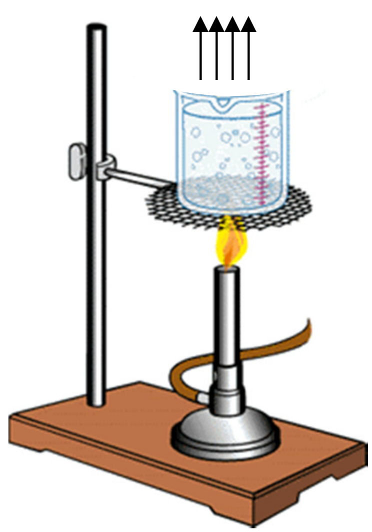
DRYING

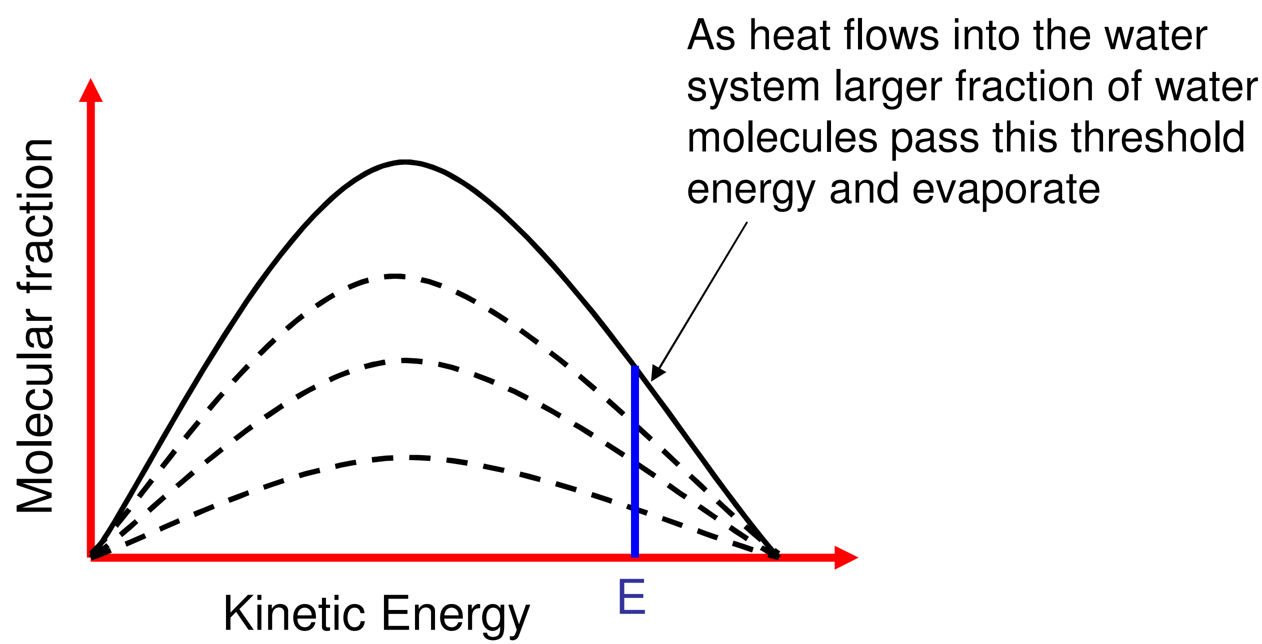
Drying is defined as removal of water from a material using a certain natural (sun drying) or artificial method

Water activity

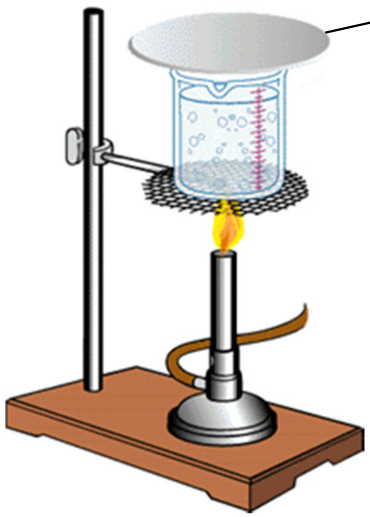
Vapor pressure: Water molecules evaporates at every temperature. If certain amount of heat flows into the water as shown in following figure water molecules start moving faster (their kinetic energy increases). When the molecules obtain certain amount of kinetic energy (E) they evaporate and leave the liquid state. Unless the heat flow rate is not too high the temperature of the system does not change.

