Average molecular mass of the air

Molecular mass is defined for a given chemical compound as the mass of one mole of molecules of this compound.

The air is not a chemical compound. The air is a mixture of molecules of chemical elements and of chemical compounds and of atoms of chemical elements. Taking into account only oxygen and nitrogen as the gases of the air occupying 21% and 78% of the air by volume we can define the average molecular weight of molecules of the air as the weighted average

$$M_a = P_{O_2} M_{O_2} + P_{N_2} M_{N_2} \tag{1}$$

where M_a is the average molecular mass of the oxygen and nitrogen of the air, which is approximately equal to the average molecular mass of the air, and P_{O_2} and P_{N_2} are the probabilities of finding the molecule O_2 and the molecule N_2 in the air, M_{O_2} and M_{N_2} are the molecular masses of oxygen and nitrogen, respectively.

We have that

$$P_{O_2} = \frac{n_{O_2}}{n_{O_2} + n_{N_2}} \tag{2}$$

$$P_{N_2} = \frac{n_{N_2}}{n_{O_2} + n_{N_2}} \tag{3}$$

where n_{O_2} and n_{N_2} are the number of moles of oxygen and nitrogen in a given volume of air.

If we separate oxygen from nitrogen from certain volume V of the air, what can be achieved on a gas chromatography column, assuming the approximation that the air contains only oxygen and nitrogen and neglecting the very small amount of other air components, we have

$$\frac{V_{O_2}}{V_{N_2}} = \frac{n_{O_2}}{n_{N_2}} = \frac{21}{78} \tag{4}$$

because the number of moles of the gas is proportional to its volume at any temperature or pressure, what follows from the equation of state of ideal gas, and

$$V = V_{O_2} + V_{N_2} \tag{5}$$

where V_{O_2} and V_{N_2} are the volumes of oxygen and nitrogen separated from the volume V of the air.

We have then

$$P_{O_2} = \frac{n_{O_2}}{n_{O_2} + n_{N_2}} = x_{O_2} = \frac{21g}{21g + 78g} = \frac{21}{99} \tag{6}$$

$$P_{N_2} = \frac{n_{N_2}}{n_{O_2} + n_{N_2}} = x_{N_2} = \frac{78g}{21g + 78g} = \frac{78}{99} \tag{7}$$

where x_{O_2} and x_{N_2} are molar fractions which are proportional to the probabilities P_{O_2} and P_{N_2}.

We can compute the average molecular mass of the air as

$$M_a = P_{O_2} M_{O_2} + P_{N_2} M_{N_2} = \frac{21}{99} * 32g + \frac{78}{99} * 28g = 28.848484g = 29g \tag{8}$$

Sometimes the car tires are being filled with nitrogen instead of with the air. By comparing the molar mass of nitrogen which is equal to 28 grams with the average molar mass of the air which is equal to 29 grams we can see that the tires filled with nitrogen are slightly lighter than the same tires filled with the air. Besides that the lack of oxygen in the compressed nitrogen gas filling the tire prevents the rubber oxidation.

The tires filled with carbon monoxide CO would be approximately of the same weight as the tires filled with nitrogen because the molar masses of carbon monoxide and nitrogen are approximately equal to 28 grams however it is not advised to use the carbon monoxide to fill any tires because CO is poisonous and combustible.

It is interesting to observe what happens with water molecules in water vapour in the air in Earth's atmosphere. The molecular mass of water H_2O is equal to 18 grams per mole. The average molecular mass of the air is 29 grams per mole of oxygen and nitrogen in the air so water vapour will move upwards in the Earth's atmosphere because of buoyancy force and it will form clouds at certain altitude where the low temperature is causing the water vapour to condensate.

Also at normal conditions of temperature of 293 Kelvin degrees and pressure 760 mm Hg 29 grams of air occupies the volume of 22.4 liters and this volume contains the Avogadro number of molecules of oxygen and nitrogen counted together under assumption used in this article that this volume can be separated into two volumes V_{O_2} of oxygen and V_{N_2} of nitrogen in ratio $21 : 78$.

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