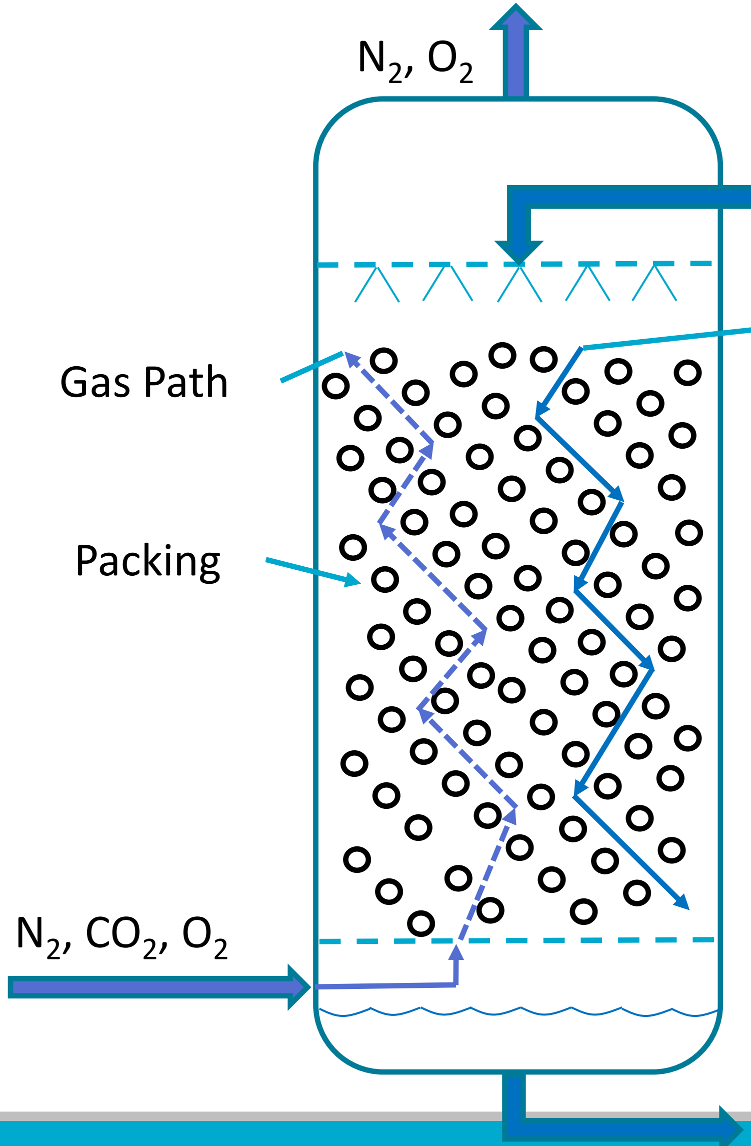
The physical process

- Gas-liquid contacting
- Mass transfer in packed columns
- CO_2 stripping

Gas-liquid contacting: PACKED COLUMNS

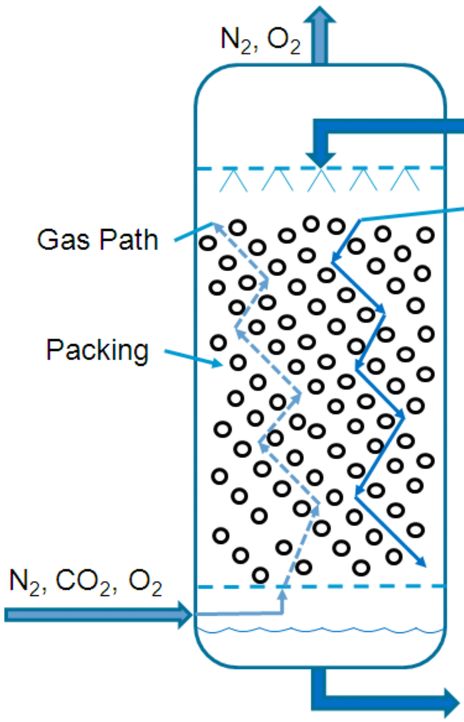


Random Packing

Structured Packing

