A gas of unknown molecular mass was allowed to effuse through a small opening under constant pressure conditions. It required 52 s for 1.0 L of the gas to effuse. Under identical experimental conditions it required 29 s for 1.0 L of O2 gas to effuse. Calculate the molar mass of the unknown gas. (Remember that the faster the rate of effusion, the shorter the time required for effusion of 1.0 L; that is, rate and time are inversely proportional.)

Solution:

It is known that the rate of gas outflow, expressed in moles per liter, is inversely proportional to the square root of the molecular mass of the gas, that is: $Q \sim \frac{1}{\sqrt{M}}$, where Q is the velocity of gas outflow, mol / L; M is the molar mass of the gas, g / mol.

In the condition of the problem, the volumes of the unknown gas and oxygen are equal and amount to 1 liter. Let us find the number of moles of gases under normal conditions, having mastered the unknown gas for X. Then: $n(O_2)=n(X)=\frac{V(gas)}{Vm} = \frac{1}{22.4} = 0.045\ mol.$

The rate of oxygen flow will be: $Q(O_2)=\frac{n(O_2)}{t(O_2)} = \frac{0.045}{29} = 0.0016\ \frac{mol}{s}.$

The rate of expiration of the unknown gas is: $Q(X)=\frac{n(X)}{t(X)} = \frac{0.045}{52} = 0.00086\ \frac{mol}{s}.$

The molar mass of oxygen, $M(O_2)$, is 32 $\frac{g}{mol}$, the molar mass of the unknown gas is M(X). Then:

$0.0016\,\frac{mol}{s} \sim \frac{1}{\sqrt{32}}$

$0.00086\,\frac{mol}{s} \sim \frac{1}{\sqrt{M(X)}}$

Let's square the right and left parts of the proportion, then:

$0.00000256\,\frac{mol}{s} \sim \frac{1}{32}$

$0.0000007396 \sim \frac{1}{M(X)}$

Then: $\frac{1}{M(X)} = \frac{0.0000007396}{0.00000256\times 32}=0.009\,\frac{mol}{g}.$

$M(X)=\frac{1}{0.009} = 111\,\frac{g}{mol}.$

Answer: 111 $\frac{g}{mol}$.

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