Chemistry 201

Cryoprotectants

NC State University

Cyroprotectants

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There are many naturally occurring sugars and other solutes that function as cryoprotectants. In fact, some of these can lower the freezing point of water so much that the freezing transition forms a glass rather than ice. The lack of an abrupt change in molar volume is advantageous in cells that freeze. The role of such molecules is crucial in maintaining life for many organisms.

One example is trehalose, which is a non-reducing disaccharide composed of two glucose monomers. However, glucose itself is a cryoprotectant and glycerol is produced naturally in frog's livers to protect them during the winter months.

Glass transition

The formation of a low temperature glass is a consequence of freezing point depression, but also occurs when the solute concentration is sufficiently high that the properties of the solution are a mixture of two substances. In biological and biophysical studies the glycerol/buffer glass is important. Mixtures of 50% glycerol in water (by volume) do not freeze, but rather form a low temperature glass. Cryoprotectants in living organisms can protect organs against freezing in a similar way. Glycerol and glucose are produced naturally in quantities that can prevent tissues from undergoing a phase transition that would damage cell membranes.

Trehalose in a bacterial cell

A bacterial cell produces at 6.5 M trehalose solution in its Cytosol in response to lowering temperature. Assuming that the solution freezes at all, i.e. and therefore does not form a glass, what is the predicted freezing point of the cytosol?

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Solution: This is a freezing point depression question.

$$\Delta T = K_f \, \boldsymbol{m}$$

The values are

$$\Delta T = -\left(1.86 \, \frac{^oC}{molal}\right)(6.5 \, molal)$$

and the final temperature is

$$\Delta T = -12.0 \, ^oC \quad or \quad 261 \, K$$