Parallels in fractionation of isotopes and partitioning of trace elements

For fractionation of isotopes between two substances A and B, we speak of a fractionation factor "α":

Fractionation factor

$$\alpha_{A\text{-}B} = \frac{R_A}{R_B} = \frac{{}^{18}O/{}^{16}O_A}{{}^{18}O/{}^{16}O_B} \text{ or } \frac{{}^{13}C/{}^{12}C_A}{{}^{13}C/{}^{12}C_B} \text{ or } \frac{{}^{56}Fe/{}^{54}Fe_A}{{}^{56}Fe/{}^{54}Fe_B}$$

Two substances A and B

Specifically, for fractionation of oxygen between a mineral ("min") as A and H_2O ('w") as B:

$$\alpha_{min\text{-}w} = \frac{R_{min}}{R_w} = \frac{{}^{18}O/{}^{16}O_{min}}{{}^{18}O/{}^{16}O_w}$$

Ratio of abundance of scarce isotope to abundance of abundant isotope in mineral

Ratio of abundance of scarce isotope to abundance of abundant isotope in water

On the other hand, for partitioning of a trace element ("t") into a mineral of the corresponding dominant element "d", we speak of a distribution coefficient "D":

$$D_{min\text{-}w} = \frac{[t]/[d]_{min}}{[t]/[d]_w}$$

Ratio of concentration of scarce element to concentration of abundant element in mineral

Ratio of concentration of scarce element to concentration of abundant element in precipitating aqueous solution

For example, t might be Mg^{2+} or Mn^{2+} in calcite, where d is Ca^{2+}.

The point of this page is to show the similarity of these two formulations:

Ratio of scarce entity to abundant entity in mineral

$$\alpha_{min\text{-}w} = \frac{{}^{18}O/{}^{16}O_{min}}{{}^{18}O/{}^{16}O_w} \qquad D_{min\text{-}w} = \frac{[t]/[d]_{min}}{[t]/[d]_w}$$

Ratio of scarce entity to abundant entity in water

For fractionation of O isotopes, we have determined variation of fractionation factors (α) with temperature. Those values of α vary only with T, so long as there is equilibrium precipitation wherein precipitation rate or other factors have no effect on fractionation. O isotopes have thus been used widely as a proxy for paleotemperature.

For partitioning of trace elements, both temperature and precipitation rate have been shown to control D, but when precipitation rate is constant, we may be able to relate D solely to T and so develop a paleotemperature proxy from trace elements.