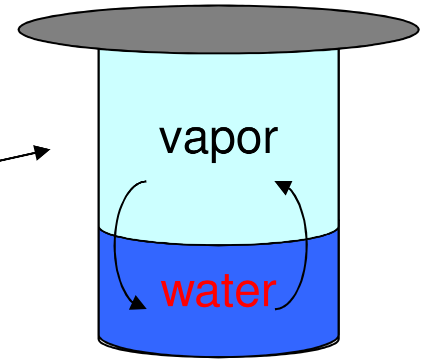
EVAPORATION





Water activity





If this cap is sealed, molecules will evaporate into the space above the liquid and fill it completely. After a time, equilibrium is reached (number molecules evaporate = number of molecules condensate).

This vapor exerts (applies) a pressure just like a gas and we call this pressure the vapor pressure of the liquid.

The value of vapor pressure is independent of the amount of liquid in the container as long as there is some.

Vapor pressure is the pressure of a vapor in equilibrium with its non-vapor phases (usually liquid)

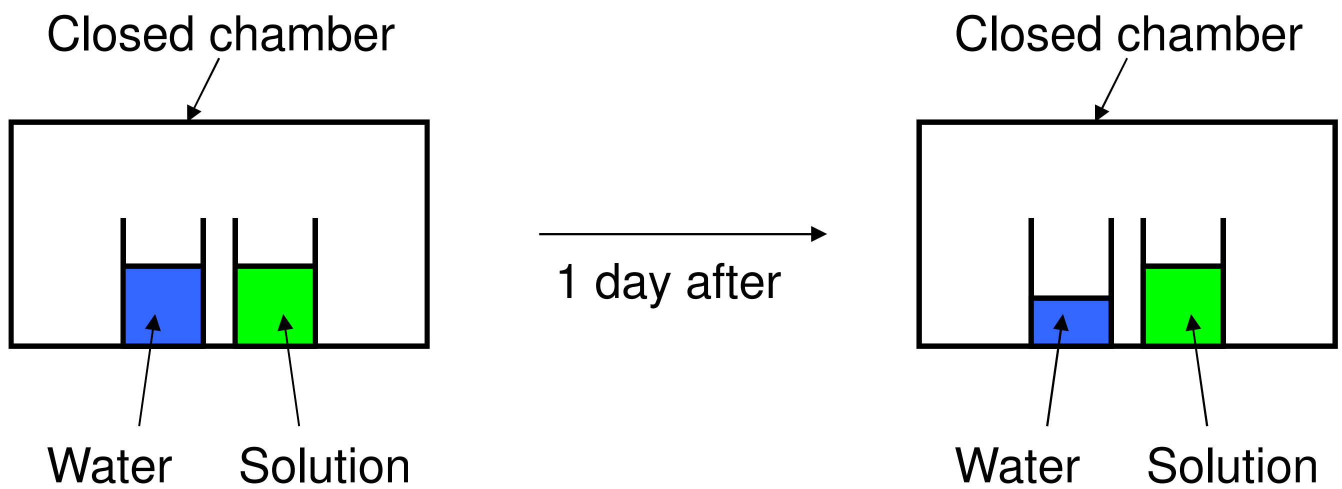
Vapor pressure of liquid depends on type of liquid, density of the liquid, and temperature.

The attraction forces between molecules of each liquid is different. If this force is relatively low then the vapor pressure becomes relatively high

For example water has lower vapor pressure compared to the ethyl alcohol at same temperature.

Vapor pressure is indirectly proportional to the density and directly proportional to the temperature.

$$\text{Water activity is define as} = \frac{\text{Vapor pressure of food}}{\text{Vapor pressure of pure water at the same temperature}}$$



Water level decreases much more than the level of the solution. Addition of a solute into a solvent reduces the vapor pressure (this is called vapor pressure depression) . That is why the solution reaches equilibrium quickly.

HUMIDITY

Dry air: Dry air is air without any water vapor. It is a mixture of gasses and its composition is assumed as 79% N_2 and 21% O_2.

Under normal conditions 1 mole air is 22.4lt.

1m3 dry air is composed of 210 lt O_2 and 790 lt N_2.

