2.6 Phase separation and fractional distillation

Phase separation as found for the $p-x$ diagrams exists for the $T-x$ phase diagrams as well. Fig. 2.8 illustrates typical phase diagrams with a phase separation between the liquid and vapor phase. In a simple distillation the vapor is withdrawn and condensed. This technique is used to separate a volatile liquid from a non volatile solute or liquid. To separate two volatile liquids with a phase diagram as shown in Fig. 2.8 fractional distillation is used, i.e. the boiling and condensation cycle is repeated successively. In each cycle the vapor is richer in the more volatile component. The number of theoretical plates characterizes the effort needed for a separation of the liquids and the fractionating column must be designed to correspond to this number of theoretical plates.

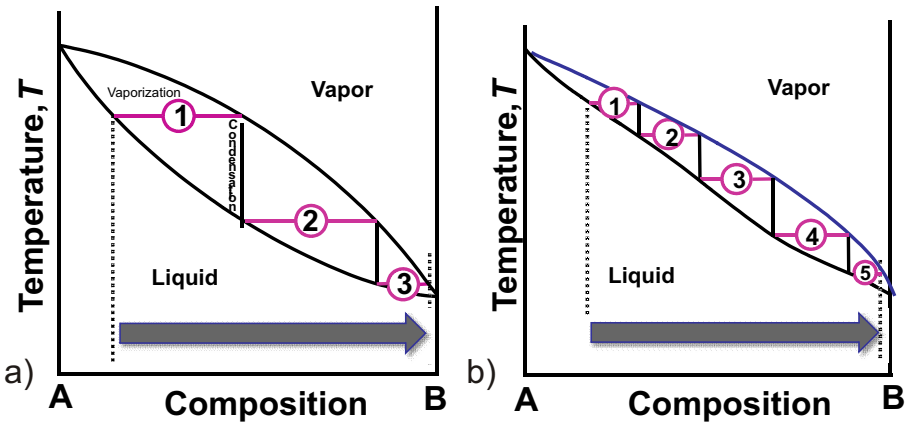

Figure 2.8: T-x phase diagrams for illustrating fractional distillation, i.e. the effect of ideal behavior for cyclic boiling / condensing.

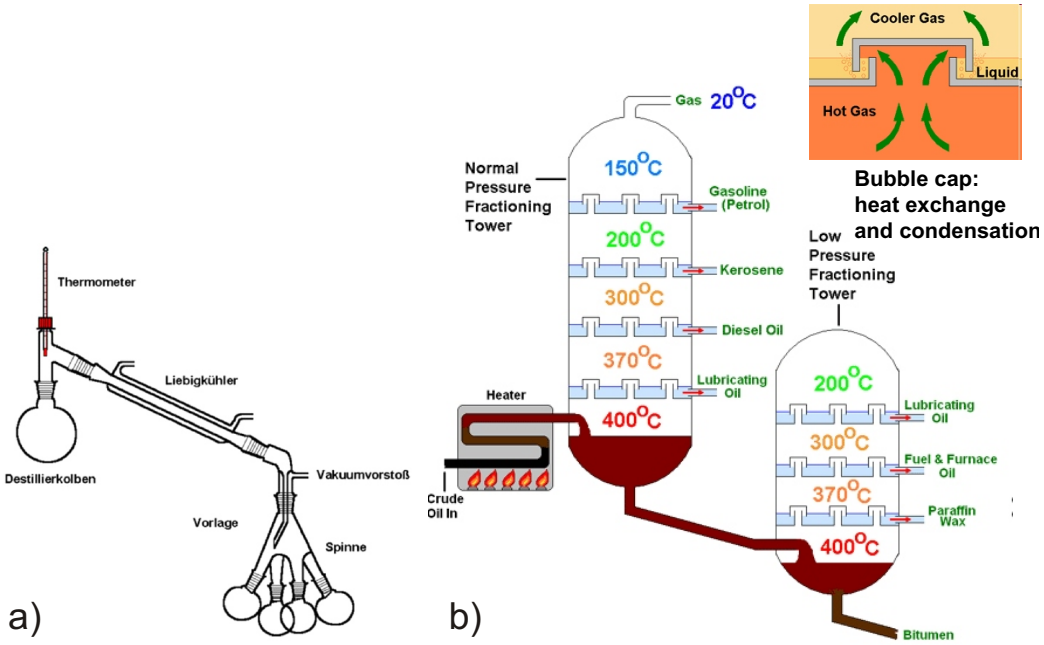

Figure 2.9: Examples of fractional distillation: a) discontinuous process in the lab; b) continuous fractional distillation of crude oil.

Examples for fractional distillation in lab and industry are shown in Fig. 2.9. For the lab setup careful heating is mandatory. When boiling of one component starts, no increase of T occurs, but condensation in the Liebig-condenser. The fractional distillation of crude oil needs for a large number of theoretical plates and thus a complicated arrangement of the fractionating column. The inside of a fractional-distillation column consists of a set of perforated trays with vertical temperature gradient. Each perforation is fitted with a device called a bubble

cap, which forces the oil vapor coming up through the tray to bubble through the liquid sitting on the top of the tray. As heat is transferred from the vapor to the liquid during bubbling, some of the heavier hydrocarbons in the vapor condense (liquefy). Meanwhile, vapor with lighter hydrocarbons moves up to the next tray, where the same process takes place. The amount of liquid on each tray increases as some of the hydrocarbons are removed from the rising vapor. Excess liquid overflows to the next lower tray through a down-comer. At several levels in the column, liquid is drawn off–lighter products from the top of the column and heavier products from the bottom. Note that not only temperature but pressure differences are used the separate the various components of crude oil.