1) (a) $\frac{dV}{dt} = \$ \text{ (a constant)}$ $V = \frac{nRT}{P}$, $\frac{dV}{dP} = nRT\left(\frac{-1}{P^2}\right)$

$V = 0.4\,m \times \pi (0.5)^2 = 0.314\ m^3$

$nRT = PV = 1\ \text{bar} \times 0.314\,m^3$

$$\frac{dV}{dP} \cdot \frac{dP}{dt} = \$$$

$$-\frac{nRT}{P^2}\,dP = \$\,dt$$

$$nRT\left[\frac{1}{P_2} - \frac{1}{P_1}\right] = \$(\Delta t)$$

$$\Rightarrow \frac{1\ \text{bar} \cdot 0.314\,m^3}{16.\ m^3/hr}\left[\frac{1}{10^{-3}\,\text{bar}} - \frac{1}{1\ \text{bar}}\right] = \Delta t$$

$\Delta t = 19.6$ hr [because the P_2 is so low] unrealistic

(b) $$-\frac{nRT}{P^2}\,dP = \left(1 - \frac{P}{1050}\right)\$_1\,dt$$

$$-nRT\left(\frac{1}{P^2}\right)\frac{1}{(1 - P/1050)}\,dP = \$\,dt$$

$$-nRT\left(\frac{1}{P} + \frac{\ln[P-1050]}{1050} - \frac{\ln[P]}{1050}\right)\Bigg[_{1\ \text{bar}}^{10^{-3}\,\text{bar}} = 16.\ \frac{m^3}{hr}(\Delta t)$$

$\Delta t \sim 19.6$ hr [essentially the same because P_2 is so low]

(c) $Q = 0.2$ SCFH → std cubic feet per hour

$Q = C(\Delta P)$ need "C" for small tube $\frac{1}{8}$" ID, 1m long

see fig from notes $\frac{Q}{d} = ?$ $Pd = ?$

$$\frac{Q}{d} = \frac{0.2 \text{ atm ft}^3}{1 \text{ hr} \times 3600 \frac{s}{hr}} \times 101325 \frac{Pa}{atm} \times 0.02832 \frac{m^3}{ft^3} \Big/ \frac{1}{8}\text{ inch} \times 0.0254 \frac{m}{in}$$

$$\frac{Q}{d} = \frac{0.1594 \text{ Pa m}^3/s}{3.175 \times 10^{-3} \text{ m}} = 50.2 \text{ Pa m}^2/s$$

$$Pd = 5 \text{ torr} \times \frac{101325 \text{ Pa}}{760 \text{ torr}} \times 3.17 \times 10^{-3} \text{ m} = 667 \text{ Pa} \times 3.175 \times 10^{-3} \text{ m}$$
$$= 2.12 \text{ Pa-m}$$

$$\& \quad L/D = 1 \text{ m} / 3.175 \times 10^{-3} \text{ m} = 315.$$

$\Rightarrow$ viscous flow should be OK from figure ...

$$Q = \left(\frac{\pi d^4}{128 \eta l}\right)\left(\frac{P_1 + P_2}{2}\right)\left(P_2 - P_1\right) \qquad \text{need } \eta \text{ (octane)}$$

$$0.1594 \frac{\text{Pa m}^3}{s} = \frac{\pi (3.175 \times 10^{-3} m)^4}{128 \eta * 1 m * 2} (P_1 + P_2)(P_2 - P_1)$$

$$1.278 \times 10^{11} \frac{Pa}{s} (\eta) = P_2^2 - P_1^2$$

$$P_1^2 = (667 \text{ Pa})^2 - 1.278 \times 10^{11} \frac{Pa}{s} \times \eta$$

if $\eta = 1 \ \mu\text{Pa-s}$

$$P_1^2 = (667)^2 - 1.278 \times 10^5 \text{ Pa}^2$$

$$P_1^2 = 3.17 \times 10^5 \text{ Pa}^2$$

$$P_1 = 563 \text{ Pa}$$

or (4.2 torr)