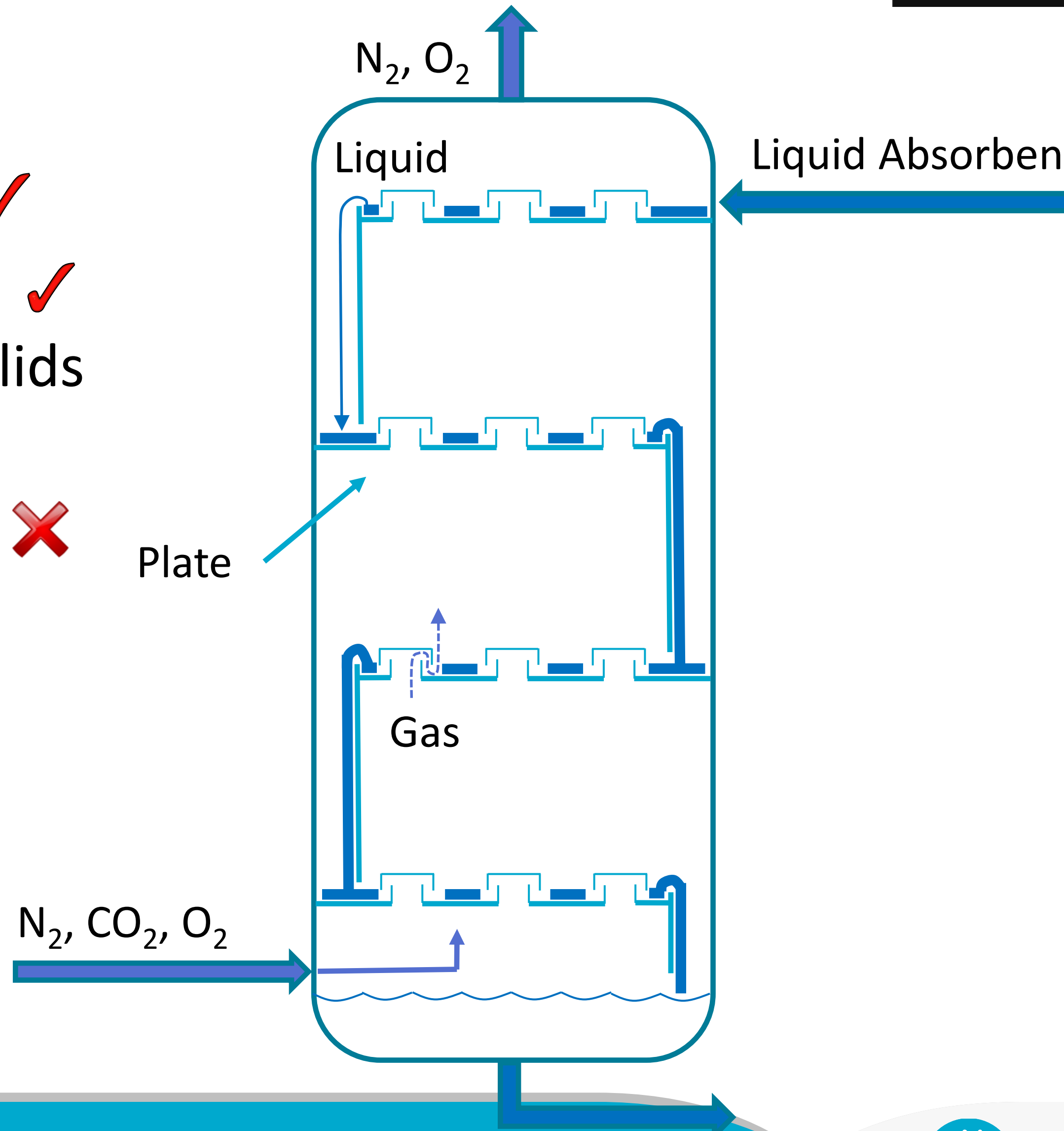
Gas-liquid contacting: PACKED COLUMNS

- Packing provides the contact area ✓
- Low liquid hold-up ✓
- Low gas-side pressure drop ✓
- Moderate liquid residence time ✓
- Not suitable for liquids with solids present ✗



