RELATIVE HUMIDITY AND DEW POINT

Link to: physicspages home page.

To leave a comment or report an error, please use the auxiliary blog.

Reference: Daniel V. Schroeder, *An Introduction to Thermal Physics*, (Addison-Wesley, 2000) - Problem 5.42.

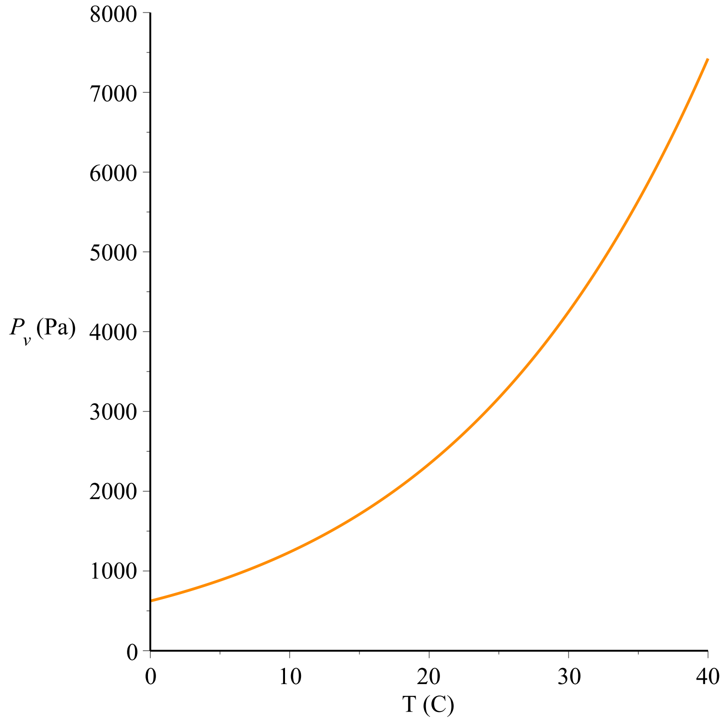
The vapour pressure equation gives the phase boundary curve between the liquid and gas phases of a substance if we can assume that the gas is an ideal gas:

$$P_v = Ke^{-L/RT} \tag{0.1}$$

where K is a constant and L is the latent heat of vapourization. If we're interested in the vapour pressure of water for temperatures typical of Earth's weather, we could look at a temperature range of 0° C to 40° C. From Schroeder's Figure 5.11, we can use the values at $T = 25^\circ$ C to estimate K. Here, $L = 43.99\times10^3$ J mol^{-1} and $P_v = 0.0317\times10^5$ Pa. The gas constant is $R = 8.314$ in SI units. This gives

$$\begin{aligned}
K &= P_v e^{L/RT} && (0.2)\\
&= 0.0317\times10^5 e^{43.99\times10^3/(8.314\times298)} && (0.3)\\
&= 1.63\times10^{11}\text{ Pa} && (0.4)
\end{aligned}$$

This gives a graph as follows:



We can see from the graph that P_v roughly doubles for each increase in temperature of 10 degrees.

The *relative humidity* is defined as the ratio of the actual vapour pressure to the equilibrium vapour pressure at a given temperature. A high humidity is what makes it feel hotter than the actual temperature on a warm summer day, because it decreases the evaporation rate of the sweat that is attempting to cool you down.

The *dew point* is the temperature at which the current vapour pressure would be the equilibrium vapour pressure. At the dew point, the air is said to be saturated, meaning that liquid water will not spontaneously evaporate. If the vapour pressure exceeds the equilibrium pressure, vapour will condense spontaneously to form dew, fog or rain.

As an example, suppose the air temperature is 30° C $= 303$ K. From the above, this gives an equilibrium vapour pressure of

$$P_v(303) = 4.249 \times 10^3 \text{ Pa} \tag{0.5}$$

If the relative humidity is 90%, the actual vapour pressure is

$$P = 0.9P_v(303) = 3.824 \times 10^3 \text{ Pa} \tag{0.6}$$

The dew point at this humidity is found by solving 0.1 for T:

$$T = \frac{L}{R\ln(K/P)} \tag{0.7}$$

Plugging in the numbers gives

$$T = 301.2\text{ K} = 28.2^{\circ}\text{ C} \tag{0.8}$$

For a relative humidity of 40%, the vapour pressure is

$$P = 0.4P_v(303) = 1.700\times 10^3\text{ Pa} \tag{0.9}$$

The dew point is now

$$T = 287.9\text{ K} = 14.9^{\circ}\text{ C} \tag{0.10}$$

PINGBACKS

Pingback: Relative humidity: seeing your breath
Pingback: Wet adiabatic lapse rate
Pingback: Surface tension and cloud formation