## Modelling of processes – Multicomponent flash distillation

### Derivation of Rachford-Rice equation

Assuming both the temperature and the pressure in the drum are known, only the mole balances and the equations for the liquid-vapour equilibrium are needed to describe the process of flash distillation (there is no need for the enthalpy balance).

$$\dot{n}_V + \dot{n}_L = \dot{n}_F \tag{1}$$

$$y_i \dot{n}_V + x_i \dot{n}_L = z_i \dot{n}_F \qquad i = 1, \ldots, n \tag{2}$$

$$y_i = K_i\, x_i \qquad i = 1, \ldots, n \tag{3}$$

$$\sum_{i=1}^{n} x_i = 1 \tag{4}$$

$$\sum_{i=1}^{n} y_i = 1 \qquad , \tag{5}$$

where $K_i = K_i(t, p)$ are distribution coefficients of individual components depending on the drum temperature and pressure. Let us define a parameter $a$ as the fraction of the vapour phase to the feed

$$a \equiv \frac{\dot{n}_V}{\dot{n}_F}, \tag{6}$$

and substitute it together with the balance (1) into the component balance (2). Then one obtains

$$a y_i + (1 - a) x_i = z_i$$

Substitute for $y_i$ from the equilibrium eqaution (3)

$$a K_i x_i + (1 - a) x_i = z_i$$

and after modification

$$x_i = \frac{z_i}{a(K_i - 1) + 1}$$

$$y_i = \frac{z_i K_i}{a(K_i - 1) + 1}.$$

Now subtracting the equation (4) from (5)

$$\sum_{i=1}^{n} y_i - \sum_{i=1}^{n} x_i = 0$$

$$\sum_{i=1}^{n} (y_i - x_i) = 0$$

and substituting for $x_i$ and $y_i$ from previous equations, one finally obtains a Rachford-Rice equation

$$\sum_{i=1}^{n} \frac{z_i(K_i - 1)}{a(K_i - 1) + 1} = 0. \tag{7}$$

The advantage of Rachford-Rice equation becomes clear if the feed composition $z_i$ is known (most of the practical applications). Set of equations (1–5) is replaced by a single equation (7) with only one uknown – fraction $a = \dot{n}_V / \dot{n}_F$. After its value is obtained, the remaining uknowns can be easily calculated from explicit formulas.