

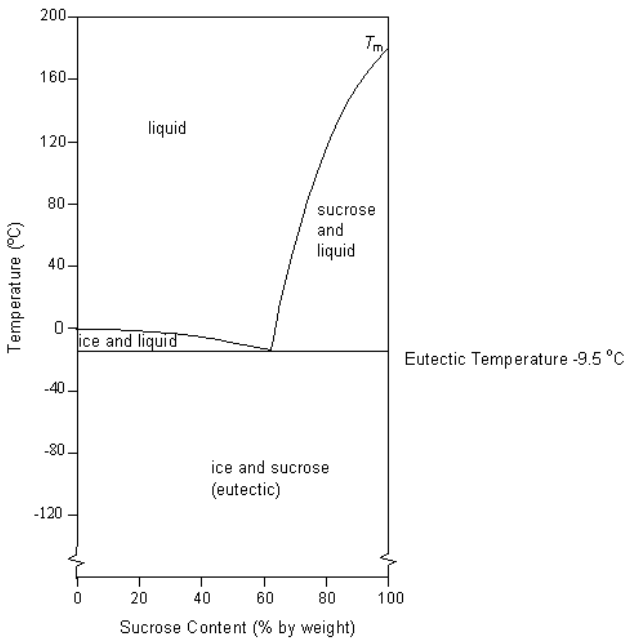
Phase Equilibria of Ice Cream Making

In class exercise

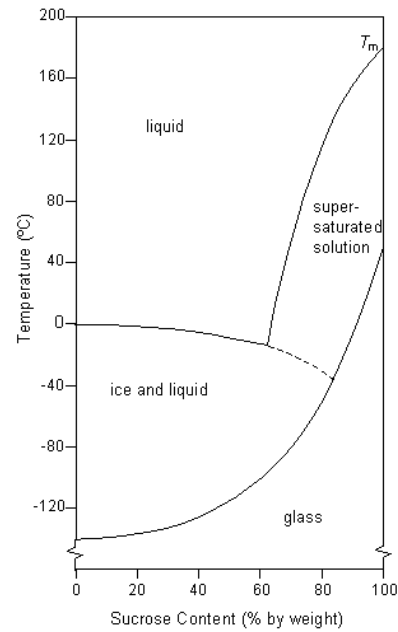
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Name _____

(a)



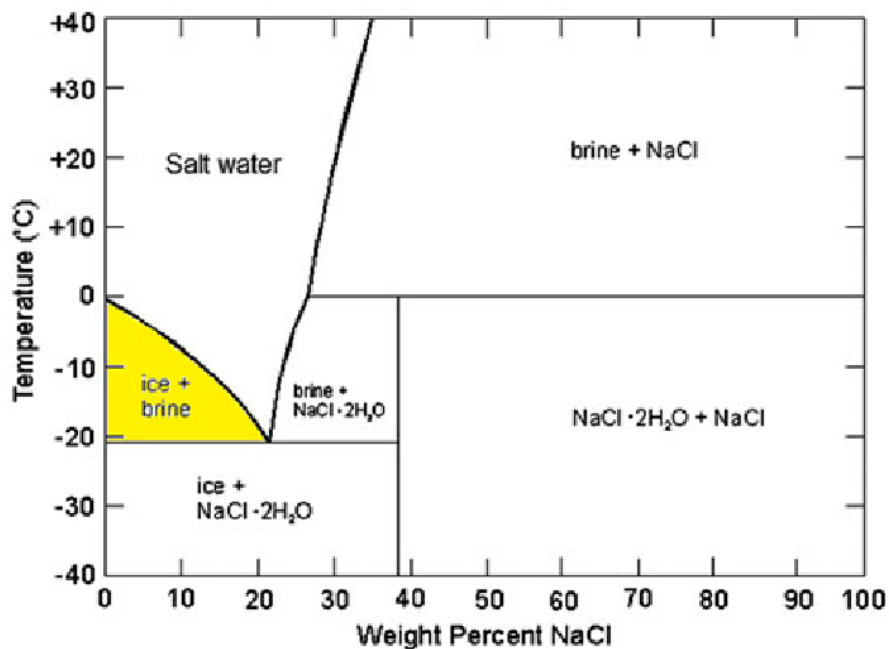
(b)



The phase diagrams above describe phase equilibria in the sucrose (sugar)-water system relevant to ice cream. The diagram on the left **(a)** presents the equilibrium phase assemblages as a function of temperature and composition. Because sugar crystals are slow to nucleate and grow from solution, the diagram on the right **(b)** is more practical for ice cream making because it describes the phases that form over ice cream-relevant timescales.

1. Label the liquidus, solidus and the eutectic point in **(a)**.
2. Label the liquidus and solidus in **(b)**. What do you think is represented by the dashed line? Why is it present in this phase diagram? What is the special term we use to describe the stability of this type of phase?
3. Although real ice cream contains sugar, fat, proteins and water, the phase equilibria of ice cream mixtures can be approximated as a 20% sugar – water solution. Label the bulk composition of the ice cream mixture in **(a)** and **(b)** at room temperature as X. How many degrees of freedom are there for point X in this system?

- Cool the mixture until the liquidus is reached. What is the composition of the liquid when the first crystal forms? What is the temperature? How many degrees of freedom are there?
- A most delicious ice cream mixture is near-eutectic. Use phase diagram **(a)** to answer these questions. What is the temperature required to achieve a eutectic mixture? Apply the lever rule to your solid solution. How much ice and how much sucrose solution is there in the liquid? How many degrees of freedom does the system have at the eutectic? What is the composition of the eutectic liquid?



Above is the phase diagram for halite-water solutions. Old fashioned ice cream makers take advantage the depressed melting point of salt-ice mixtures to cool liquid ice cream below its liquidus. The ice-salt mixture is present in a bucket around the vessel where the ice cream is churned.

- What is the minimum amount of salt that should be added to the salt-ice mixture to reach the sucrose-water eutectic?
- Roads are salted in many parts of the country to promote safe driving conditions by melting ice at eutectic temperatures. Downsides of this practice are that cars in these communities rust out quickly, and water quality and fisheries are degraded by the salt. Some towns are now substituting sugar beet (sucrose)-based solutions for halite. Are the sucrose-based solutions as effective for melting road ice? Explain your reasoning using information provided in the phase diagrams.