1. $H \rightarrow$ constant, u (the linear vilocity of the solute) $\rightarrow$ constant.

Then, $T_0 = \frac{H}{u}$ (the time for the solute to travel one plate)

$\underset{\text{constant}}{T_0}$

$N = \frac{t_R}{T_0}$ .... (1)

$N = (\frac{t_R}{\sigma})^2$ .... (2)

Combine (1) and (2). $\frac{t_R}{T_0} = (\frac{t_R}{\sigma})^2 \Rightarrow \sigma = \sqrt{t_R \cdot T^0}$ .... (3)

$$\left.\begin{array}{l} \text{At } t_1,\ \sigma_1 = 1.0S, \text{ then } 1.0S = \sqrt{t_1 \times T^0} \quad \cdots\cdots (4) \\ \text{At } t_2,\ \sigma_2 = 2.0S. \text{ then, } 2.0S = \sqrt{t_2 \times T^0} = \sqrt{(t_1 + 21\,\text{min}) \times T^0} \cdots (5) \\ \text{At } t_3,\ \sigma_3 = ? \quad \text{then } \sigma_3 = \sqrt{(t_1 + 21 + 21\,\text{min}) \times T^0} \cdots\cdots (6) \end{array}\right\} \Rightarrow \sigma_3 = 2.66\,S$$

2. $\sigma = \sqrt{2Dt}$

$$\left.\begin{array}{l} 1.0\text{mm} = \sigma_1 = \sqrt{2Dt_1} \\ 2.0\text{mm} = \sigma_2 = \sqrt{2D(t_1+21)} \\ \sigma_3 = \sqrt{2D(t_1+21+21)} \end{array}\right\} \Rightarrow \sigma_3 = 2.66\text{ mm} \doteq 2.7\text{ mm}.$$

3. $N = (\frac{t_R}{\sigma})^2 = (\frac{2.354 t_R}{W_h})^2 = (\frac{2.354 \times 9\,\text{min}}{2.\,\text{min}})^2 \doteq 112$

$H = \frac{L}{N} = \frac{10\,\text{cm}}{112} = 0.0893\,\text{cm}.$

4.

$$K = \frac{t_R'}{t_m} = \frac{t_R - t_M}{t_M} = \frac{t_R}{t_m} - 1 = \frac{433\,s}{63\,s} - 1 = 5.873$$

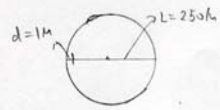
$$k = \underline{K}\frac{V_s}{V_M} \Rightarrow \underline{K} = k \times \frac{V_m}{V_s}$$

$$\frac{V_m}{V_S} = \frac{S_m \times L}{S_s \times L} = \frac{\pi\left(\frac{L-2d}{2}\right)^2 \times L}{\left[\pi\left(\frac{L}{2}\right)^2 - \pi\left(\frac{L-2d}{2}\right)^2\right] \times L} = \frac{(L-2d)^2}{L^2 - (L-2d)^2} \doteq 102.8$$

$$\boxed{\underline{K} = 5.873 \times 102.8 = 603.5}$$

$$k = \frac{T_s(\text{time in stationary phase})}{T_m(\text{time in mobile phase})} \Rightarrow \frac{T_s}{T_s + T_M} = \frac{k}{1+k} = \frac{5.873}{1+5.873} = 85.5\%$$

5.



(1) $t'_{R(benzene)} = t_{R(benzene)} - t_M = 251\,s - 42\,s = 209\,s$

$t'_{R(toluene)} = t_{R(toluene)} - t_M = 333\,s - 42\,s = 291\,s$

$k_{benzene} = \frac{t_R'}{t_M} = \frac{209\,s}{42\,s} = 4.98$

$k_{toluene} = \frac{t_R'}{t_m} = \frac{291\,s}{42\,s} = 6.93$

(2) $\underline{K}_{(b)} = k \cdot \frac{V_s}{V_m} = k_{(b)} \frac{S_m \cdot L}{S_s \cdot L} = k_{(b)} \frac{(L-2d)^2}{L^2 - (L-2d)^2} = 4.98 \times \frac{(250-2\times1)^2}{250^2 - (250-2)^2} = 307.5$