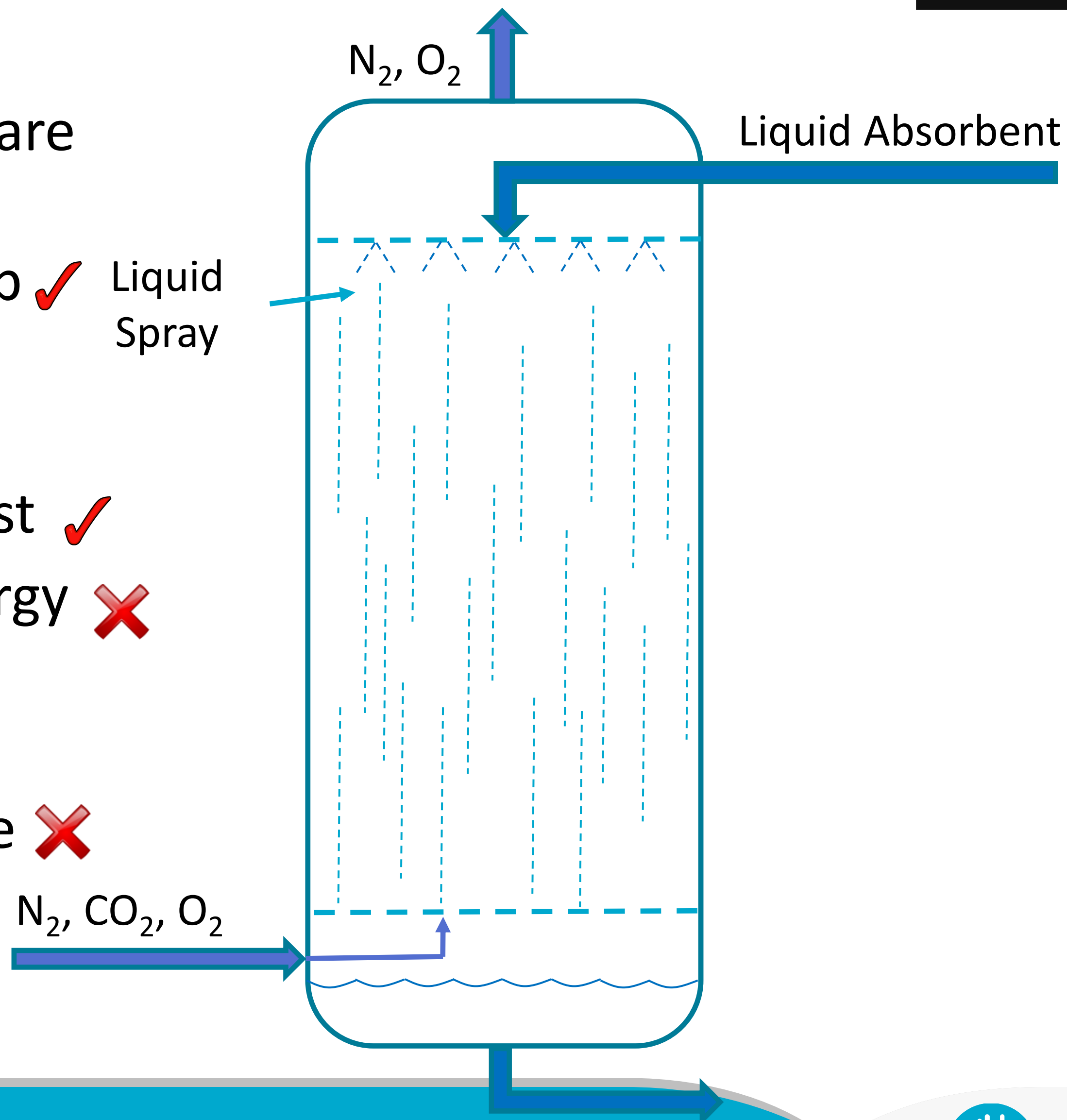
Gas-liquid contacting: PLATE COLUMNS

- Long residence time and complete mixing on plates ✓
- Intermediate liquid hold-up ✓
- Can work for liquids with solids present ✓
- High gas-side pressure drop ✗
- High capital cost ✗



