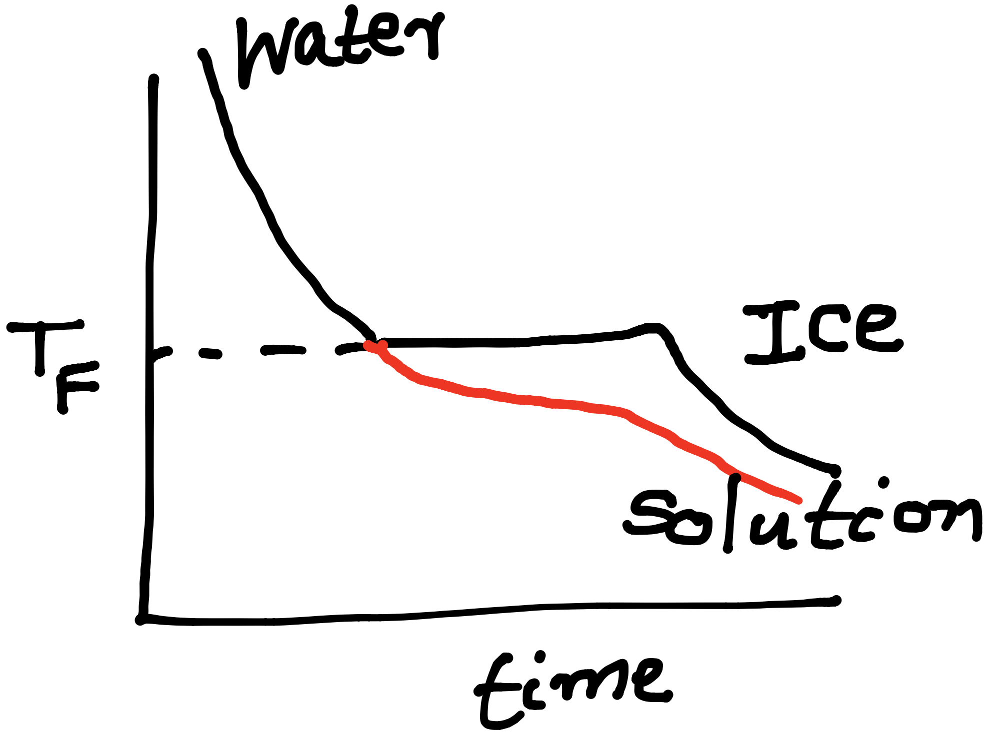
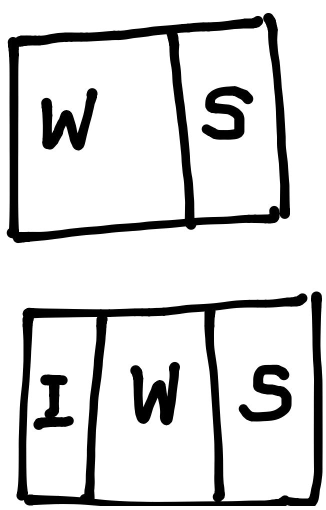
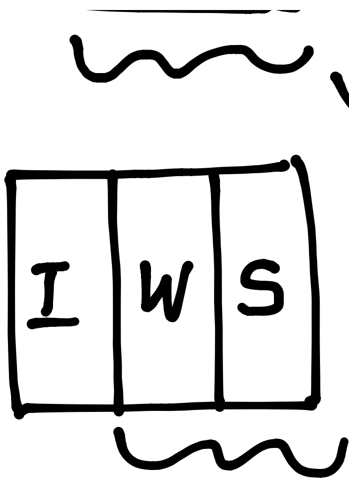
Freezing is a method of preservation of food and biological systems since one would slow the growth of microorganisms at very low temperature. Consequenlty, freezing can increase the shelf life of the product.



