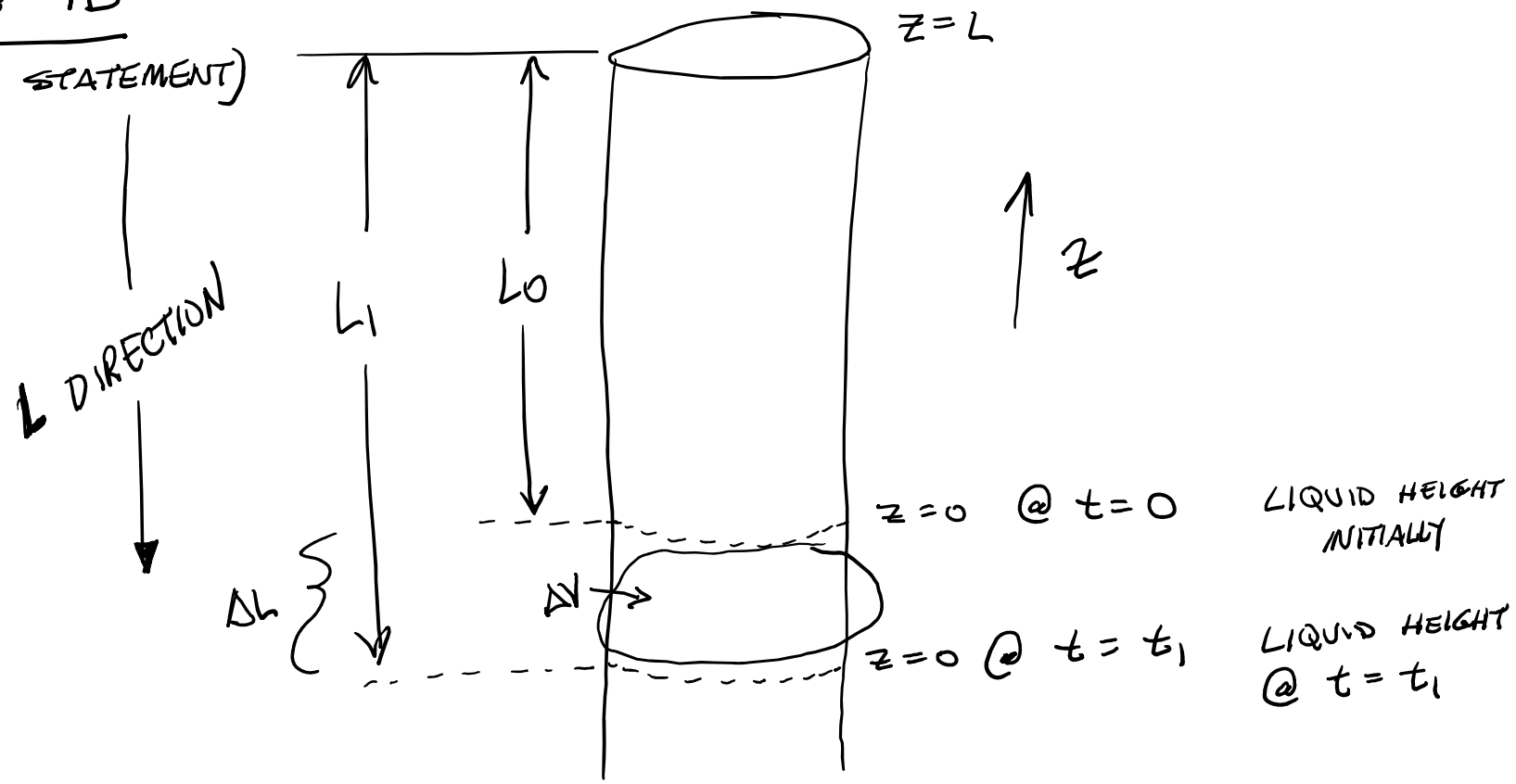
EXAMPLE 1B

(SEE PROBLEM STATEMENT)



MATERIAL BALANCE ON LIQUID: (MOLE)

NOTE THAT THE SIZE OF THE SYSTEM DECREASES WITH TIME DUE TO THE LOWERING OF THE LIQUID LEVEL

$$ACC = IN - OUT + GEN$$

ACCUMULATION: $$\frac{dn}{dt} = \frac{d\left(C_{A(LIQ)} V\right)}{dt} = C_{A(LIQ)} \frac{dV}{dt}$$

$C_{A(LIQ)}$ = CONC OF "A" IN LIQUID, FOR EXAMPLE, MOLAR CONC. OF WATER.