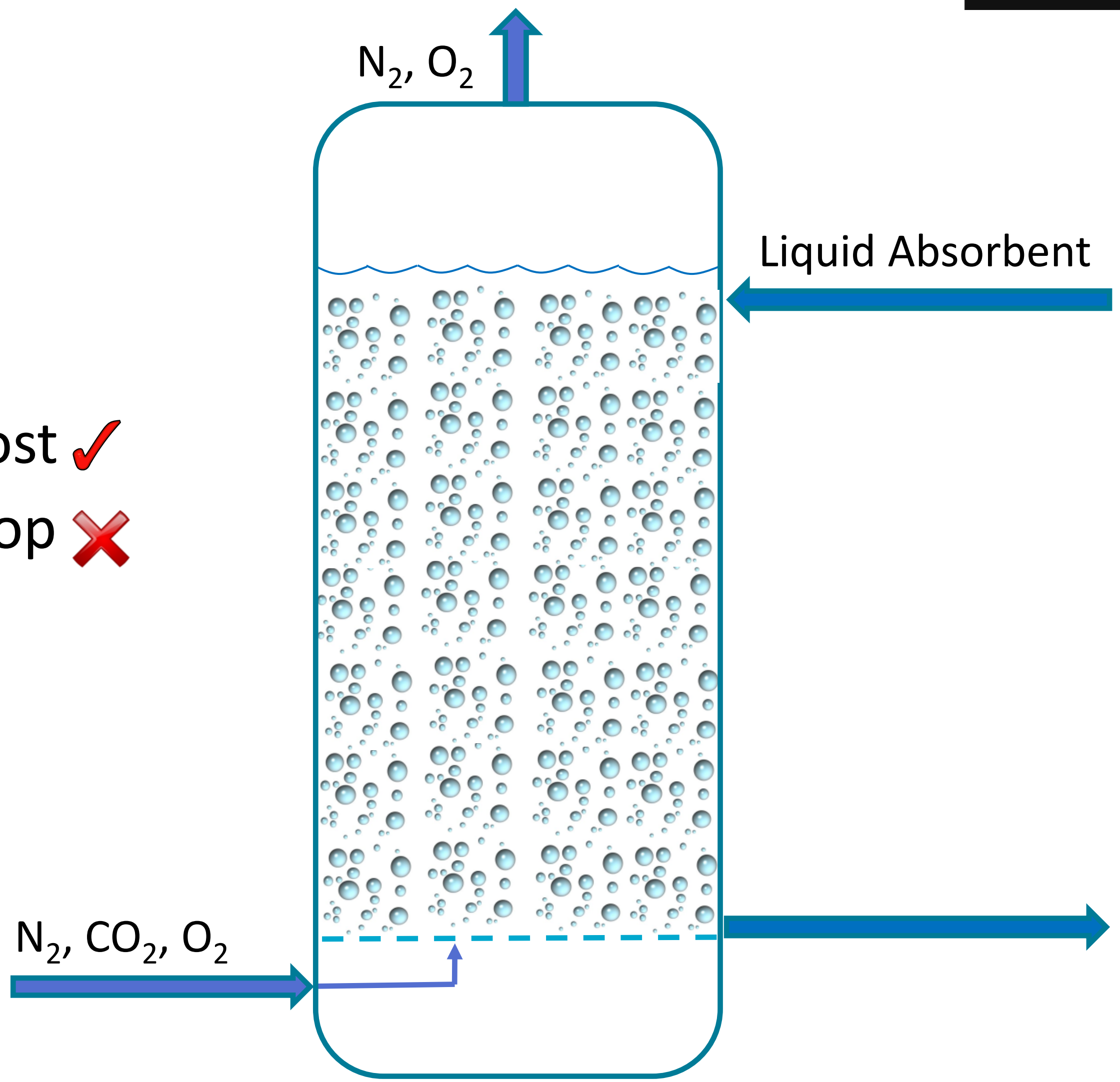
Gas-liquid contacting: SPRAY COLUMNS

- The liquid and gas phases are dispersed
- Low gas-side pressure drop ✓
- Suitable for liquids with solids present ✓
- Simple with low capital cost ✓
- Spray formation costs energy ✗
- Liquid can be entrained in gas outlet ✗
