

**Today, we will:**

- Discuss **Relative Humidity** (water vapor in air)
- Do an example problem

 $j \rightarrow H_2O$ **Relative Humidity:** (The standard way to describe the amount of water vapor in the air)**Introduction:**

- “**Dry air**” is defined as air with no water vapor (zero humidity).
- When we quote the standard molecular weight for air it is typically for **dry air**:  
★  $M_{\text{air}} = 28.97 \text{ kg/kmol}$  for dry air.
- “**Moist air**” is defined as air with *some* water vapor, but less than 100% humidity (the air has water vapor but is *not* saturated).  $M_{\text{air}}$  changes slightly due to the water vapor.
- “**Wet air**” is typically defined as air with 100% humidity (the air is saturated with as much water vapor as it can hold).  $M_{\text{air}}$  changes slightly due to the water vapor.
- The relative humidity of moist air must lie **between 0 and 100%**.  
[ $RH = 0\%$  for dry air.  $RH = 100\%$  for wet air]

**Definition of humidity:**

$$\star \text{ humidity} = P_{H_2O} \quad (\text{= partial pressure } P_j \text{ where species } j = \text{water vapor})$$

**Definition of relative humidity** (we will use  $RH$  but some books use  $\phi$ ):

$$\text{relative humidity} = RH = \frac{P_{H_2O}}{P_{v,H_2O}} \times 100\% = \frac{P_{H_2O}}{P_{\text{sat},H_2O}} \times 100\%$$

where  $P_v =$  vapor pressure =  $P_{\text{sat}}$  = saturation pressure (they are the same thing).

Fluids

look up  $P_v$  or  $P_{\text{sat}}$  in tables

$$P_v = P_{\text{sat}}$$

See Table on website

$$\begin{aligned} P_{\text{sat}} &= \text{fnc}(T) \\ T_{\text{sat}} &= \text{fnc}(P) \end{aligned}$$

$$P_{\text{sat}} \uparrow \text{ as } T \uparrow$$

air holds more water as  $T \uparrow$ 

In words,

$$RH = \frac{\text{actual partial pressure of water vapor} = P_{H_2O}}{\text{maximum possible partial pressure of water vapor at the same } T = P_{\text{sat},H_2O}} \times 100\%$$

or,

$$RH = \frac{\text{actual partial pressure of water vapor} = P_{H_2O}}{\text{partial pressure of water vapor if it were saturated at the same } T = P_{\text{sat},H_2O}} \times 100\%$$

Eg. Denver  $\rightarrow$   $P_{\text{atm}} \approx 82 \text{ kPa} \rightarrow T_{\text{sat}} \approx 94^\circ\text{C} \rightarrow T \text{ e which water boils}$

### Example: Relative Humidity

**Given:** A hot summer day:

- $T = 95.0^\circ\text{F}$  ( $35.0^\circ\text{C}$ ) ←
- $P = 99.6 \text{ kPa}$
- $RH = 90.0\%$  (90% relative humidity)

NOTE: The word "mol" is sometimes used erroneously in this video. For example, "mol fraction" should be written instead as "mole fraction" since "mole" is the name of the unit whereas "mol" is the unit itself. This is analogous to "meter" being the name of the unit and "m" being the unit itself.

**To do:** Calculate the mol fraction of water vapor in the air (in units of PPM).

### Solution:

- Look up saturation pressure of water in thermo table at  $35.0^\circ\text{C}$ .  $P_{v, \text{H}_2\text{O}} = 5.628 \text{ kPa}$ .

- Equation from Eq. Sht:  $RH = \frac{P_{\text{H}_2\text{O}}}{P_{v, \text{H}_2\text{O}}} \times 100\%$

$$P_{\text{H}_2\text{O}} = RH * P_{v, \text{H}_2\text{O}}$$
$$y_{\text{H}_2\text{O}} = \frac{P_{\text{H}_2\text{O}}}{P_{\text{atm}}}$$
$$y_{\text{H}_2\text{O}} = \frac{(RH) P_{v, \text{H}_2\text{O}}}{P_{\text{atm}}}$$

$$y_{\text{H}_2\text{O}} = \frac{(0.900)(5.628 \text{ kPa})}{99.6 \text{ kPa}} = 0.050855 = 50,900 \text{ PPM}$$

Comment:  $\approx 5\%$  by volume of  $\text{H}_2\text{O}$  ( $y_j = \frac{V_j}{V}$ )

$$\text{CO}_2 \quad y_{\text{CO}_2} = 414 \text{ PPM}$$
$$y_{\text{H}_2\text{O}} = 51,000 "$$

### Example: Relative humidity

**Given:** The same hot summer day as in the previous example:

- $T = 95.0^\circ\text{F}$  ( $35.0^\circ\text{C}$ )
- $P = 99.6 \text{ kPa}$
- $RH = 90.0\%$  (90% relative humidity) [we previously calculated  $y_{\text{H}_2\text{O}} = 50,855 \text{ PPM}$ ]
- Now the temperature drops rapidly to  $86.0^\circ\text{F}$  ( $30.0^\circ\text{C}$ )
- At the same time, the pressure drops to  $98.5 \text{ kPa}$

**To do:** Calculate the new relative humidity of water vapor in the air and discuss.

### Solution:

- Look up saturation pressure of water in thermo table at  $30.0^\circ\text{C}$ .  $P_{v, \text{H}_2\text{O}} = 4.246 \text{ kPa}$ .

- Equation from Eq. Sht:  $RH = \frac{P_{\text{H}_2\text{O}}}{P_{v, \text{H}_2\text{O}}} \times 100\%$

Same air  $\rightarrow \therefore y_{\text{H}_2\text{O}}$  does not depend on  $T$  or  $P$

Set  $y_{\text{H}_2\text{O}} = 0.050855$   $(y_j = \frac{P_j}{P})$

$$RH = \frac{P_{\text{H}_2\text{O}}}{P_{v, \text{H}_2\text{O}}} \times 100\% = \frac{y_{\text{H}_2\text{O}} P_{\text{atm}}}{P_{v, \text{H}_2\text{O}}} \times 100\% = \frac{(0.050855)(98.5 \text{ kPa})}{4.246 \text{ kPa}} \times 100\%$$

$$RH = 117.98\% \approx 118\% \quad \times > 100\% !!$$

★ It will rain  $\rightarrow$  correct ans is  $RH = 100\%$