

## Gas Flow Notes

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**mole** = gram molecule = weight of a substance in grams numerically equal to its atomic weight  
1 mole of any substance contains Avogadro's number of molecules.

$N_A = 6.062 \times 10^{23}$  molecules/mole

$R$  = gas constant =  $N_A k$  ( $k$  = Boltzmann's constant)

$R = 6.24 \times 10^4$  (Torr  $\text{cm}^3$ )/(mole K)

## General Gas Law

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$$PV = nRT$$

where  $n$  = number of moles

Can divide by time  $t$ :

$$\frac{PV}{t} = \frac{n}{t} RT$$

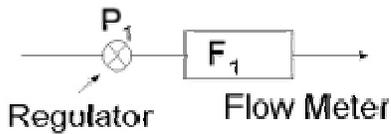
let  $F_v$  = volumetric flow rate

$F_n$  = molar flow rate

$$\text{or } PF_v = F_n RT$$

## For a single gas $G_1$ @ $P_1$ and $T_1$

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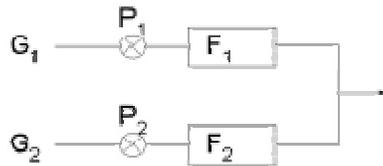


Then

$$F_{n1} = \frac{PF_{v1}}{RT_1}$$

Now, let's mix 2 gases from two separate sources:

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then

$$\frac{P_1 F_{v1} - \frac{F_{n1} T_1}{P_2 F_{v2}} - \frac{F_{n2} T_2}{P_1 F_{v1}}}$$

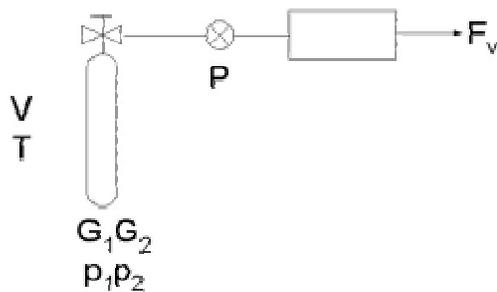
Obviously, you can get sub-cases, e.g. if  $P_1 = P_2$ ,  $T_1 = T_2$  then the volumetric flow ratio = x becomes

$$x = \frac{F_{n1}}{F_{n2}} = \frac{n_1}{n_2}$$

since time will cancel.

Now consider the case of 2 gases that have been premixed and stored in a tank.

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By **Dalton's Law** - the pressure exerted by a mixture of gases is equal to the sum of the pressures each gas would exert if it, alone, occupied the whole volume.

i.e.

$$PV = (p_1 + p_2 + \dots)V$$

Then for the mixed gases:

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$$p_1V = n_1RT$$

$$p_2V = n_2RT$$

$$\frac{P_1}{P_2} = \frac{n_1}{n_2}$$

$$PV = (n_1 + n_2)RT = \left(1 + \frac{n_1}{n_2}\right)n_2RT$$

Then if they are flowing out - can divide by time to get

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$$PF_v = \left(1 + \frac{n_1}{n_2}\right)F_{n_2}RT$$

or

$$PF_v = (1+r)F_{n_2}RT$$

where  $r = \text{molar ratio} = n_1/n_2$

**Example:**

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say we have hydrogen (h) and phosphine (p) in the tank,

$$P_T F_{vT} = (1 + r)F_{np}RT_T$$

or

$$F_{np} = \frac{P_T F_{vT}}{(1+r)RT_T}$$

**Now, in direct contrast to the above, we next consider the case of a vapor *in equilibrium, say with its vapor phase.***

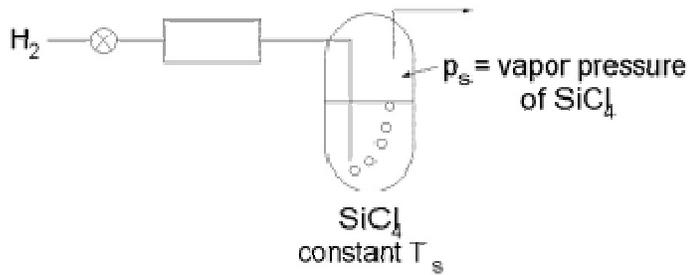
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Usually the ideal gas law does not apply, rather the vapor pressure for a given substance is  $f(T)$  alone. If, however, the pressure is low the ideal gas law may be used, as assumed here.

See  $\text{SiCl}_4$  curves.

**Typical setup:**

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$$p_H V = n_H R T_s \text{ - dividing by } t$$

or

$$p_H F_{vH} = F_{nH} R T_s \text{ - by Dalton's law } V \text{ is the same so } F_v \text{'s are the same.}$$

so

$$p_s F_{vs} = F_{ns} R T_s$$

**Therefore, since the same volume is involved, the volumetric flow rates are the same. Hence:**

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$$\frac{F_{ns}}{F_{vH}} = \frac{p_s}{p_H}$$

But

$$F_{nH} = \frac{p_H F_{vH}}{R T_s}$$

and

$$F_{ns} = \frac{p_H F_{vH}}{R T_s} \frac{p_s}{p_H} = \frac{F_{vH} p_s}{R T_s}$$

Where  $p_s$  is a  $f(T_s)$

All quantities on the RHS are known: therefore,  $F_{ns}$  can be calculated.