- Short liquid residence time ✗



Gas-liquid contacting: BUBBLE COLUMNS

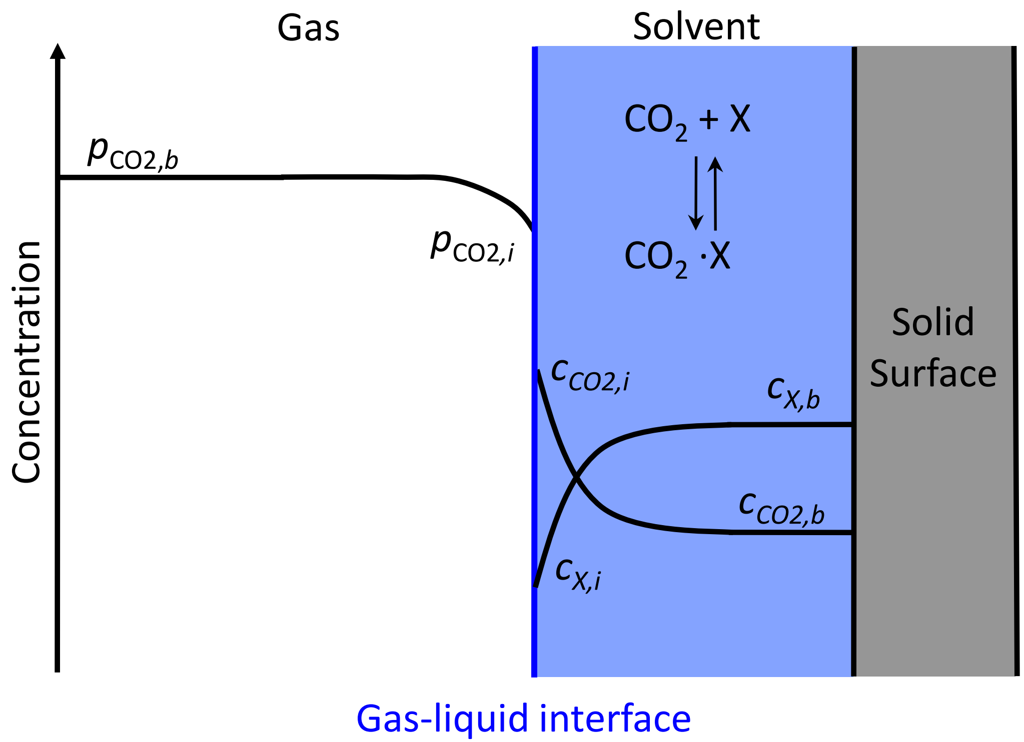
- Large liquid hold-up and long residence time ✓
- Suitable for liquids with solids present ✓
- Simple with low capital cost ✓
- High gas-side pressure drop ✗
- Bubble coalescence ✗



