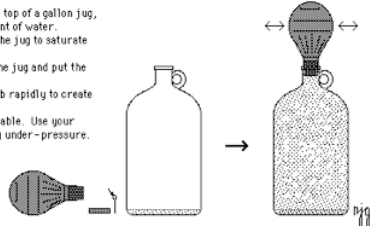


Cloud in a Jar Demonstration

Adiabatic Processes EXPANSION CLOUD CHAMBER

- A rubber bulb fits into the top of a gallon jug, which contains a small amount of water.
- Slosh the water around in the jug to saturate the air with water vapor.
- Drop a lighted match into the jug and put the bulb on the top.
- Squeeze and release the bulb rapidly to create the "cloud".
- A 5-gallon jug is also available. Use your lungs to create the necessary under-pressure. (The bulb is too small.)



http://groups.physics.umn.edu/demo/old_page/demo_gifs/4B70_20.GIF

Lecture Ch. 6b

100%. For simplicity, we assume here that clouds form in the atmosphere when the water vapor reaches its saturation value and $\mathcal{H} = 100\%$.

- Saturation of moist air
- Relationship between humidity and dewpoint
 - Clausius-Clapeyron equation
- Dewpoint
 - Temperature
 - Depression
- Isobaric cooling

Curry and Webster, Ch. 6
For Tuesday: Read Ch. 7

How does saturation occur?

- By increasing water vapor
 - Evaporation of water at surface
 - Evaporation of falling rain
- By cooling
 - Isobaric
 - Radiative cooling of rising air
- By mixing of two unsaturated air parcels

Curry and Webster, Ch. 6

Saturation of Moist Air

- Dew point temperature

The temperature at which saturation is reached in an isobaric cooling process is the *dew-point temperature*, which is illustrated in Figure 6.1a. The dew-point temperature, denoted by T_D , can be defined by

$$e = e_s(T_D) \quad (6.14)$$

or equivalently by

$$w_v = w_s(T_D) \quad (6.15)$$

Curry and Webster, Ch. 6

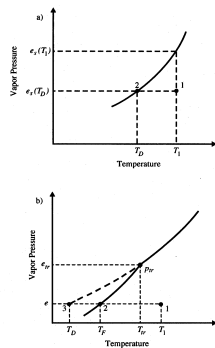


Figure 6.1 a) Relationship between temperature and vapor pressure in an isobaric cooling process. Air initially at temperature T_1 (point 1) is cooled isobarically until it reaches saturation (point 2). The temperature at point 2 defines the dew-point temperature, T_D . b) Air at T_1 (point 1) cools isobarically until it reaches saturation. If the saturation is reached with respect to ice (point 2), the temperature is called the frost point, T_f .

Saturation of Moist Air

- Clausius-Clapeyron equation at dew point

$$\frac{dp}{dT} = \frac{L_{lv}}{T v_v} \quad (4.18)$$

$$\frac{dp}{dT} = \frac{L_{lv} p}{R_v T^2} \quad (4.19)$$

$$\frac{d \ln p}{dT} = \frac{L_{lv}}{R_v T^2} \quad (6.18)$$

Clausius Clapeyron

- Recall by integration between two temperatures we had

$$\int_{e_1}^{e_2} d(\ln e) = \int_{T_1}^{T_2} \frac{L_v}{R_v T^2} dT \quad (4.21)$$

to yield

$$\ln \frac{e_2}{e_1} = -\frac{L_v}{R_v} \left(\frac{1}{T_2} - \frac{1}{T_1} \right) \quad (4.22)$$

or

$$e_2 = e_1 \exp \left[-\frac{L_v}{R_v} \left(\frac{1}{T_2} - \frac{1}{T_1} \right) \right] \quad (4.23)$$

Dewpoint and Humidity

- Integrating from ambient to saturation

$$\ln \frac{e_s}{e} = -\ln \mathcal{H} = \frac{L_v}{R_v} \left(\frac{1}{T_D} - \frac{1}{T} \right)$$

or equivalently

$$\mathcal{H} = \exp \left[-\frac{L_v}{R_v} \left(\frac{T - T_D}{T T_D} \right) \right] \quad (6.19)$$

- Dew point depression ($T - T_D$)

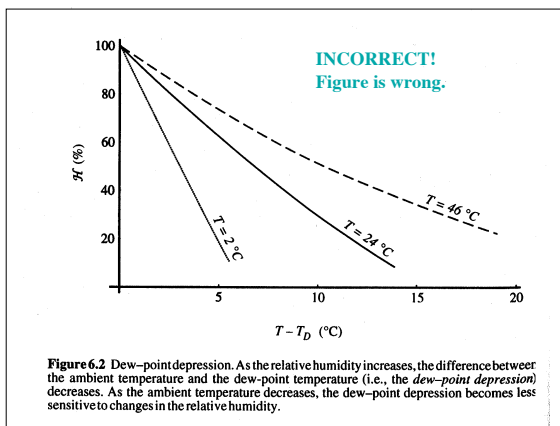


Figure 6.2 Dew-point depression. As the relative humidity increases, the difference between the ambient temperature and the dew-point temperature (i.e., the *dew-point depression*) decreases. As the ambient temperature decreases, the dew-point depression becomes less sensitive to changes in the relative humidity.

Pressure Altitude Calculator

Let's compare the hydrostatic equation to the atmosphere

$$p = p_0 \left(\frac{T}{T_0} \right)^{\frac{1}{R_d \Gamma}}, T = T_0 - \Gamma z \rightarrow p = p_0 \left(\frac{T_0 - \Gamma z}{T_0} \right)^{\frac{1}{R_d \Gamma}}$$

Hydrostatic Equation	
Surface Temperature	294 K
Lapse Rate	0.005 K/m
Surface Pressure	1013 mbar or hPa
Altitude	10000 m
Rd	287 J/K/kg
Calculated Pressure	272.62518 mbar or hPa

<http://www.csgnetwork.com/pressurealtcalc.html>

Cumulus Cloud Base Altitude Calculator

$$\text{Cloud Base Altitude} = \left(\frac{\text{temperature} - \text{dew point}}{4.5} \right) * 1000 + \text{measure station altitude}$$

Assumes:

- The rate at which air cools as it rises is averaged at 5.5°F per 1000 feet
- The dew point also decreases at about 1.0°F over the same distance.

<http://www.csgnetwork.com/estcloudbasecalc.html>