

EFB 462 Animal Physiology: Environmental & Ecological
Gas concentrations and potential energy for driving gas fluxes

What drives diffusion gas flux?

Any movement of mass involves work, and the energy to do this work must come from some store of potential energy. As it is usually written, Fick's Law implies that this store of potential energy resides in the concentration gradient, or concentration difference, between two compartments or regions.

$$\dot{M} = \frac{D \cdot A}{x} \cdot (C_I - C_{II})$$

What is it about *concentration* that makes it a store of potential energy, however? Applying Fick's law to diffusion of gases offers a ready way to explore this question.

Gas "concentration": How to express it?

There are several common ways that gas concentrations are expressed. Here are a few:

[X]	molar concentration	mol m ⁻³ , mol l ⁻¹
ρ _x	density	g m ⁻³ , kg m ⁻³ , g cm ⁻³
p _x	pressure, partial pressure	Pa, N m ⁻² , kg m s ⁻²
mf	mole fraction	n _X /n _T

For gases, all units are convertible through the ideal gas law. For example, molar concentration is related to the pressure by starting with the ideal gas law:

$$pV = nRT$$

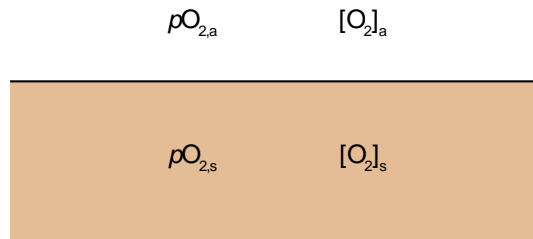
which can be rearranged to express molar concentration:

$$\frac{n}{V} = \frac{p}{RT}$$

However, all ways of expressing concentration are not consistent with being the potential energy driving a flux. Energy is equivalent to work, that is force X distance, and the only quantity in the ideal gas law that contains a unit for force is *pressure*. In other words, the proper way to write Fick's Law for gases is:

$$\dot{m} = \frac{D \cdot A}{x \cdot R \cdot T} \cdot (p_I - p_{II})$$

where \dot{m} is molar flux (mol s⁻¹) of the gas in question. This is more than a mere quibble. Failure to be precise about the nature of the driving force behind the flux can lead to all sorts of confusion. Consider the simple problem of equilibrium between a parcel of water and a parcel of gas above it.



How oxygen moves between the aqueous and gaseous phases will be determined not by the molar concentration difference ($[O_2]_a - [O_2]_s$) but by the partial pressure difference ($p_{O_{2,a}} - p_{O_{2,s}}$). At equilibrium, the partial pressures will be identical (that is $p_{O_{2,a}} - p_{O_{2,s}} = 0$). However, there will be no net flux of gases between the aqueous and gaseous phases, despite the substantial molar concentration difference that Henry's Law would predict for either.