Homework & quiz

- Read pages 115-116
- Solve 5.1, 5.2, 5.3 and 5.6
- Quiz on Saturday, 25 Jan 2014 (?tentatively?)

Example 5.1

Illustration 5.1 A wetted-wall absorption tower, 1 in (2.54 cm) ID, is fed with water as the wall liquid and an ammonia-air mixture as the central-core gas. At a particular level in the tower, the ammonia concentration in the bulk gas is 0.80 mole fraction, that in the bulk liquid 0.05 mole fraction. The temperature = 80°F (26.7°C), the pressure 1 std atm. The rates of flow are such that the local mass-transfer coefficient in the liquid, from a correlation obtained with dilute solutions, is $k_L = 0.34$ mol/ft$^2 \cdot$ h $\cdot$ (lb mol/ft^3) $= 2.87 \times 10^{-5}$ kmol/m$^2 \cdot$ s $\cdot$ (kmol/m^3), and the local Sherwood number for the gas is 40. The diffusivity of ammonia in air $= 0.890$ ft^2/h $= 2.297 \times 10^{-5}$ m^2/s. Compute the local mass-transfer flux for the absorption of ammonia, ignoring the vaporization of water.

$$N_A = \frac{N_A}{\Sigma N} F_G \ln \frac{N_A/\Sigma N - y_{A,i}}{N_A/\Sigma N - y_{A,G}} = \frac{N_A}{\Sigma N} F_L \ln \frac{N_A/\Sigma N - x_{A,L}}{N_A/\Sigma N - x_{A,i}}$$

$$\frac{N_A/\Sigma N - y_{A,i}}{N_A/\Sigma N - y_{A,G}} = \left(\frac{N_A/\Sigma N - x_{A,L}}{N_A/\Sigma N - x_{A,i}} \right)^{F_L/F_G}$$

Liquid

$$\frac{N_A/\Sigma N - y_{A,i}}{N_A/\Sigma N - y_{A,G}} = \left(\frac{N_A/\Sigma N - x_{A,L}}{N_A/\Sigma N - x_{A,i}}\right)^{F_L/F_G}$$

Table 3.1 Relations between mass-transfer coefficients

Rate equation		
Equimolal counterdiffusion	Diffusion of A through nondiffusing B	Units of coefficient
$N_A = k'_L \Delta c_A$	$N_A = k_L \Delta c_A$	$\frac{\text{Moles transferred}}{(\text{Area})(\text{time})(\text{mol/vol})}$
$N_A = k'_x \Delta x_A$	$N_A = k_x \Delta x_A$	$\frac{\text{Moles transferred}}{(\text{Area})(\text{time})(\text{mole fraction})}$
Conversions: $F = k_x x_{B,M} = k_L x_{B,M} c = k'_L c = k'_L \frac{\rho}{M} = k'_x$		

$c = 1000/18 = 55.5 \text{ kmol/m}^3$

$$F_L = (2.87 \times 10^{-5})(1.0)(55.5) = 1.590 \times 10^{-3} \text{ kmol/m}^2 \cdot \text{s}$$

Gas

$$d = 0.254 \text{ m}$$

$$\text{Sh} = \frac{F_G d}{c D_A} = 40$$

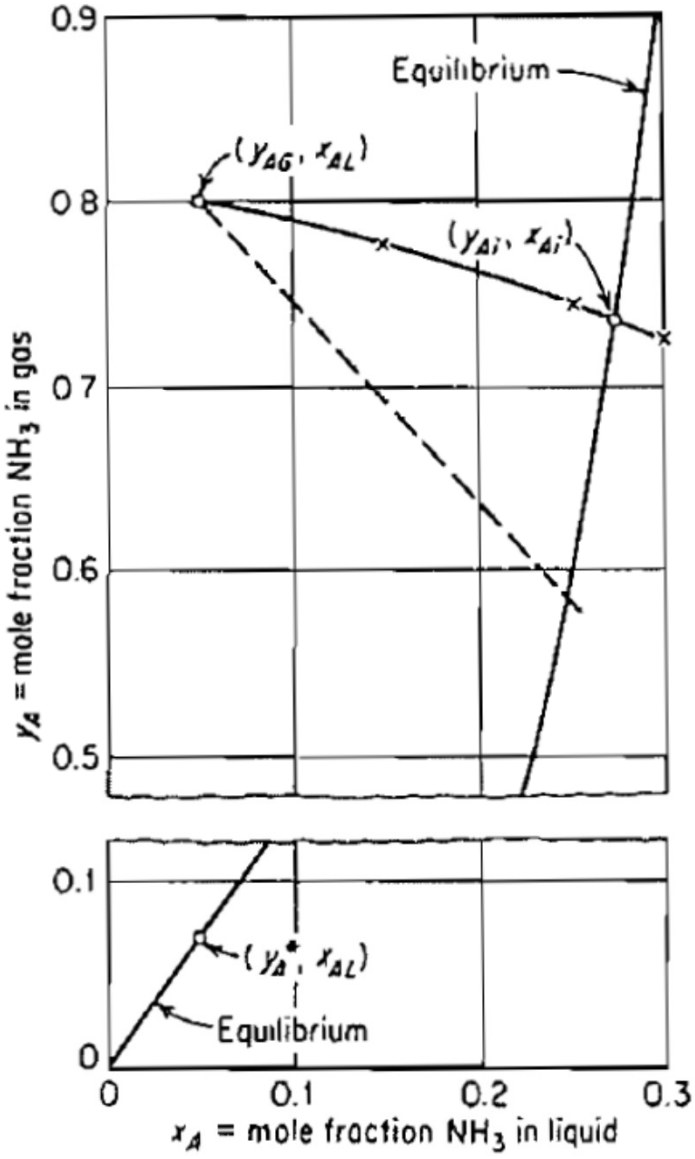
$$c = \frac{1}{22.41} \frac{273}{273 + 26.7} = 0.04065 \text{ kmol/m}^3$$