IT IS NOT CONVENIENT TO HAVE A DERIVATIVE AS A FUNCTION OF VOLUME. WE WOULD LIKE TO HAVE A DERIVATIVE IN TERMS OF L.

$$\Delta V = -S\Delta L \quad \Rightarrow \quad dV = -S\,dL$$

AS THE VOLUME DECREASE THE VALUE OF L INCREASES!

$$\text{SO,} \quad C_{A(LIQ)}\frac{dV}{dt} = -C_{A(LIQ)}S\frac{dL}{dt}$$

IN: $\emptyset$

OUT: $S\Phi_A\Big|_{z=0}$

GEN: $\emptyset$

What is $\Phi_A\big|_{z=0} = ?$

FROM EX. 1A:

$$\Phi_A = -\frac{P D_{AB} \ln(1-y_{A0})}{LRT}$$

FOR $z=0$ AND FOR ANY z

$$ACC = IN - OUT + GEN$$

$$-c_{A(LIQ)} S \frac{dL}{dt} = \frac{S P D_{AB} \ln(1-y_{A0})}{LRT}$$

$$-c_{A(LIQ)} \int_{L_0}^{L_1} L\,dL = \frac{P D_{AB} \ln(1-y_{A0})}{RT} \int_0^{t_1} dt$$

VARIOUS TERMS (P, D_{AB}, T, $c_{A(LIQ)}$) DO NOT CHANGE WITH TIME OR LOCATION.

$$-\frac{C_{A(LIQ)}}{2}\left[L_1^2 - L_0^2\right] = \frac{PD_{AB}\ln(1-y_{A0})t_1}{RT}$$

$$\boxed{\frac{C_{A(LIQ)}}{2}\left[L_1^2 - L_0^2\right] = \frac{-PD_{AB}\ln(1-y_{A0})t_1}{RT}}$$

KNOW t_1 & CALCULATE L_1

OR KNOW L_1 & CALCULATE t_1

USE THIS EQUATION

HOW MUCH TIME IS REQUIRED FOR DEPTH TO CHANGE FROM 2.0 cm TO 3.0 cm? FOR ACETONE, ETHANOL, WATER

$P = 760\ mmHg = 1\ atm$

$T = 298K$

$R = 0.08206\ L\ atm/mol\ K$

$L_0 = 2\ cm$

$L_1 = 3\ cm$

$D_{AB} =$

$C_{A(LIQ)} =$

$y_{A0} =$

} DEPENDS ON SPECIFIC CHEMICAL

LIQUID	D_{AB} #1	$C_{A(LIQ)}$ #2	Y_{A0} #3
ACETONE	0.109 cm^2/s (0°C)	13.62 mol/L	0.303
$(0.109)\left(\frac{298}{273}\right)^{3/2}$ →	0.124 cm^2/s (25°C)		
ETHANOL	0.102 cm^2/s (0°C)	17.13 mol/L	0.077
	0.116 cm^2/s (25°C)		
WATER	0.220 cm^2/s (0°C)	55.50 mol/L	0.031
	0.240 cm^2/s (25°C)		

#1 CHEMICAL ENGINEER'S HANDBOOK, PERRY & CHILTON DIFFUSION OF SPECIES IN AIR @ 0°C

$D \propto T^{3/2}$

#2 $$c_{A(LIQ)} = \frac{\rho_A}{M_A} \Rightarrow \frac{0.791\ g/mL}{58.08\ g/mol} \times \frac{1000\ mL}{L} = 13.62\ mol/L$$

#3 AT THE SURFACE THE GAS & LIQUID PHASES ARE IN EQUILIBRIUM. THUS, THE GAS AT SURFACE IS SATURATED WITH THE LIQUID (e.g. 100% rel. humidity).

$$P^*_{ACETONE} = 10^{\wedge}\left[7.11714 - \frac{1210.595}{229.66+25}\right] = 230\ mm\ Hg$$

(25 = Temp)

$$y_{A0} = \frac{230}{760} = 0.303$$

Acetone $t_1 = 18600\,s = 5.17\,h$

Ethanol $t_1 = 112700\,s = 31.3\,h$

Water $t_1 = 448700\,s = 125\,h$ (5.2 days)