Humidity (absolute humidity) is defined as kg of vapor contained in 1 kg of dry air. The humidity depends on the partial pressure of water vapor in air and on the total pressure.

$$H \frac{\text{Kg water}}{\text{kg dry air}} = \frac{P_w}{P - P_w} \frac{\text{Kg mol water}}{\text{kg mol dry air}} * \frac{18 \text{ Kg water}}{\text{Kg mol water}} * \frac{\text{kg mol dry air}}{29 \text{ Kg dry air}}$$

$$H = \frac{18}{29} \frac{P_w}{P - P_w}$$

P_w → Partial pressure of vapor

P → Total pressure

H ← absolute humidity

Percentage Humidity. The percentage humidity is defined as the 100 times the actual humidity of the air divided by the humidity if the air were saturated at the same temperature and pressure.

Percentage Relative Humidity. The percentage relative humidity is defined as the 100 times the actual vapor pressure of the air divided by the vapor pressure of air if the air were saturated at the same temperature and pressure

$$H_r = 100 \frac{P_w}{P_s}$$

P_w → Actual vapor pressure

P_s → Vapor pressure of saturated air

Specific heat of humid air (humid heat).

Specific heat of humid air is defined as the amount of heat required to increase or decrease the temperature of 1 kg-*dry air and water vapor mixture* by 1°C.

$$c_s = c + Hc_w$$

- c → Dry air specific heat 0.24 kcal/kg°C
- H → Absolute humidity
- c_w → Water vapor specific heat 0.44 kcal/kg°C

$$C_s = 0.24 + 0.44H$$

C_s → Specific heat of humid air

Enthalpy of humid air.

Enthalpy is total heat. Usually described as the total heat of 1 kg mixture of water vapor and dry air in Kcal/kg.

$$E = cT + H(c_w T + \lambda)$$

- c: 0.24
- T: Temperature in ^{o}C
- H: Absolute humidity
- c_w: 0.44
- λ: Heat required to evaporate 1 kg of water at 0^{o}C (597.8Kcal).

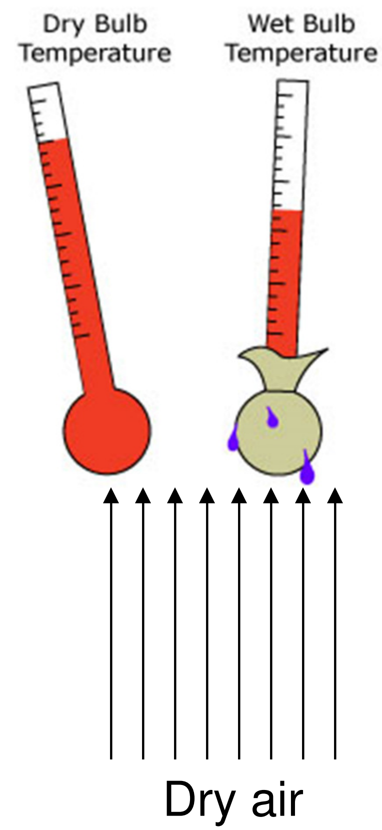
Example: Calculate the enthalpy increase of humid air with 0.015 kg water vapor / kg dry air humidity when it temperature is increased from 20^{o}C to 70^{o}C.

PSYCHROMETRY

A useful concept in psychrometry is the wet-bulb temperature, as compared with the ordinary temperature, which is called the **dry-bulb temperature**.

The wet-bulb temperature is the temperature reached by a water surface, such as that registered by a thermometer bulb surrounded by a wet cloth, when exposed to air passing over it.

The cloth and therefore the thermometer bulb decreases in temperature below the dry-bulb temperature until the rate of heat transfer from the warmer air to the cloth is just equal to the rate of heat transfer needed to provide for the evaporation of water from the cloth (wick) into the air stream



By using both wet-bulb temperature and dry-bulb temperature the relative humidity can be calculated.

$$P_w = P_d - 05(T_{db} - T_{wb})$$

Partial pressure of water vapor (P_w)