$$D_A = 2.297 \times 10^{-5} \text{ m}^2/\text{s}$$

$$F_G = \frac{40 c D_A}{d} = \frac{40(0.04065)(2.297 \times 10^{-5})}{0.0254} = 1.471 \times 10^{-3} \text{ kmol/m}^2 \cdot \text{s}$$

Equilibrium data

NH_3 mole fraction x_A	NH_3 partial pressure, lb_f/in^2	NH_3 partial pressure, $N/m^2 = \bar{p}_A$	$y_A = \bar{p}_A / 1.013$
0	0	0	0
0.05	1.04	7 171	0.0707
0.10	1.98	13 652	0.1347
0.25	8.69	59 917	0.591
0.30	13.52	93 220	0.920



Mass transfer flux

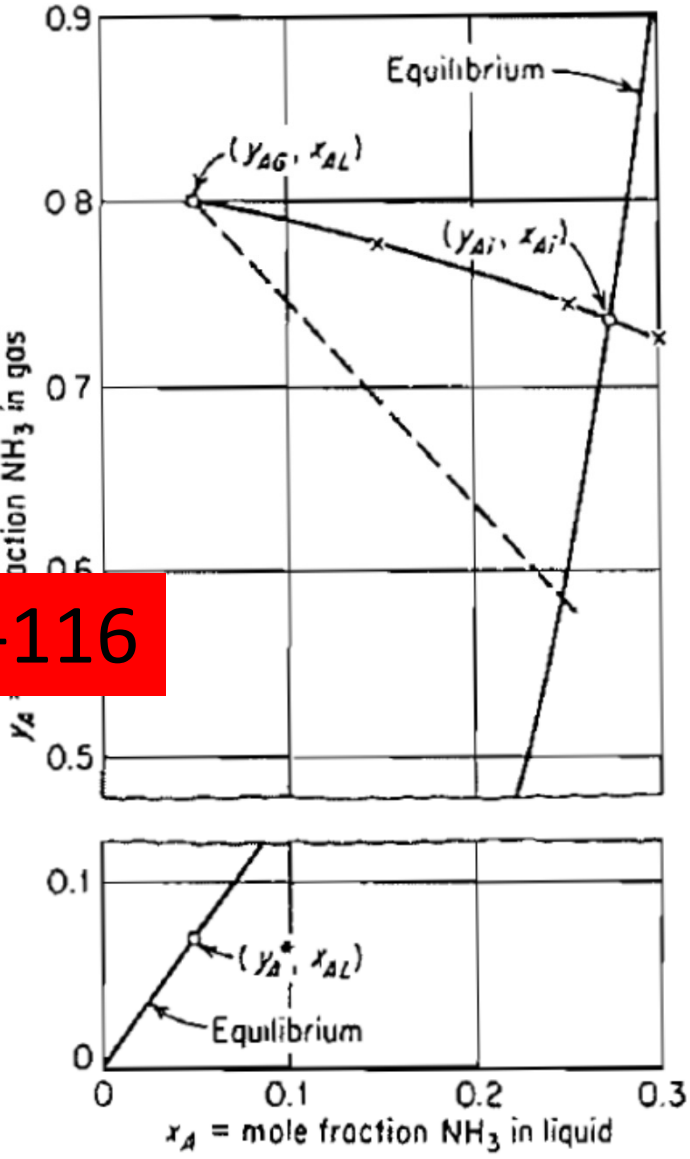
$$\frac{N_A/\Sigma N - y_{A,i}}{N_A/\Sigma N - y_{A,G}} = \left(\frac{N_A/\Sigma N - x_{A,L}}{N_A/\Sigma N - x_{A,i}}\right)^{F_L/F_G}$$

