**Example: Freezing point depression: $[T_f\,(\text{pure solvent}) - T_f\,(\text{solution})] \equiv \Delta T_f = i\, K_f\, m$**

i = number of dissolved particles per formula unit of solute (Van't Hoff **i** factor)
i = 1 for soluble non-electrolytes; i > 1 for soluble electrolytes

$K_f$ = molal freezing point depression constant (cryoscopic constant) characteristic of the solvent

m = molality of the solution (molality = moles of dissolved solute per kg of solvent)

**Experimentally observed freezing point depressions in some aqueous solutions:**

**Non-electrolytes:** molecular solutes that do not ionize in solution
**Weak electrolytes:** molecular solutes that ionize to some extent in solution
**Strong electrolytes:** ionic solutes that ionize completely in solution

Molal freezing point depression constant of water (cryoscopic constant of $H_2O$):
$K_f = 1.86\ K/m = 1.86\ K/(\text{moles solute}/\text{kg water})$

| **Non-electrolytes** | | |
|---|---|---|
| **dissolved substance** | **concentration (molality)** | **$\Delta T_f$ (K)** |
| glycerine | 0.100 | 0.187 |
| ethanol | 0.100 | 0.183 |
| sucrose | 0.100 | 0.188 |
| | 0.200 | 0.376 |
| dextrose | 0.100 | 0.186 |
| | 0.200 | 0.372 |
| | 0.300 | 0.558 |

| **Weak electrolytes** | | |
|---|---|---|
| **dissolved substance** | **concentration (molality)** | **$\Delta T_f$ (K)** |
| acetic acid | 0.0100 | 0.0194 |
| nitrous acid | 0.0750 | 0.150 |

| **Strong electrolytes** | | | |
|---|---|---|---|
| **ion types** | **dissolved substance** | **concentration (molality)** | **$\Delta T_f$ (K)** |
| (1:1) | HCl | 0.100 | 0.352 |
| | LiCl | 0.0100 | 0.0360 |
| | NaCl | 0.00500 | 0.0182 |
| | | 0.0100 | 0.0360 |
| | | 0.0150 | 0.0538 |
| | KCl | 0.100 | 0.345 |
| | $KNO_3$ | 0.1000 | 0.0359 |
| | | 0.100 | 0.331 |
| | $AgNO_3$ | 0.0100 | 0.0360 |
| (2:2) | $MgSO_4$ | 0.0100 | 0.0285 |
| (1:2) | $Na_2SO_4$ | 0.0100 | 0.0504 |
| | | 0.100 | 0.434 |
| (2:1) | $CaCl_2$ | 0.0100 | 0.0511 |
| | | 0.100 | 0.494 |
| | $NiCl_2$ | 0.100 | 0.538 |
| (1:3) | $K_3Fe(CN)_6$ | 0.0100 | 0.0626 |

**Note:** HCl(g) consists of HCl molecules only, so HCl is not an ionic substance in its pure state. However, when HCl(g) dissolves in water, in which it is very soluble, the HCl molecules dissociate completely into $H^+$ ions and $Cl^-$ ions. HCl in aqueous solution is a strong electrolyte. All the other strong electrolytes listed are salts, crystalline ionic solids in their pure states.

**Note:** Because ions interact strongly with each other and therefore move about in solution less freely than uncharged molecules do, the actual freezing point depression caused by any given number of ions is less than that caused by the same number of uncharged molecules. Observe, for example, that the freezing point depression caused by 0.1 m strong 1:1 electrolytes is slightly less than the freezing point depression caused by 0.2 m non-electrolytes, and the freezing point depression caused by 0.1 m strong 1:2 electrolytes or 0.1 m strong 2:1 electrolytes is less than the freezing point depression caused by 0.3 m non-electrolytes. In other words, assuming a value for i based on the formula will overestimate ΔT values by a bit.