35.24 What is the partial pressure of water in atmostpheric air at $120°F$ and 70% RH?

A. $0.3psi$

B. $0.8psi$

C. $1.2psi$

D. $1.7psi$

There are 3 alternative approaches to this problem.

Approach #1: Search for Properties of Saturated Water by temperature and find $120°F$ in the steam table. The saturation pressure at $120°F$ is:

$$p_{ws@120°F} = 1.7psia$$

Since the relative humidity is 70%, the partial pressure of water vapor in the air is only 70% of the saturation pressure. Recall that saturation pressure is the maximum possible pressure water vapor can have in air at a given temperature. Apply the definition of relative humidity to find the partial pressure of water.

$$\phi = \frac{p_w}{p_{ws}}$$

$$p_w = p_{sat}\phi = (1.7psia)\,(.7) = 1.19psia$$

Approach #2: This method involves looking up the dew point temperature on the Psychrometric Chart for High Temperature air. Recall that the dew point is the temperature at which the air would be saturated if it were sensibly cooled until reaching the saturation curve.

$$T_{dp} \approx 107°F$$

Return to the steam table and look up the saturation pressure at the dew point temperature. By definition, the partial pressure of water vapor in moist air is the saturation pressure at the dew point temperature.

$$p_w = p_{ws@T_{dp}} = 1.17psia$$

Approach #3: This method involves looking up the humidity ratio on the Psychrometric Chart for High Temperature air.

$$\omega \approx .055\frac{lb_{H2O}}{lb_{da}}$$

Since the humidity ratio is a ratio of the mass of water vapor to the mass of dry air, it is possible to work out the mole fraction of water vapor in the air. There are $0.055lb_{H2O}$ for every $1lb_{da}$. Find the corresponding number of moles for water and dry air using the molecular weights. Refer to the periodic table as needed. Rounding is permissible.

$$MW_{H20} = (2)\,(1) + (16) = 18\frac{lb}{mol}$$

$$MW_{da} = (2)(14)(.79) + (2)(16)(.21) \approx 29\frac{lb}{mol}$$

Determing the number of moles of water vapor and dry air.

$$N_{H2O} = \frac{0.055lb}{18\frac{lb}{mol}} = 0.00305mol$$

$$N_{da} = \frac{1lb}{29\frac{lb}{mol}} = 0.03448mol$$

Find the mole fraction of water vapor.

$$x_{H2O} = \frac{N_{H2O}}{N_{H2O} + N_{da}} = \frac{0.00305mol}{0.00305mol + 0.03448mol} = .081$$

The ratio of the partial pressure of water vapor to the total pressure is the same as the ratio of the number of moles of water vapor to the total number of moles i.e. the mole fraction. (Note: This holds true for any mixture of gases. The contribution of any one gas in the mixture to the total pressure - its partial pressure - is equal to its mole fraction!)

$$\frac{p_w}{p_t} = x_{H2O}$$

$$p_w = (x_{H2O})(p_t) = (.081)(14.7psia) = 1.19psia$$

Answer C