Vacuum Technology, Gas Flow –4–

MICHIGAN STATE UNIVERSITY

Flow Summary

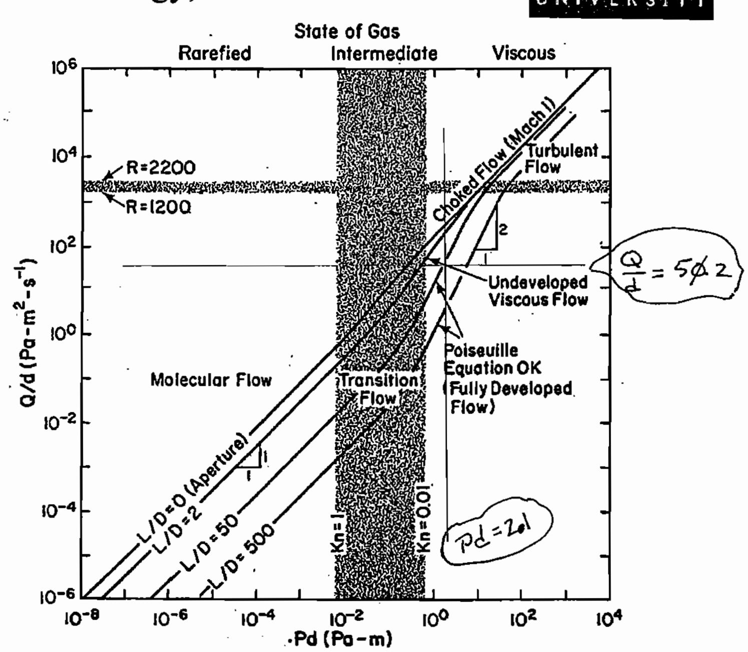
Figure 3.17
O'Hanlon, 2nd Ed.

Figure 3.18
O'Hanlon, 3rd Ed.

Round tube

D

L



(1d) ① $\frac{dE}{dx}$ is low for low atomic numbers $\propto Z^2$ so signal is smaller, closer to threshold

② $\frac{dE}{dx}$ signal much larger for Ca $\sim \left(\frac{20}{6}\right)^2 \approx 10$

but position is determined by charge division at ~~edges~~ center of detector then 2 position signals get $\frac{1}{2}$ of charge, at edges one signal is large $\approx Q$ and the other is small ~ 0

(1e) $Q = \frac{\Delta E}{W} = \frac{1\ \text{MeV} \times 10^6\ \text{eV/MeV}}{29.1\ \text{eV/IP}}$ Table 5.1 α's into CH_4

$Q = 34{,}360$ IP

① need multiplication factor... parallel plate $M = e^{\alpha x}$

② need α $E/p = \frac{500\,\text{V}}{5\ \text{torr}\ 0.3\ \text{cm}} = 333.3 \frac{\text{V}}{\text{cm torr}}$

from fig $\frac{\alpha}{E} \approx 0.01\,\text{V}^{-1}$ $\alpha \sim 5$ /cm

$$C = \frac{A\epsilon_0}{d} = \frac{10 \times 10\ \text{cm}^2\ \epsilon_0}{0.3\ \text{cm}} = 333\,\text{m}\,\epsilon_0 = 333\ \text{m} \times 8.85 \times 10^{-12} \frac{F}{m} = 2.95\,\text{nF}$$

$$V_R = \frac{Q}{C} = \frac{3.436 \times 10^4 \times 1.602 \times 10^{-19}\ \text{coul}\ e^{5 \times 0.3}}{2 \times 2.95 \times 10^{-9}\ F} = 4.18 \times 10^{-6}\ V$$

divide charge

check $RC = 50\,\Omega\ 2.95 \times 10^{-9}\ F = 148.\ \text{ns}$

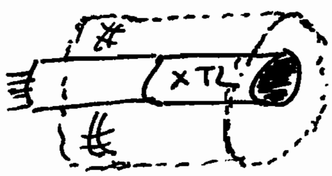
(2) CsF from NIM 179 (1981) 271

light yield is 3-5% of NaI → $0.04 \times 38\text{k} \ \frac{\text{photons}}{\text{MeV}}$

1520 photons/MeV

$$Q = 1.332\ \text{MeV} * \underbrace{0.04 \times 38 \times 10^3}_{\left(\frac{\text{photons}}{\text{MeV}}\right)} * \overset{\text{fraction collected}}{0.25} * \underbrace{0.15}_{\left(\frac{\text{photo-e}}{\text{photon}}\right)} * (4.5)^{10} * q_e$$

$$Q = \underbrace{75.9 * (4.5)^{10}}_{2.59 \times 10^8 \text{ electrons}} * q_e = 41.4 \text{ pcoulomb}$$

(3) 

small inorganic crystal in close Pb shield

↳ ^{40}K 89% β^- to ^{40}Ca ground state (no γ)
11% EC to 1461 keV 2^+ state in ^{40}Ar
↳ one γ ray 1461 keV

- all three processes possible PE, CS, Pair Prod
- small crystal so should have escape peaks
- also have interactions in shield