Humidity

The amount of water vapor in the air.
Definitions

- **Specific Humidity**: mass of water vapor per mass of air (g/kg).
- **Absolute Humidity**: mass of water vapor per volume of air (g/m$^3$).
- **Mixing Ratio**: mass of water vapor per mass of "dry air" (g/kg).
- **Vapor Pressure**: partial pressure of water vapor (mb).

- **Relative Humidity**: (actual water vapor content of air)/(maximum water vapor capacity of air)
  - $RH = (VP/\text{Saturation VP}) \times 100\%$
The transition from liquid to gas depends mostly on the water temperature and the transition from gas to liquid depends mostly on the humidity.
Saturation

If the box at right is sealed and initially has no water vapor, the humidity will start to increase as liquid water molecules escape the surface tension. As the humidity increases, gas molecules hit the water surface more and more frequently.
Eventually the humidity increases to a point where the rate of gas to liquid transitions is equal to the rate of liquid to gas transitions.

- This is an equilibrium.
- At this point, the humidity no longer increases and the air is said to be saturated.
- The relative humidity is 100%.
What would happen if you suddenly increase the temperature of the whole box?

Answer: That would increase the kinetic energy of the water causing the humidity to start increasing. We would observe evaporation taking place. Eventually, the air will reach a new equilibrium at a higher humidity.
What would happen if you suddenly decreased the temperature of the box?

Answer: The rate of gas-liquid transitions would continue at about the same rate, while the rate of liquid-gas transitions would decrease. We would observe condensation taking place. This would result in a reduction in the humidity. Eventually a new equilibrium would be reached at a lower humidity.
The humidity at which the air becomes saturated depends on the temperature.

Dew point temperature is the temperature to which you would have to cool unsaturated air in order to saturate it.
Calculating Saturation Vapor Pressure

\[ e_s = 0.61078 \exp\left( \frac{17.269T}{T + 237.30} \right) \]

where:

\[ e_s = \text{vapor pressure (kPa)} \]

\[ T = \text{air temperature (°C)} \]
Relative humidity is affected by the amount of water vapor and the temperature:

\[ RH = \left( \frac{VP}{VP_{\text{sat}}} \right) \times 100\% \]

So, if the VP remains relatively constant, RH should be greatest at what time of day?
Humidity Problems

1. If the vapor pressure is 2.0 kPa and the air temperature is 25°C, what is the relative humidity?

First, compute $e_s$ as a function of temperature:

$$e_s = 3.17 \text{ kPa}$$

Then get RH:

$$RH = 100\% \times \frac{2.0}{3.17} = 63\%$$
Humidity Problems

2. If the relative humidity is 75% and the air temperature is 30°C, what is the vapor pressure?

\[ e_s = 4.24 \text{ kPa} \]
\[ e = 0.75 \times 4.24 \text{ kPa} = 3.18 \text{ kPa} \]
3. If the air temperature is 20°C and the dew point temperature is 15°C, what is the relative humidity?

By calculating $e_s$ at the dew point temperature, you are actually calculating $e$:

$e = 1.70 \text{ kPa}$.

Then calculate $e_s$ at the air temperature:

$e_s = 2.34 \text{ kPa}$.

$\text{RH} = 100 \times \frac{1.70 \text{ kPa}}{2.34 \text{ kPa}} = 73\%$
Other Definitions

- **Vapor Pressure Deficit**: $\text{VPD} = e_s - e$

- **Wet Bulb Temperature**: used to estimate humidity; bulb of thermometer with a moist cloth covering is ventilated, lowering the temperature.