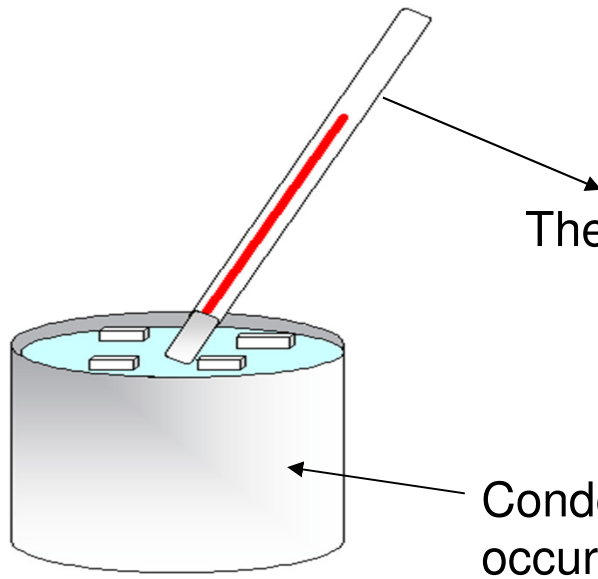
Saturation pressure (P_d)

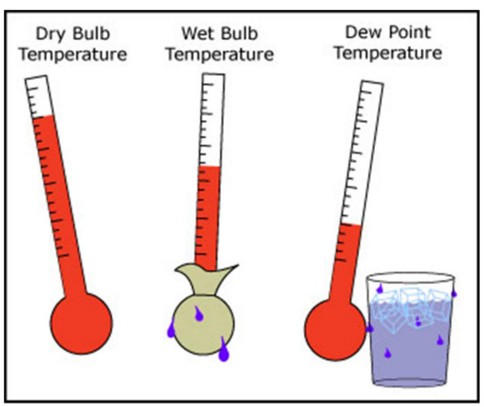
Dew Point

The **dew point** or **dewpoint** of a given humid air is the temperature to which the air must be cooled, at constant pressure, for the water vapor component to condense into water

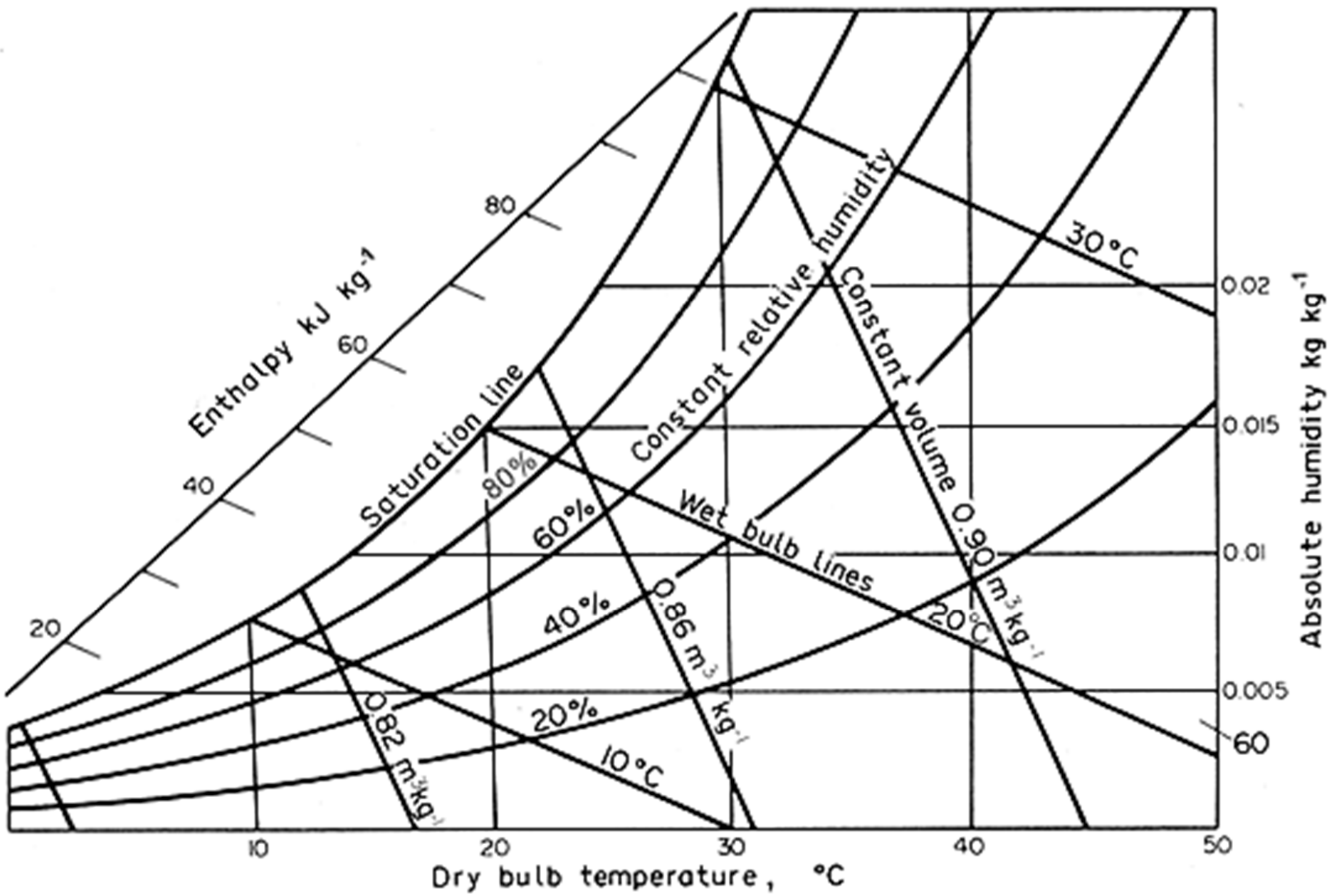
At dew point the , Pw = Pd, therefore relative humidity is equal to 100%