$$y_A = 1 - (1 - y_{A,G})\left(\frac{1 - x_{A,L}}{1 - x}\right)^{F_L/F_G}$$

Read pages 115-116

$$x_{A,i} = 0.274, y_{A,i} = 0.732$$

$$N_A = 1(1.590 \times 10^{-3}) \ln \frac{1 - 0.05}{1 - 0.274}$$



$= 4.30 \times 10^{-4}$ kmol NH_3 absorbed/$m^2 \cdot s$, local flux

Homework & quiz

- Read pages 115-116
- Solve 5.1, 5.2, 5.3 and 5.6
- Quiz on Saturday, 25 Jan 2014 (?tentatively?)

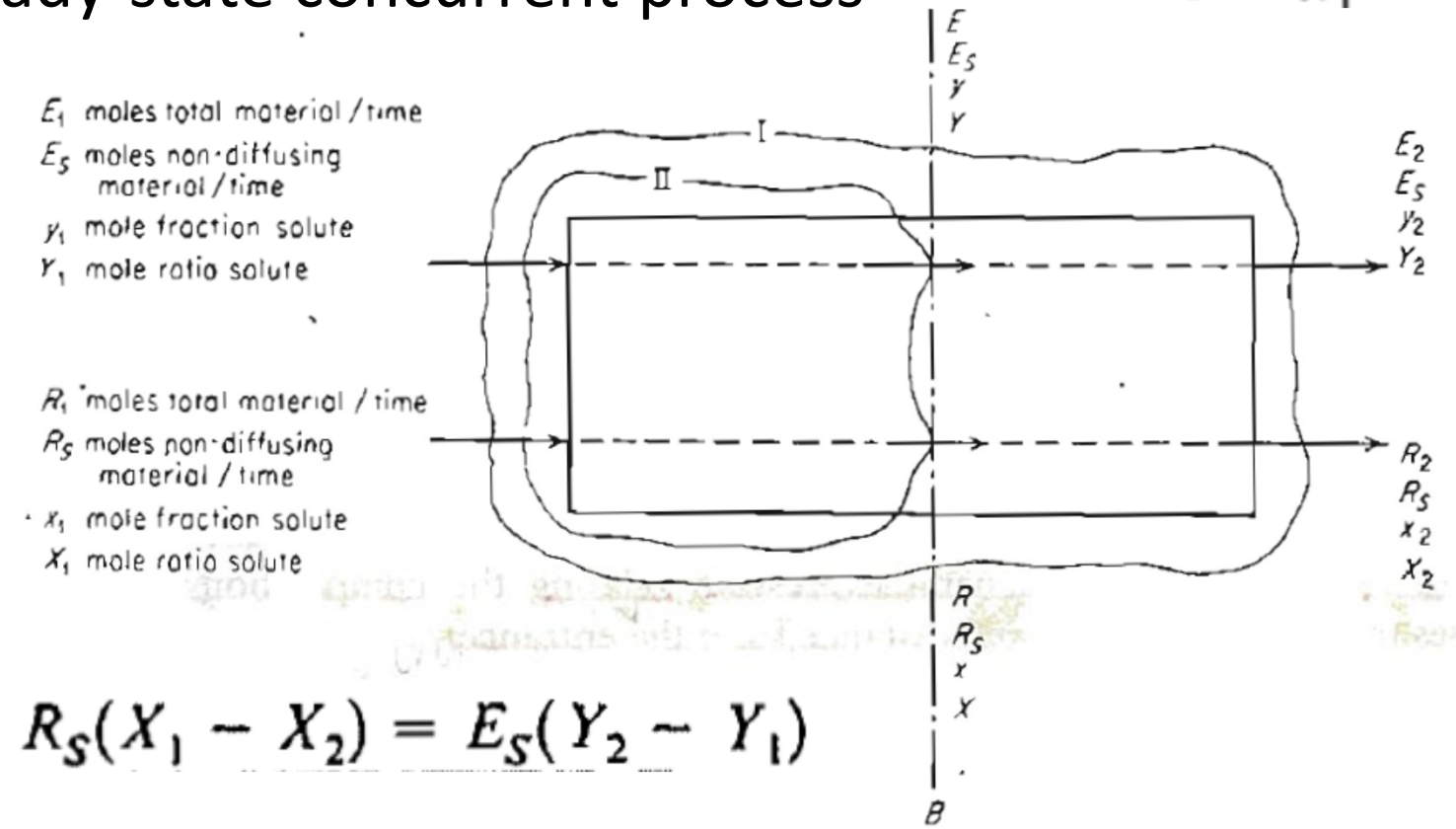
Operating line

$$R_1x_1 + E_1y_1 = R_2x_2 + E_2y_2$$

$$R_1x_1 - R_2x_2 = E_2y_2 - E_1y_1$$

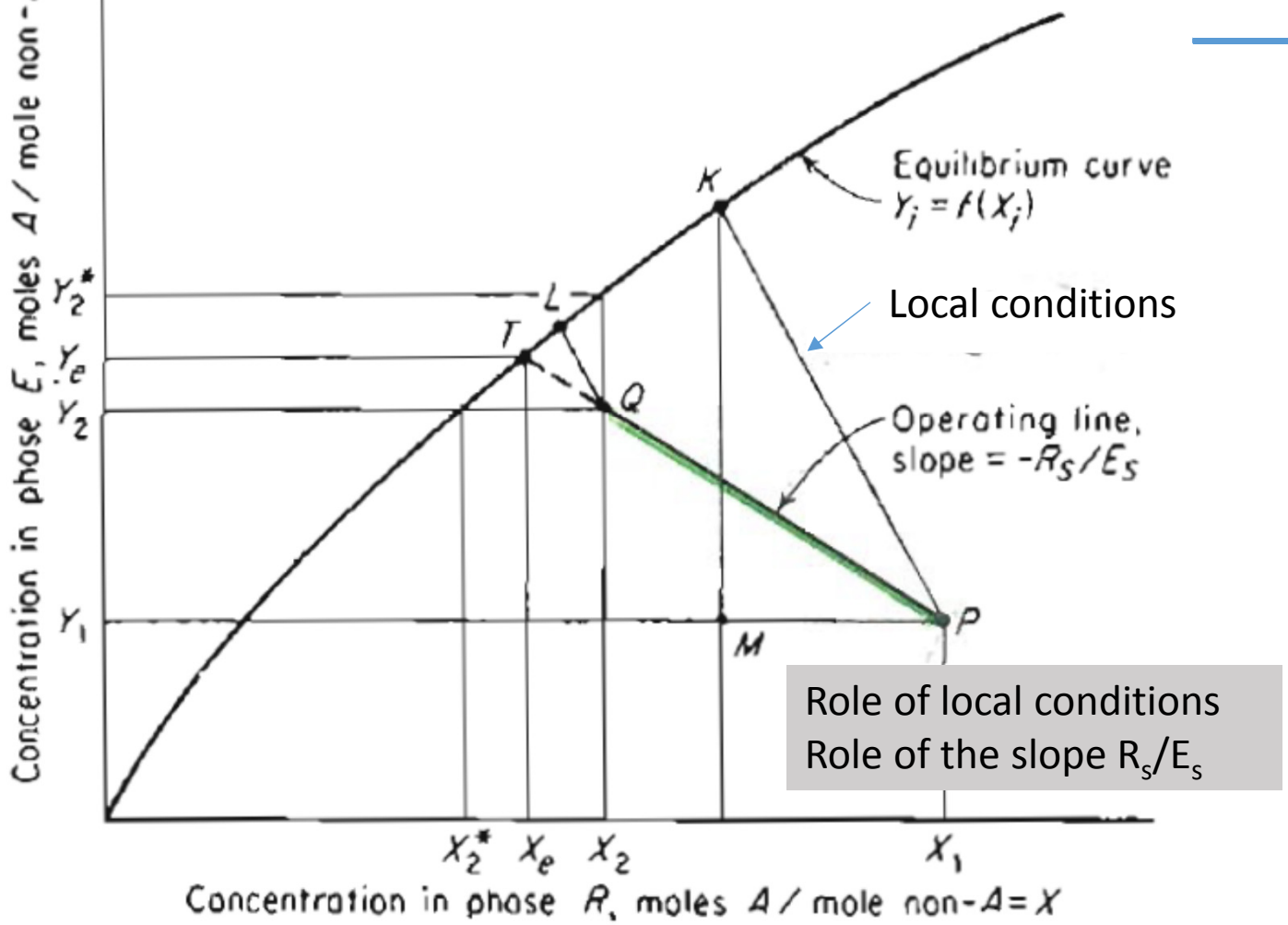
$$R_1x_1 = R_S\frac{x_1}{1-x_1} = R_SX_1$$

