Adiabatic Heating and Cooling

Demonstrations

1 Adiabatic changes in a syringe

A plastic syringe is firmly fixed to the bench on wooden blocks with double-sided tape. A Vernier pressure sensor is connected to the syringe. A motion detector plots the position of the plunger in real time.

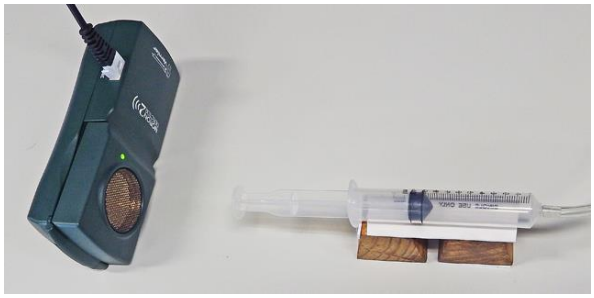

Fig 1 – a syringe, motion detector and pressure sensor (not shown).

Figure 2 is a plot of pressure versus the volume of air enclosed in the syringe. .

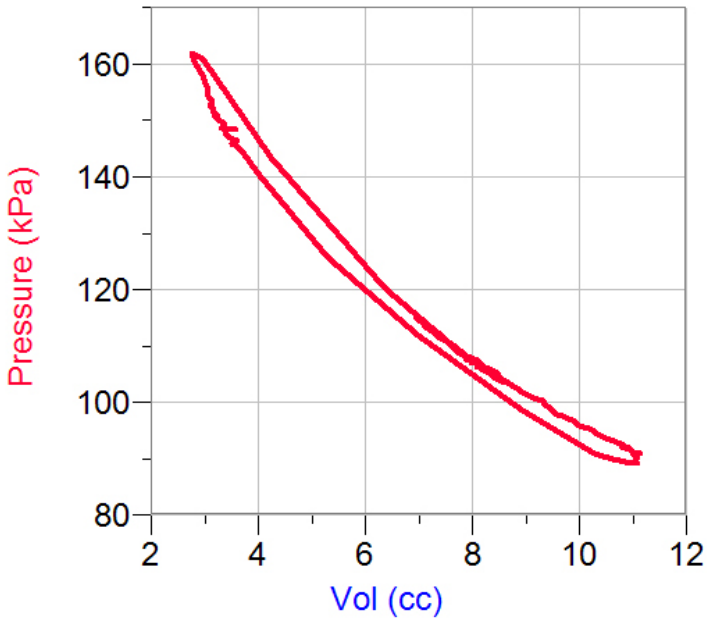

Fig 2 –a loop appears on the PV diagram.

Position data has been converted to volume with a calculated column. In this case the motion is rapid, a cycle is completed in less than one second, and the PV diagram is not the simple hyperbola that is seen if the changes are made slowly.

Figure 2 has been redrawn as an idealized PV diagram below.

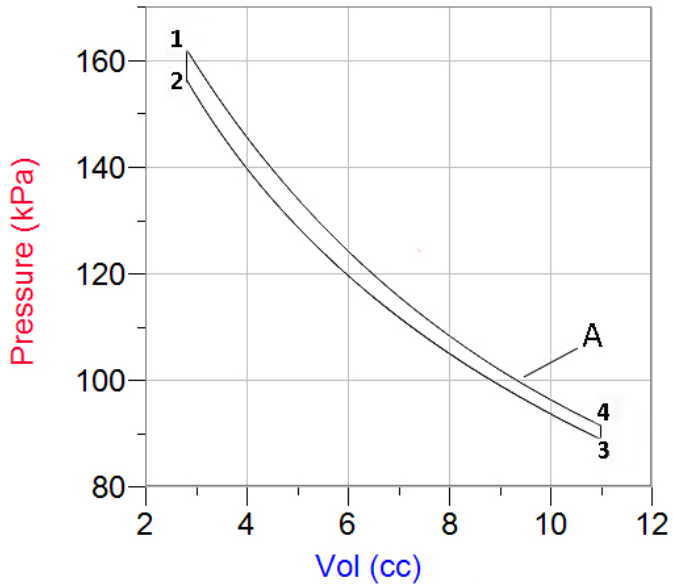

Fig 3 – an idealized PV diagram.

Rapid compression from A to 1 does work on the trapped air and the temperature rises. As the volume is kept constant (1–2) the warmed air cools to room temperature and the pressure falls. Rapid expansion from points 2–3 leads to further cooling. Holding the volume constant (3–4) allows the gas to return to room temperature. The cycle can then be repeated. Figure 4 shows the position of the piston as a function of time.

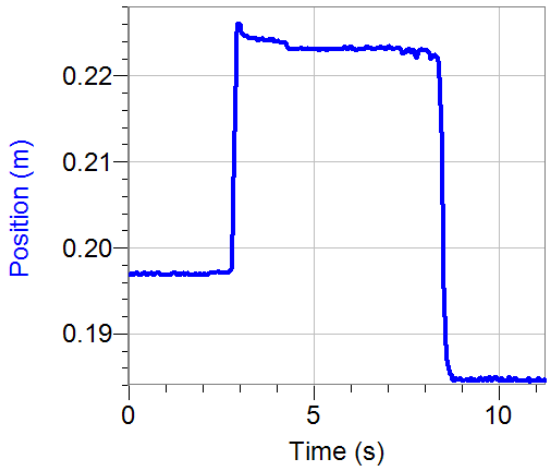

Fig 4 – The position of the piston as a function of time.

The low-pressure end of the loop in figure 2 is a close approximation to the idealized diagram (figure 3). The high-pressure end is not. Look carefully at figure 4 and suggest a reason.

2 A cloud in a bottle

Figure 5 shows the props needed for a simple demonstration of adiabatic cooling and condensation in saturated air.

Fig 4 – equipment for making a cloud in a bottle.

The reader is encouraged to do this for themselves.

Put a few drops water in a PET bottle and pump it to a pressure 3 or 4 atmospheres. Shake the bottle to saturate the air and then gently ease out the bung. ***Whumph*!**

Fig 5 – Cold air rushes out and a cloud appears in the bottle.

3 A cycle in a bottle

Fig 6 – You will need a large PET bottle, wide shoes and a board (optional). You will also need a little water, a slip of paper and a match (not shown).

Put a little water in the bottle and shake it. Light a small slip of paper with the match and drop it into the bottle to add condensation nuclei (smoke particles). Screw the top on and stand on the bottle for 10 s. Step off the bottle suddenly. A cloud appears. Stand on the bottle and the cloud evaporates. The cycle can be repeated again and again.

Make an estimate of temperature change

Use the ideal gas equation … $PV = RT$ … where R is the specific gas constant for air, 287 J/(kg K).

a *Estimate the maximum temperature change inside the bottle.*

Assume the plastic doesn't stretch during the compression. Estimate the pressure increase when standing on the bottle. Is there a significant volume change? What measurements are needed? What might be the advantage of inserting the wooden plate between the shoes and the bottle?

b *Why might this temperature change not be realized in practice?*

4 Fire pistons

A fire piston is a narrow cylinder fitted with a sliding air-tight piston. Sudden compression raises the temperature of the trapped air sufficiently to ignite tinder and start a fire. The can be bought. We are working on making our own.