Today, we will:

- Discuss ***relative humidity*** (water vapor in air), and do some example problems
- Begin discussing the classification of air pollutants (CAPS, HAPS, NAAQS, etc.)

Relative Humidity (deals with the amount of water vapor in the air)

$$RH = (\text{some books use } \phi) = \frac{\text{Actual partial pressure of water vapor}}{\text{Partial pressure of water vapor if it were a saturated vapor @ the same } T} \times 100\%$$

$$RH = \frac{P_{H_2O}}{P_{v\,H_2O}} \times 100\%$$

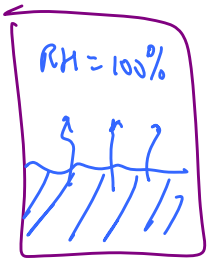
$P_{H_2O} = P_j$ when $j = H_2O$

P_{H_2O} = humidity

P_v used by fluids, P_{sat} used by thermo $\quad P_{sat} = P_v$

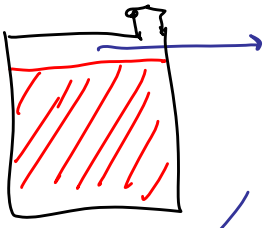
(P_{sat} listed in thermo tables) $\rightarrow$ P_{sat} vs T_{sat}

Note: Liquid water in a container will evaporate until $RH = 100\%$



Same thing is true for any volatile liquid

e.g. acetone in a can



What is the mol fraction of acetone in this air?

We need P_{sat} or P_v @ 20°C $\rightarrow$ Look up MSDS $\Rightarrow$ Vapor Pressure = 180 mm Hg

$$y_j = \frac{P_j}{P} = \frac{180 \text{ mm Hg}}{760 \text{ mm Hg}} = 0.237 \text{ or } 237{,}000 \text{ ppm}$$

Example: Relative Humidity

Given: A hot summer day:

- T = 95.0°F (35.0°C)
- P = 99.6 kPa
- RH = 90.0% (90% relative humidity)

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

Solution:

Look up $P_{sat} = P_v$ @ $T = 35.0°C$ (thermo tables, Internet) etc

See Links tab on website → thermo properties table for water

@ $T = 35°C$, $P_{v_{H_2O}} = P_{sat} = 5.628$ kPa

$RH = \frac{P_{H_2O}}{P_{v,H_2O}}$ → P_{H_2O} = partial pressure of water vapor

$P_{H_2O} = (RH)\, P_{v_{H_2O}}$

∴ $y_{H_2O} = \frac{P_{H_2O}}{P_{atm}}$ → $y_{H_2O} = \frac{(RH)\, P_{v_{H_2O}}}{P_{atm}}$ (× 10^6 to get PPM)

$y_{H_2O} = \frac{(0.900)(5.628\ kPa)}{99.6\ kPa} = 0.050855 = 50{,}900$ PPM

≈ 5% of the air is H_2O

Example: Relative humidity

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

- T = 95.0°F (35.0°C)
- P = 99.6 kPa
- RH = 90.0% (90% relative humidity)

} we had $y_{H_2O} = 50,855$ ppm

- Now the temperature drops rapidly to 86.0°F (30.0°C)
- At the same time, the pressure drops to 98.5 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 °C. $P_{v,\,H2O}$ = 4.246 kPa.

$$RH = \frac{P_{H_2O}}{P_{v\,H_2O}} \times 100\% = \frac{y_{H_2O}\,P_{atm}}{P_{v\,H_2O}} \times 100\%$$

($P_{H_2O} = y_{H_2O}\,P_{atm}$)

Key → y_{H_2O} does not change

$$RH = \frac{(0.050855)(98.5\ kPa)}{4.246\ kPa} \times 100\% = 117.97\% \approx 118\%$$

RH cannot be > 100%!

It will rain

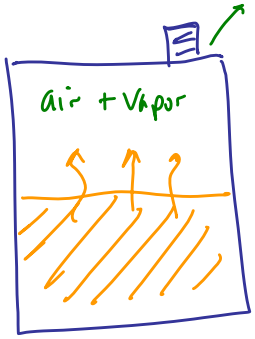
Correct ans → 100%

Example: Partial pressure of a volatile liquid

Given: A half-full can of liquid benzene sits in a storage can for several days at T =20°C and at atmospheric pressure (P = 101.325 kPa = 760 mm Hg).

To do: Calculate the mass fraction of benzene in the air in the can as a percentage.

Solution:



assume not air tight

assume $P \approx P_{atm}$

look up $M_{benzene} = 78.1\ g/mol$

$PV_{benzene} = VP = 75\ mm\ Hg$

The benzene will evaporate until it saturates the air

@ $P_j = P_v = 75\ mm\ Hg$

$$y_j = \frac{P_j}{P} = \frac{P_j}{P_{atm}} \rightarrow \boxed{y_j = 0.098684}$$

recall,

$$f_j = y_j \frac{M_j}{M_t} = \frac{P_j}{P_{atm}} \frac{M_j}{M_t}$$

What is M_t

Simplest approx: $M_t = M_{air} = 28.97\ g/mol$ (ignore the benzene)

$$f_j = \frac{75\ mm\ Hg}{760\ mm\ Hg} \frac{78.1\ g/mol}{28.97\ g/mol} = 0.26684 \approx \boxed{27\% = f_j}$$ Approx

Better method: $M_t = \sum (y_j M_j)$

$$= (0.098684)(78.1) + (1-0.098684)(28.97) = 33.818$$

So, $$f_j = \frac{75}{760} \frac{78.1}{33.818} = 0.227901 \approx \boxed{23\% = f_j}$$

Better method (if sealed container)

estimate that $P \uparrow$ by P_v $\rightarrow$ $P = 760 + 75 = 835$ mm Hg

inside the tank

$$y_j = \frac{75}{835} = 0.089820$$

$$M_t = \sum (y_i M_j) = 33.383 \text{ g/mol}$$

$$f_j = \frac{75}{835}\,\frac{78.1}{33.383} = 0.21014 \rightarrow f_j \simeq 0.21 \text{ or } 21\%$$

Best answer

CLASSIFICATION OF AIR POLLUTANTS

* Know these terms *

- **Primary Pollutant** – Emitted directly from the source

  Eg's: CO (carbon monoxide) from combustion
  NO (nitrous oxide) " " , electrical discharge
  SO_2 (sulfur dioxide) burning coal, volcanic eruptions
  other VOC (volatile organic compound) – paints, gasoline, etc.
  (evaporation of liquids, typically)

- **Secondary Pollutant** – Created in atm from primary sources

  E.g. * $NO + VOC_s \rightarrow NO_2 + \text{other } VOCs + HNO_2 + O_3$

  NO_2: nitrogen dioxide; O_3: Ozone

e.g. Acid Rain → SO_2 is primary pollutant from burning coal.

$2SO_2 + O_2 \rightarrow 2SO_3$ sulfur trioxide

then ↓

(2 step process)

$SO_3 + H_2O \rightarrow H_2SO_4$ → sulfuric acid

↙

gets into rain drops

∴ falls as acid rain

OR

$2SO_2 + 2H_2O + O_2 \rightarrow 2H_2SO_4$ (combined eq.)

EPA is concerned about BOTH primary and secondary air pollutants ✱