Slowly add ice cubes to the water in a shiny can to lower the can temperature. Stir the water with a thermometer while adding the ice cubes to insure the same can and water temperature. When condensation occurs on the outside of the can, note the dew point temperature.





Psychrometry is the science of studying the thermodynamic properties of moist air and the use of these properties to analyze conditions and processes involving moist air

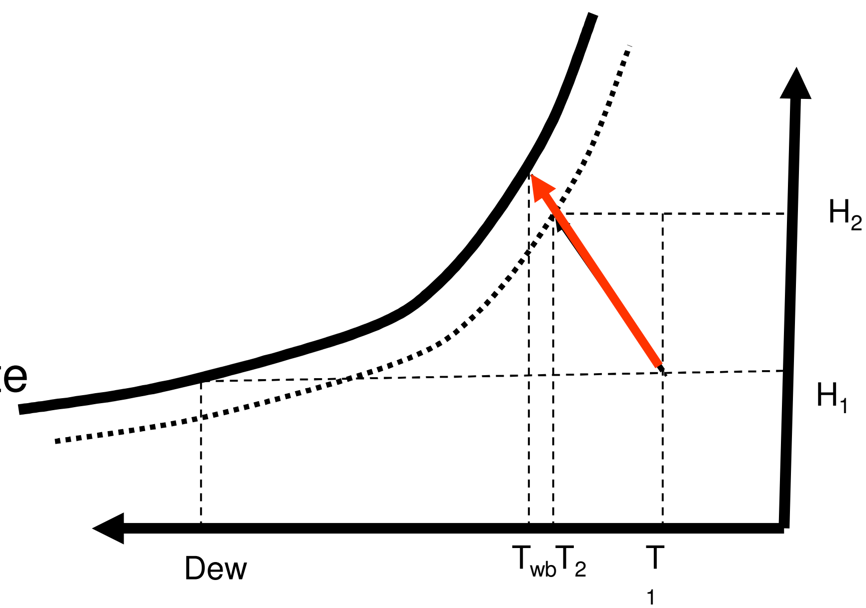


Adiabatic processes

*An **adiabatic process** is one in which no heat is gained or lost by the system. Adiabatic process can only take place when the system is completely insulated. Drying with hot air is usually assumed an adiabatic process. During drying, when the hot air gets into contact with the moist products, water evaporates and releases it latent heat of vaporization. During this process energy comes from the hot air therefore air cools down.*
Since the energy lost by hot air is equal to the energy gained by the water vapor the process is said to be adiabatic process.

Adiabatic process takes place on adiabatic curves on psychometric charts

During an adiabatic cooling, the wet bulb temperature remains constant but the relative humidity and absolute humidity increases and dry bulb temperature decreases.



Drying capacity of hot air

Drying capacity of a drying air can be expressed using the psychometric chart. Drying capacity is simply the distance between characteristic point and saturation point along the adiabatic cooling curve. Air can be used as a drying medium until its temperature reaches to wet bulb temperature.