Answer on Question #47306 – Chemistry – Inorganic Chemistry

Question

The USEPA assumes that each person breathes 20 cubic meters of air per day. If the air we breathe in has 50% relative humidity at 20 °C, and we breathe it out with 100% relative humidity at 37 °C, how many milliliters of water would we need to drink each day just to replace the water lost by breathing? The vapor pressure of water at 20 °C is 17.5 mmHg and at 37 °C it is 47.1 mmHg. Assume the volume of air breathed in is the same as that breathed out.

Given

$V = 20\ m^3/day$

$\varphi_{in} = 50\%$

$\varphi_{out} = 100\%$

$T_{in} = 20\ ^oC = 293\ K$

$T_{out} = 37\ ^oC = 310\ K$

$e^*_w(20^oC) = 17.5\ mmHg$

$e^*_w\ (37^oC) = 47.1\ mmHg$

$V_w = ?$

Solution

Relative humidity by definition is the ratio of the partial pressure of water vapor (p_w) in the mixture to the equilibrium vapor pressure of water (p^*_w) at a given temperature.

$$\varphi_{in} = \frac{p_w^{in}}{p_w^*(20^oC)}100\%$$

$$\varphi_{out} = \frac{p_w^{out}}{p_w^*(37^oC)}100\%$$

Hence

$$p_w^{in} = \frac{\varphi_{in} \cdot p_w^*(20^oC)}{100\%} = \frac{50\% \cdot 17.5\ mmHg}{100\%} = 8.75\ mmHg = 1167\ Pa$$

$$p_w^{out} = \frac{\varphi_{out} \cdot p_w^*(37^oC)}{100\%} = \frac{100\% \cdot 47.1\ mmHg}{100\%} = 47.1\ mmHg = 6279\ Pa$$

According to ideal gas equation

$$pV = \frac{m}{M}RT$$

where M – molar weight (for water M = 18 g/mol), p – pressure (which should be replaced by partial pressure of water in our case), V – volume, R – ideal gas constant (R = 8.314 J/mol·K), T – absolute temperature.

Mass of water breathed in and out can be calculated from the ideal gas equation. When substituting volume in m^3/day, and molar weight in g/mol, the result is obtained in g/day.

$$m_{in} = \frac{p_w^{in} \cdot V \cdot M}{R \cdot T_{in}} = \frac{1167 \cdot 20 \cdot 18}{8.314 \cdot 293} = 172\ g/day$$

$$m_{out} = \frac{p_w^{out} \cdot V \cdot M}{R \cdot T_{out}} = \frac{6279 \cdot 20 \cdot 18}{8.314 \cdot 310} = 877\ g/day$$

Mass of water lost by breathing each day is

$$m = m_{out} - m_{in} = 877 - 172 = 705\ g/day$$

Volume of water needed to be drunk a day to replace the water lost by breathing

$$V_w = \frac{m}{\rho} = \frac{705}{0.9982} = 706\ ml/day$$

Answer: to replace the water lost by breathing one need to drink **706 ml** of water each day.