Supplement: Velocities and Mass Flux

* Be careful with the velocity term when doing mass diffusion problems. Species mass transfer can give rise to bulk fluid motion.

* Fundamental principle: Total flux is related to velocity.

Example (binary mixture)

$$\underline{N}_A = c_A \underline{v} + \underline{J}_A$$

$$+ \quad \underline{N}_B = c_B \underline{v} + \underline{J}_B$$

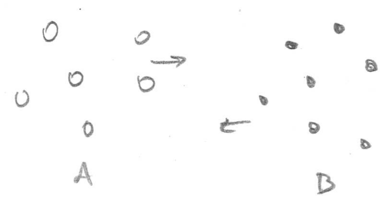
$$\underline{N}_A + \underline{N}_B = \underbrace{(c_A + c_B)}_{\sum_i c_i = c} \underline{v} + \underbrace{\underline{J}_A + \underline{J}_B}_{\sum_i J_i = 0}$$

$$\boxed{\underline{N}_A + \underline{N}_B = c\underline{v}}$$

- Of the 3 quantities: $\underline{N}_A, \underline{N}_B, \underline{v}$, only two can be independent.

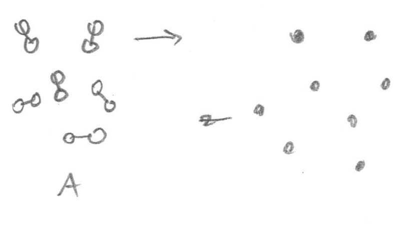
* Some examples of cases that are common:

Equimolar counter-diffusion



$\underline{N}_A = -\underline{N}_B \Rightarrow \boxed{\underline{v} = 0}$

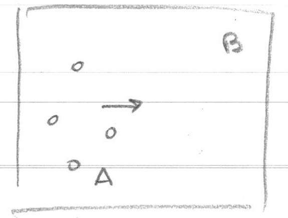
Non-equimolar counter-diffusion



$N_A \neq -N_B \Rightarrow \boxed{\underline{v} \neq 0}$

(Mol. weight difference)

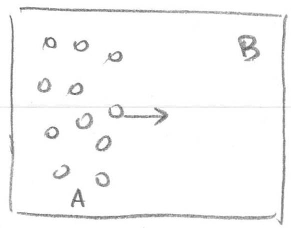
dilute solute in stagnant solvent



$c_A << c_B \,, \quad N_B = 0$

$v \approx v_B = \dfrac{N_B}{c_B} \qquad \boxed{v \approx 0}$

non-dilute solute in stagnant solvent



$N_A \neq 0 \,, \quad N_B = 0$

$v = \dfrac{N_A}{c} \Rightarrow \boxed{v \neq 0}$

* other cases exist. For example a heterogeneous chemical reaction can cause a bulk flow. Obviously forced convection also happens. Also $v = 0$ in solids.

* when in doubt, solve the full, coupled system of total and species mass balances. Don't assume incompressibility (for gases). However, the above are common "story problem" ways to skip this process & jump straight to a 1D solution.