Gas-liquid contacting: SUMMARY

- For post-combustion capture using a chemical absorbent:
  - **Packed columns are favoured due to the low pressure drop and large mass transfer area**
  - Spray columns are also considered due to their simplicity and low cost
- For pre-combustion capture with a physical or chemical absorbent:
  - **Either packed or plate columns can be used due to the sufficient driving force of the high pressure gas stream**
  - Spray columns are not suitable due to liquid entrainment
- Bubble columns are used for gas absorption involving slow reactions and the high pressure drop makes the unattractive for CO_2 capture

Mass transfer in packed columns



Gas-side mass transfer - diffusion

- As the gases in flue gas are unreactive diffusion controls mass transfer on the gas side
- Fick's First and Second Laws:

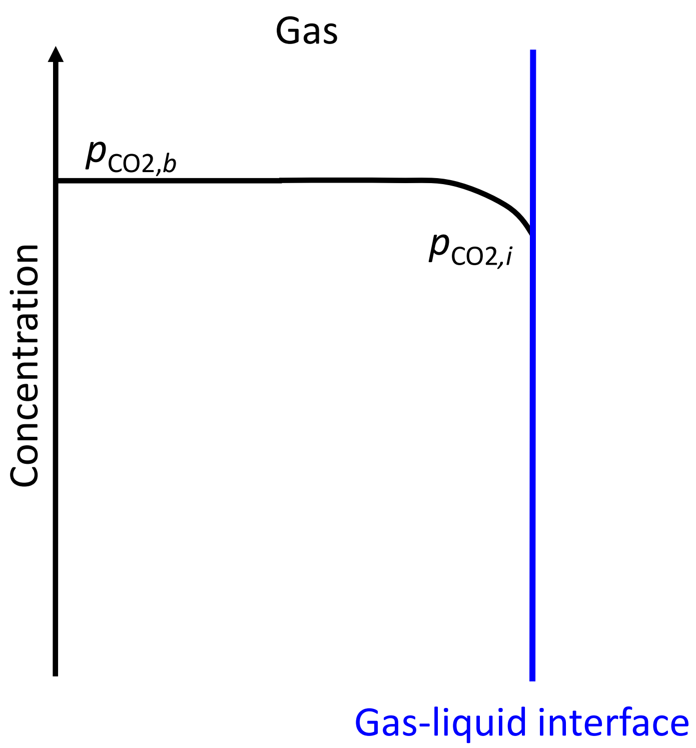
Steady-state (1st law)

$$N_{CO2} = D_{CO2}\frac{\partial c_{CO2}}{\partial x}$$

$$N_{CO2} = k_g(p_{CO2,b} - p_{CO2,i})$$

$$\frac{\partial c_{CO2}}{\partial t} = \frac{\partial}{\partial x}(D_{CO2}\frac{\partial c_{CO2}}{\partial x})$$

Dynamic (2nd law)



Liquid-side mass transfer – diffusion and reaction

- In the liquid phase both diffusion and reaction controls mass transfer
- Fick's First and Second Laws:

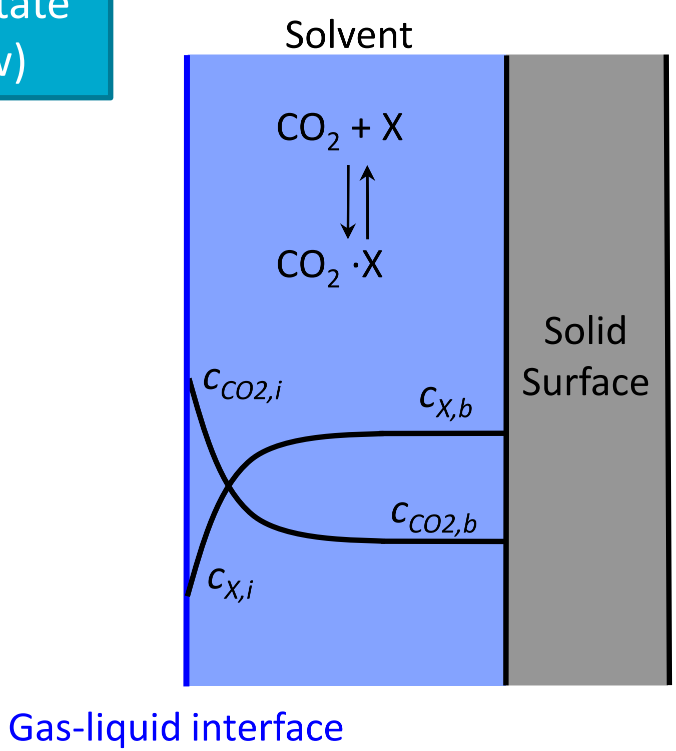
Steady-state (1st law)

