FILMTEC Membranes

Water Chemistry and Pretreatment: Scaling Calculations

General

Scaling calculations must be carried out in order to determine whether a sparingly soluble salt presents a potential scaling problem in an RO system. The calculation procedures described in this section are adapted from the corresponding ASTM standards, cited in the references /6, 7, 8/. To determine the scaling potential, you need to compare the ion product IP_c of the considered salt in the concentrate stream with the solubility product K_{sp} of that salt under conditions in the concentrate stream. Generally, scale-control measures are not needed if $IP_c < K_{sp}$.

The ion product IP of a salt A_mB_n is defined as

$$IP = [A]^m[B]^n \quad \text{Eq. 1}$$

where:

[A], [B] = molal concentrations of the corresponding ions

For the concentration ranges present in RO applications, molal concentrations (mol/kg) can be considered equivalent with molar concentrations (mol/L).

The concentration of ion species in the concentrate stream is usually not known, but can easily be estimated from the concentration in the feed stream by multiplication with the concentration factor CF. The concentration factor is derived from the recovery *Y* (expressed as a decimal):

$$CF = \frac{1}{1-Y} \quad \text{Eq. 2}$$

where the rejection is assumed to be 100%.

The solubility product K_{sp} is generally also expressed in molal concentrations and is dependent on ionic strength and temperature as shown in the figures of this section.

The temperature in the concentrate stream is about the same as in the feed stream.

The ionic strength of the feed water is:

$$I_f = \frac{1}{2}\sum m_i z_i^2 \quad \text{Eq. 3}$$

where:

m_i = molal concentration of ion i (mol/kg)
z_i = ionic charge of ion i

Where the water analysis is not given in molal (or molar) concentrations, the conversion is as follows:

$$m_i = \frac{c_i}{1{,}000\,\mathrm{MW}_i} \quad \text{Eq. 4}$$

where:

c_i = concentration of ion i in mg/L
MW_i = molecular weight of ion i

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Having calculated the ionic strength I_f of the feed stream with Eq. 3, the ionic strength I_c of the concentrate stream is obtained from:

$$I_c = I_f\left(\frac{1}{1-Y}\right) \quad \text{Eq. 5}$$

With the ionic strength of the concentrate stream, the solubility product K_{sp} of scaling salt can be obtained - see *Calcium Carbonate Scale Calculation (Section 2.4.2)*, *Calcium Sulfate Scale Calculation (2.4.3)*, *Barium Sulfate Scale Calculation (2.4.4)*, *Strontium Sulfate Scale Calculation (2.4.5)*, *Calcium Fluoride Scale Calculation (2.4.6)*, *Silica Scale Calculation (2.4.7)*.

Calculation example of the ionic strength of the concentrate (I_c):

Feed Water Analysis

Ion	mg/L	mol/L	mol/kg
Ca^{2+}	200	5.0	$\times 10^{-3}$
Mg^{2+}	61	2.51	$\times 10^{-3}$
Na^{+}	388	16.9	$\times 10^{-3}$
HCO_3^{-}	244	4.0	$\times 10^{-3}$
SO_4^{2-}	480	5.0	$\times 10^{-3}$
Cl^{-}	635	17.9	$\times 10^{-3}$

The ionic strength I_f of the feed water is

$$I_f = \frac{1}{2}\left[4\left([Ca^{2+}] + [Mg^{2+}] + [SO_4{}^{2-}]\right) + \left([Na^{+}] + [HCO_3{}^{-}] + [Cl^{-}]\right)\right]$$

$$I_f = \frac{1}{2}\left\{4\left[(5.0 + 2.51 + 5.0)\times 10^{-3}\right] + \left[(16.9 + 4.0 + 17.9)\times 10^{-3}\right]\right\}$$

$$I_f = 0.0444$$

With a recovery of, for example, 75% (Y = 0.75), the ionic strength of the concentrate becomes

$$I_c = 0.0444\left(\frac{1}{1-0.75}\right)$$

$$I_c = 0.178$$

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