- Steady-state concurrent process



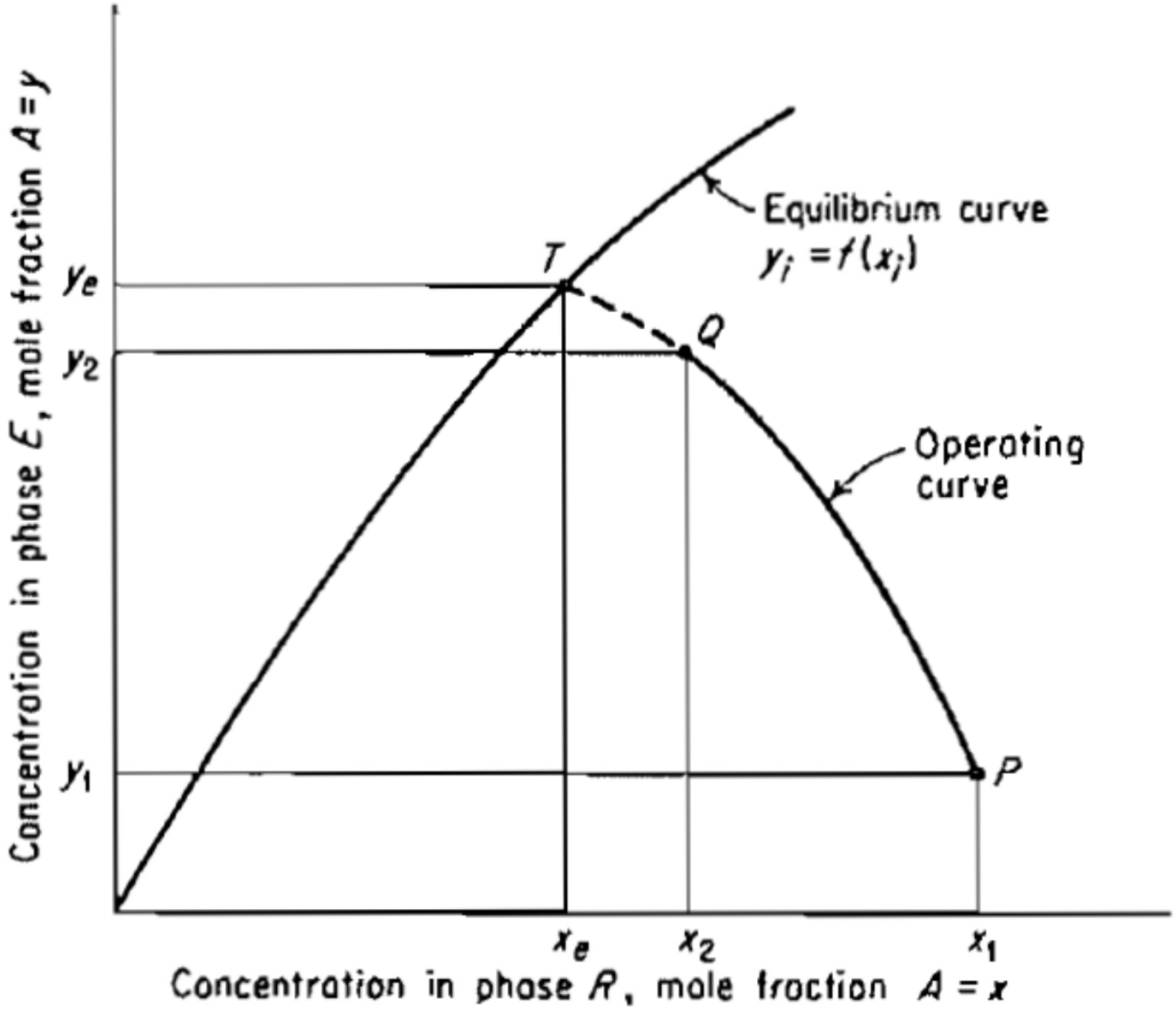
$$R_S(X_1 - X_2) = E_S(Y_2 - Y_1)$$

$$R_S(X_1 - X_2) = E_S(Y_2 - Y_1)$$



Role of local conditions
Role of the slope R_s/E_s

Transfer from phase R to E


Concentration in phase E, mole fraction A = y
Concentration in phase R, mole fraction A = x
Equilibrium curve
$y_i = f(x_i)$
Operating curve
T
Q
P
y_e
y_2
y_1
x_e
x_2
x_1