$$N_{CO2} = k_l(c_{CO2,i} - c_{CO2,b})$$

$$\frac{\partial c_{CO2}}{\partial t} = D_{CO2}\frac{\partial^2 c_{CO2}}{\partial x^2} + r$$

$$r = k_f c_{CO2} c_X - k_r c_{CO2 \cdot X}$$

Dynamic (2nd law)

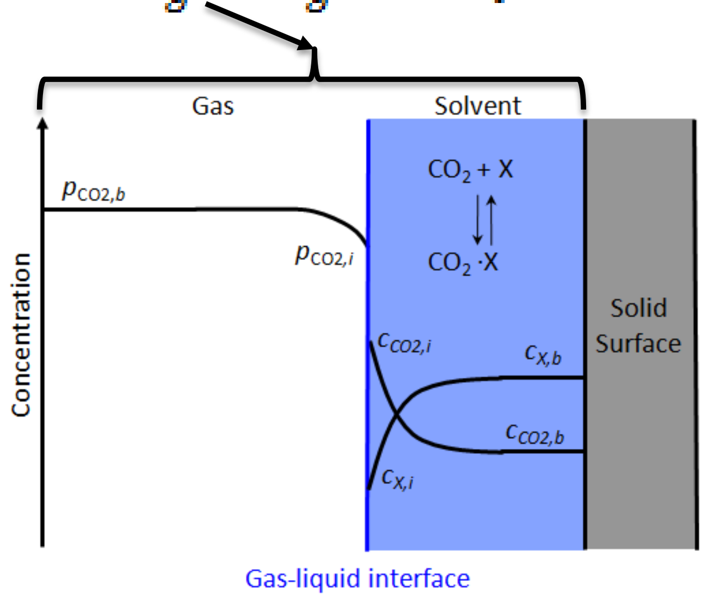


Overall mass transfer

- A combination of gas and liquid side mass transfer, although in packed columns the gas-side can usually be neglected

$$N_{CO2} = K_g(p_{CO2,b} - k_{h,CO2}c_{CO2,b})$$

$$\frac{1}{K_g} = \frac{1}{k_g} + \frac{k_{h,CO2}}{k_l} \qquad k_{h,CO2} = \frac{p_{CO2}}{c_{CO2}}$$