$\underline{K}_{toluene} = k_{(toluene)} \frac{S_m \cdot L}{S_s \cdot L} = 6.93 \times \frac{(250-2\times1)^2}{(250)^2 - (250-2)^2} = 427.9$

(3) $k = \frac{T_s}{T_m} \Rightarrow \frac{T_M}{T_s + T_M} = \frac{1}{1+k}$

for benzene, $\frac{T_M}{T_s + T_M} = \frac{1}{1+4.98} = 16.7\%$

for toluene, $\frac{T_M}{T_s + T_M} = \frac{1}{1+6.93} = 12.6\%$

6.

$$d = \sqrt{2Dt} \;=\; D = \frac{d^2}{2t}, \quad t = \frac{1s}{10^{10}} = 10^{-10}s, \; d = 0.3nm = 3\times10^{-8}cm$$

$$D = \frac{d^2}{2t} = \frac{(3\times10^{-8}cm)^2}{2\times10^{-10}s} = 4.5\times10^{-6}\ cm^2/s$$

7.

$$H = \frac{2D}{u} = \frac{2\times1.24\times10^{-5}cm^2/s}{0.04\ cm/s} = 6.2\times10^{-4}cm$$

8.

$$R = \frac{x_2 - x_1}{4\sigma} \cdots (1) \quad x_2 - x_1 = (u_2 - u_1)\times t = (u_2 - u_1)\times\frac{\bar{L}}{\bar{u}} = \frac{u_2-u_1}{\bar{u}}\times\bar{L} \cdots (2)$$

$\bar{u} = \frac{u_1+u_2}{2}$, and since u_1 and u_2 are constant

$\frac{u_2-u_1}{\bar{u}}$ is constant

At current stage, $x_2 - x_1 = (10.1 - 9.9)\ cm = 0.2\ cm$

$$\bar{L} = \frac{x_2+x_1}{2} = \frac{10.1+9.9}{2} = 10\ cm$$

$$0.2\ cm = \frac{u_2-u_1}{\bar{u}}\times 10\ cm \Rightarrow \frac{u_2-u_1}{\bar{u}} = 0.02 \cdots (3)$$

$$N = \frac{\bar{L}}{H} = \left(\frac{\bar{L}}{\sigma}\right)^2 \Rightarrow \sigma = \sqrt{\bar{L}H} \cdots (4)$$

Combine, (1), (2), (3), and (4) $\quad R = \frac{0.02\times\bar{L}}{4\sqrt{\bar{L}H}} = 0.005\times\sqrt{\frac{\bar{L}}{H}} \Rightarrow \bar{L} = (R^2\times H)/(0.005)^2$

$= 225cm$

9.

$$N = \frac{L}{H} = \left(\frac{L}{\sigma}\right)^2 \Rightarrow \sigma = \sqrt{HL} \Rightarrow$$

$$W_{z_1} = 4\sigma_1 = 4\times\sqrt{HL_1} = 4\times\sqrt{0.01\,cm\times 25\,cm} = 2.0\,cm$$

$$W_{z_2} = 4\sigma_2 = 4\times\sqrt{HL_2} = 4\times\sqrt{0.01\,cm\times 100\,cm} = 4.0\,cm$$

10.

$$k = \frac{t_R'}{t_M} = \left(\frac{t_R}{t_M} - 1\right) = \frac{\frac{L}{u_1}}{\frac{L}{u_0}} - 1 = \frac{U_0}{u_1} - 1,$$

where U_0 is the linear velocity of the flow
u_1 is the linear velocity of the solut.

$$U_0 = 0.04\,cm/s \qquad u_1 = 3\,cm/(3\times 60)\,s = \frac{1}{60}\,cm/s$$

$$k = \frac{u_0}{u_1} - 1 = \frac{0.04\,cm/s}{\frac{1}{60}\,cm/s} - 1 = 1.2$$

$$k = \frac{\text{A mol of solut in stationary phase}}{\text{A mol of solut in mobile phase}} = \frac{A_s}{A_M} \Rightarrow \frac{A_M}{A_s + A_m} = \frac{1}{k+1} = \frac{1}{1.2+1} = 45.5\%$$

$$k = \frac{t_s}{t_M} \Rightarrow \frac{t_s}{t_M + t_s} = \frac{k}{1+k} = \frac{1.2}{1.2+1} = \underline{\underline{54.5\%}}$$

