31.9 A room at atmospheric pressure contains $72°F$ air with 80% relative humidity. What is the mass fraction of nitrogen?

A. 0.36

B. 0.76

C. 0.79

D. 0.82

In a room full of *dry air*, the proportions of oxygen and nitrogen by volume would be 21% and 79%, respectively. In other words, the Mole Fractions would be $x_{O_2} = 0.21$ and $x_{N_2} = 0.79$. However, the presence of water vapor in the room slightly reduces the proportions of oxygen and nitrogen. To find the mole fraction (i.e. percent by volume) of water vapor, use the steam table, Properties of Saturated Water by temperature and obtain the saturation pressure for water at $72°F$.

$$T = 72°F \rightarrow P_{sat@72°F} = 0.39psia$$

Applying the definition or Relative Humidity, the partial pressure of water vapor is 80% of the saturation pressure.

$$\phi = \frac{p_w}{p_{sat}} \rightarrow p_w = \phi p_{sat} = (0.8)\,(0.39psia) = 0.312psia$$

Since the air in the room is at atmospheric pressure, the mole fraction of water vapor can be determined by taking the ratio of the partial pressure of water vapor to the total pressure.

$$x_{h2o} = \frac{p_w}{p_t} = \frac{0.312psia}{14.7psia} = 0.021$$

This result implies that 2.1% of the moles in the room are water vapor. The remaining 97.9% is dry air and will exist in the expected 21% oxygen / 79% nitrogen proportions mentioned earlier. Calculate the mole fractions for oxygen and nitrogen accounting for the presence of water.

$$x_{O_2} = (0.979)\,(0.21) = 0.206$$

$$x_{N_2} = (0.979)\,(0.79) = 0.773$$

Finally, determine the Mass Fraction of nitrogen by multiplying by the atomic weight, and dividing by the sum of the mass of each constituent in the air. Use the Periodic Table as needed to look up atomic weights of oxygen, nitrogen, and water.

$$y_{N_2} = \frac{x_{N_2} M_{N_2}}{x_{N_2} M_{N_2} + x_{O_2} M_{O_2} + x_{h2o} M_{h2o}} = \frac{(0.773)\,(28)}{(0.773)\,(28) + (0.206)\,(32) + (0.021)\,(18)} = 0.756$$

Answer B