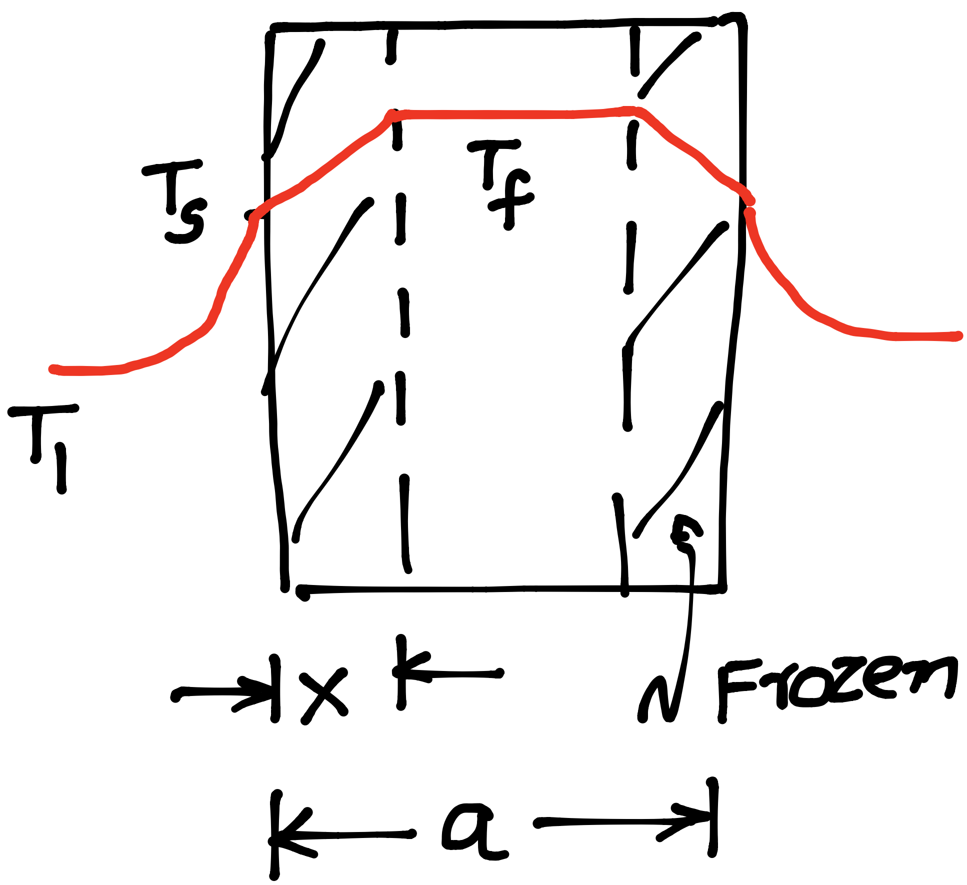
Temperature vs time curve for water and a solution are shown above. Water exhibits a single freezing point. At that temperature, latent heat of fusion is removed until all the water turns to ice. However, when you are dealing with a solution, because of freezing point depression, the freezing curve lies below that for water. Moreover, one cannot identify a single freezing point. This can be understood as follows.





solution gets more concentrated
more freezing point depression

Freezing of a slab:



$$q = hA(T_s - T_1) \quad (1)$$

$$q = \frac{kA}{x}(T_f - T_s) \quad (2)$$

$$q = \frac{(T_f - T_1)A}{\frac{x}{k} + \frac{1}{h}} \quad (3)$$

$$q = \lambda \frac{d}{dt}(Ax\rho) = \lambda A \rho \frac{dx}{dt} \quad (4)$$

$$\therefore \frac{(T_f - T_1)}{\frac{x}{k} + \frac{1}{h}} = \lambda \rho \frac{dx}{dt}$$

$$(T_f - T_1)\int_0^{t_f} dt = \lambda \rho \int_0^{a/2} \left(\frac{x}{k} + \frac{1}{h}\right) dx$$

$$(T_f - T_1)t_f = \lambda \rho \left(\frac{a^2}{8k} + \frac{a}{2h}\right)$$

$$t_f = \frac{\lambda \rho}{(T_f - T_1)}\left[\frac{a^2}{8k} + \frac{a}{2h}\right]$$

In general,

$$t_f = \frac{\lambda \rho}{(T_f - T_1)}\left[\frac{Pa}{h} + \frac{Ra^2}{k}\right]$$

$P = \frac{1}{6}$ sphere

$\frac{1}{4}$ infinite cylinder

$R = \frac{1}{24}$ sphere

$\frac{1}{16}$ infinite cylinder