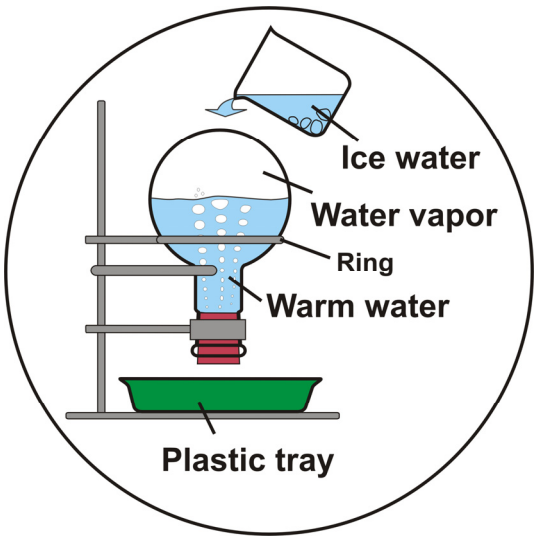
Causing Warm Water To Boil by Cooling



Equipment:

1-L round-bottomed flask
heating mantle or burner with wire gauze
rubber stopper
beaker
plastic tray
support stand, clamp holder, extension clamp, ring support

Chemicals:

water
crushed ice

Safety:

To avoid implosion-related incidents caused by the stress of the vacuum created during the experiment damaged glassware (with “stars”, cracks etc.) never should be used. It is also necessary to wear safety glasses and heat-protective gloves.

Procedure:

The round-bottomed flask is one half filled with water and a few boiling stones are added. The water is heated until boiling using a heating mantle or burner, and allowed to boil for a few minutes so that most of the air is driven out of the flask. The flask is removed from the heat, tightly stoppered and allowed to cool for a little while to make a good seal. Then the inverted flask is clamped on the stand over a plastic tray, secured by a ring and ice water is poured cautiously over the flask.

Observation:

The water inside the flask begins to boil heavily. When the pouring is stopped the boiling process also comes to an end after a little while. But the boiling starts up again by pouring more ice water over the flask. The whole “procedure” can be repeated several times.

Explanation:

The boiling process can be described by the following equation:

$$H_2O|l \rightarrow H_2O|g.$$

Liquid water has a smaller chemical potential than water vapor under standard conditions (298 K, 100 kPa), i.e. the chemical drive is negative and the process will not take place.

Necessary chemical potentials and pressure coefficients ($T^{\ominus}$ = 298 K, $p^{\ominus}$ = 100 kPa):

Substance	Chemical potential $\mu^{\ominus}$ [kG]	Pressure coefficient β [µG Pa^{-1}]
H_2O|l	–237.1	18.1
H_2O|g	–228.6	$24.8 \cdot 10^3$

But the chemical potential of gases, and therefore also that of water vapor, is strongly pressure dependent as shown by a high pressure coefficient. At sufficiently low pressure the chemical potential of water vapor will fall below the value of liquid water so that the water will boil at temperatures significantly less than 100 °C.

The flask is completely filled with water, i.e. liquid water is in equilibrium with water vapor. The cooling of its upper part causes the water vapor to condense and the pressure of the vapor to quickly drop to a low value.