11.

$$H = \nu\frac{2D}{u} \Rightarrow GC,\ H_1 = \nu\frac{2D_1}{u} = 0.60\times\frac{2\times 0.1\,cm^2/s}{2\,cm/s} = 0.06\,cm$$

$$LC,\ H_2 = \nu\frac{2D_2}{u} = 0.6\times\frac{2\times 1\times 10^{-5}\,cm^2/s}{2\,cm/s} = 6\times 10^{-6}\,cm$$

12.

(a) For an open tube, $V_m = \pi r^2 L = \pi \times \left(\frac{150\times10^{-4}\,cm}{2}\right)^2 \times (200\,cm)$

$= 3.93\times10^{-3}\,cm^3$ (or mL)

$u = F(L/V_m) = (0.01\,mL/min)\times(200\,cm/3.93\times10^{-3}\,cm^3)$

$= 509\,cm/min$

$= 8.48\,cm/s$

$R_e = \rho u d_p/\eta$

$= (1.00\,g/cm^3)\times(8.48\,cm/s)\times(50\times10^{-4}\,cm)/0.01$ poise

$= 4.24$

Laminar Flow ($Re < 2100$)

(b) $V_m = \pi r^2 L = \pi \left(\frac{250\times10^{-4}\,cm}{2}\right)^2 (2500\,cm) = 1.23\,cm^3$

$u = F(L/V_m) = (2.\,mL/min)(2500\,cm)/1.23\,cm^3$

$= 4065\,cm/min$

$= 67.8\,cm/s$

$Re = \rho u d_p/\eta = (0.08\,g/cm^3)\times(67.8\,cm/s)\times(250\times10^{-4}\,cm)/0.0002$ poise

$= 680$

Laminar Flow. ($Re < 2100$)

(c)

$V_m = 1.25$ mL

$u = F(L/V_m)$

$= (1\ mL/min)(10 cm)/1.25\ mL$

$= 8.00\ cm/min$

$= 0.133\ cm/s$

$Re = \rho u d_p/\eta = (1.00\ g/cm^3)(0.133\ cm/s)(10\times10^{-4} cm)/0.01 poise$

$= 0.0133$

Laminar Flow ($Re < 1$ for packed bed)

d : $V_m = 0.05$ mL

$u = F(L/V_m) = (10\ mL/min)(2.00\ cm)/(0.05\ mL)$

$= 4\times10^4\ cm/min$

$= 667\ cm/s$

$R_e = \rho u d_p/\eta = (0.08\ g/cm^3)(6.67\times10^2\ cm/s)(50\times10^{-4}\ cm)/(0.002\ poise)$

$= 1333.3$

$Re > 100$. For a packed bed

Turbulent Flow

13.

a.

$$k_1 = \frac{t_{R_1}'}{t_m} = \frac{t_{R_1} - t_m}{0.08\,min} = \frac{10.23\,min - 0.08\,min}{0.08\,min} = 126.9$$

$$k_2 = \frac{t_{R2}'}{t_m} = \frac{t_{R2} - t_m}{t_m} = \frac{(10.41 - 0.08)\,min}{0.08\,min} = 129.1$$

$$\alpha = \frac{k_2}{k_1} = \frac{129.1}{126.9} = 1.018$$

b.

$$N = \left(\frac{t_R}{\sigma}\right)^2 = 16\left(\frac{t_R}{w_b}\right)^2$$

$$N_1 = 16 \times \left(\frac{t_{R_1}}{w_{b_1}}\right)^2 = 16 \times \left(\frac{10.23\,min}{0.15\,min}\right)^2 = 74420.$$

$$N_2 = 16 \times \left(\frac{t_{R_1}}{w_{b_1}}\right)^2 = 16 \times \left(\frac{10.41\,min}{0.18\,min}\right)^2 = 53515$$

$$c = R_s = \frac{t_{R_2} - t_{R_1}}{[w_{b_1} + w_{b_2}]/2} = \frac{10.41 - 10.23}{(0.15 + 0.18)/2} = 1.09.$$

it is not a baseline resolution

d.