CO_2 stripping

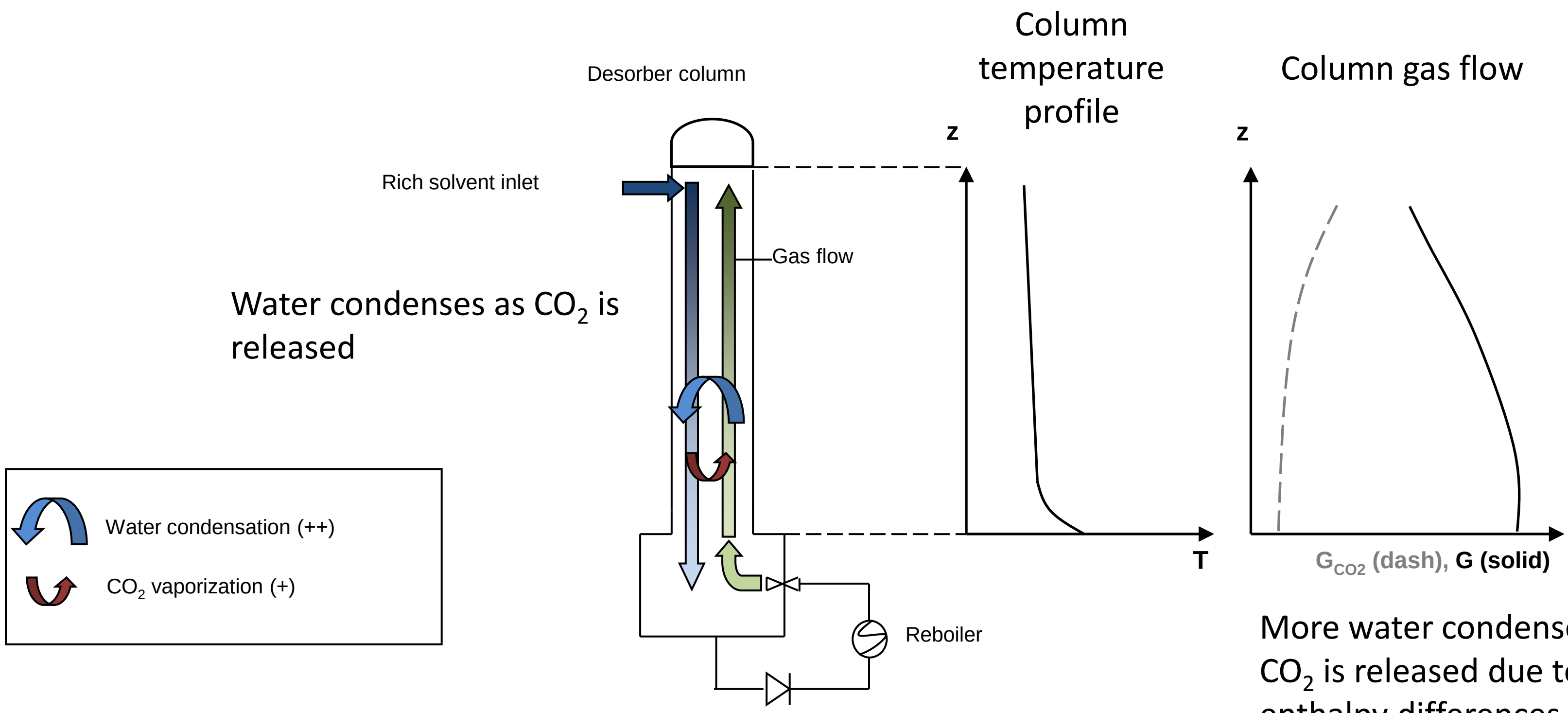
- The CO_2 stripping or desorption process is in many respects the reverse of absorption
- The absorbent is heated to shift the chemical equilibrium position more in favour of CO_2 release
- All of the same mass transfer process apply
- The two main differences in the operation of desorption rather than absorption are:
  - A stripping gas is required to dilute CO_2 and produce a driving force out of solution (and it must be possible to easily separate this stripping gas from CO_2)
  - Desorption is an endothermic process and heat must be applied along the column to maintain the required temperature

CO_2 stripping

- Packed columns are used for CO_2 stripping for the same reasons they are attractive for absorption
- Heat is applied at the base of the stripping column via a reboiler to produce stripping steam
- The stripping steam has two roles:
  - As a stripping gas to dilute CO_2
  - As an energy vector to maintain the column temperature as it condenses along the column
- One of the reasons aqueous solutions are used is that water is a good stripping gas because it can be easily separated from CO_2 by condensation

CO_2 stripping

Water condenses as CO_2 is released



Steam is produced at the bottom in the reboiler

More water condenses than CO_2 is released due to enthalpy differences resulting in a reduction in total gas flow

Acknowledgements

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