Gas Constant	R = 8.314 J K^{-1} mol^{-1}	
Quantity of gas	n = 1 mole	

Rearranging the ideal gas law yields:

$$V = \frac{n\,R\,T}{P}$$

$$= \frac{1 \times 8.314 \times 373}{101325}$$

$$= 0.0306\ m^3$$

So one mole of water converted to steam at atmospheric pressure occupies a volume of 0.0306 cubic metres. One mole of water weighs 0.018 kilograms, so the density ρ of one mole of steam in kilograms per cubic metre and at atmospheric pressure is:

$$\rho_{STEAM} = \frac{0.018}{0.0306}$$

$$= 0.588\ kg\ m^{-3}$$

The density of liquid water at room temperature is 1000 kg m^{-3} (ie one cubic metre of water weighs one tonne), so the relative density of liquid water to steam at atmospheric pressure is:

$$\frac{\rho_{WATER}}{\rho_{STEAM}} = \frac{1000}{0.588}$$

$$= 1700$$

So, a volume of water will occupy 1700 times more volume when converted to steam at atmospheric pressure.