$$d = \sqrt{2Dt} \Rightarrow t = d^2/2D = (0.02\,cm)^2/2\,(1\times10^{-1}\,cm^2/s)$$

$$= 0.002\,s$$

14.

$$F = u(V_m/L) = u(\varepsilon_{tot}\pi r^2 L/L)$$
$$= u(\varepsilon_{tot}\pi r^2) \quad \cdots ①$$

$$u = \Delta P B_0/(\varepsilon\eta L) \quad \cdots ②$$

Combining ① and ② gives

$$F = [\Delta P B_0/(\varepsilon_e\eta L)][\varepsilon_{tot}\pi r^2]$$
$$= (\Delta P r^2/L)(B_0\varepsilon_{tot}\pi/\varepsilon_e\eta)$$

Because the packing material is same. B_0, ε_{tot}, ε_e is constant

the mobile phase is same. η is constant.

Thus. $\underset{C}{\underset{\parallel}{(B_0\varepsilon_{tot}\pi/(\varepsilon_e\cdot\eta))}}$ is constant

$$F = (\Delta P r^2/L)\cdot C.$$

(1) When $r = 4.0$ mm, $L = 10$ cm, $F = 1$ mL/min

$$F_1 = (\Delta P r_1^2/L_1)C \Rightarrow 1\ mL/min = [300\ psi \times (4.0\ mm)^2/10\ cm] \times C \cdots ③$$

$$F_2 = (\Delta P r_2^2/L_2)C \Rightarrow F = [300\ psi \times (16\ mm)^2/10\ cm] \times C \cdots ④$$

Combining ③ and ④ $$F = \frac{[[(300\ psi)\times(16\ mm)^2]/10\ cm]\times C}{[[(300\ psi)\times(4.0\ mm)^2)/10\ cm]\times C} \times 1\ mL/min$$

$$= 16\ mL/min$$

(2)

$$\left.\begin{aligned} F_1 &= (\Delta p\, r_1^2/L_1)\,C \\ F_2 &= (\Delta p\, r_2^2/L_2)\times C \end{aligned}\right\}$$

$$\Rightarrow \frac{F_2}{F_1} = \frac{(\Delta p\, r_2^2/L_2)\times C}{(\Delta p\, r_1^2/L_1)\times C} = \frac{r_2^2 L_1}{r_1^2 L_2} \Rightarrow F_2 = \frac{r_2^2 L_1}{r_1^2 L_2}\times F_1 = \frac{(4.00\,mm)^2 \times 10\,cm}{(4.00\,mm)^2\times 100\,cm}\times 1\,mL$$

$$= 0.1\,mL$$

15.

$$H = B/u + Cu$$

$$H = B/u + (C_S + C_M)u$$

$$\left[\frac{2D_m}{u}\right] \qquad \left[\frac{2k}{3(1+k)^2}\right]\left[\frac{d_f}{D_s}\right]u + \left(\frac{1+6k+11k^2}{96(1+k)^2}\right)\left[\frac{d^2}{D_m}\right]u$$

$$u_{opt} = (B/C)^{1/2}$$

The Diffusion Coefficient of a solut is larger in H_2 than that in N_2

$$D_{AB} = \frac{1.00\times 10^{-3}\, T^{1.75}}{P[(\text{Sum}\,v_i)_A^{1/2} + (\text{Sum}\,v_i)_B^{1/2}]}\left(\frac{1}{MW_A}\frac{1}{MW_B}\right),$$ B is gas solvent, A is solute

$D_{A.H_2} > D_{A.N_2}$, The $B_{A.H_2} > B_{A.N_2}$, $C_{A,H_2} < C_{A,N_2}$

Therefore, $u_{opt,H_2} > u_{opt.N_2}$