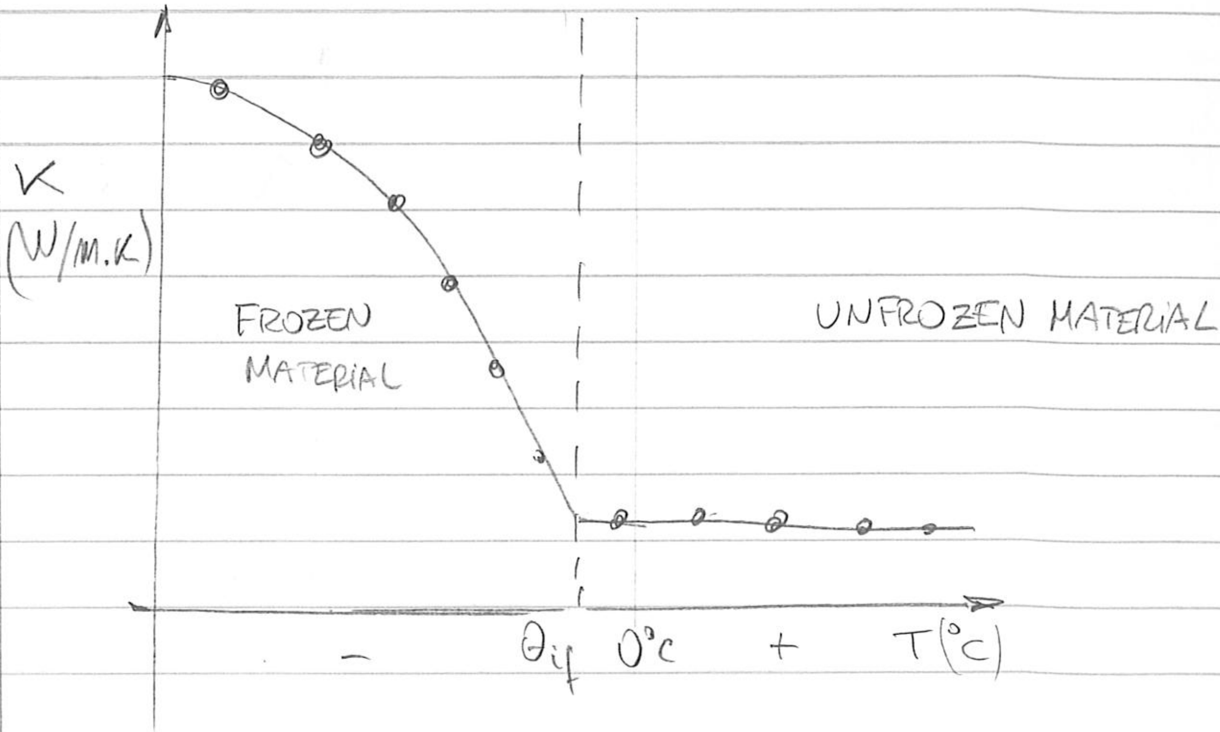
ABE 303 - EXAM 1 - Fall 2015

SOLUTIONS

Question 1

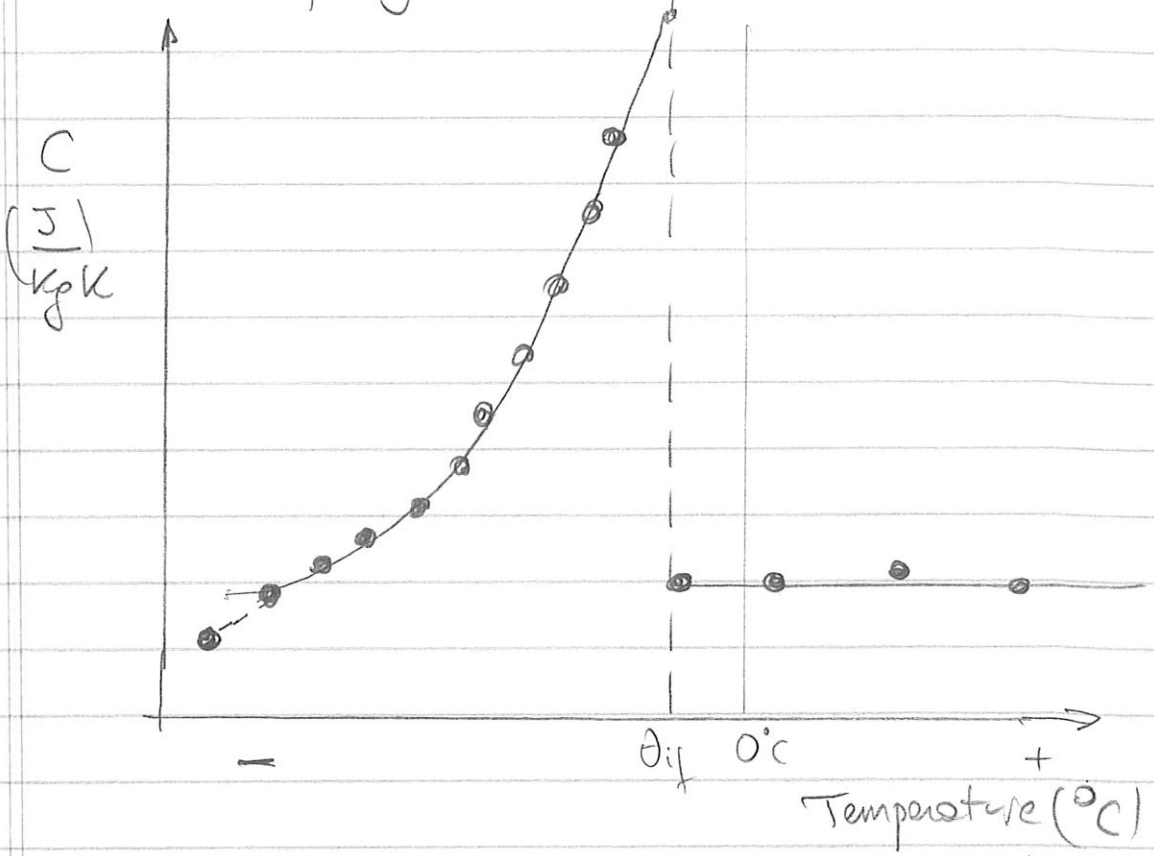
(a)

(i) Thermal conductivity versus temperature



Thermal conductivity of biomaterials is highly dependent on temperature for temperatures below the initial freezing point because the formation of ice, especially very close to the initial freezing point - when the material is at the freezing state. As unfrozen the thermal conductivity does not change much, and for biomaterials with a large moisture content is very close to the thermal conductivity than water. Thermal conductivity measures the ability of a material to conduct heat. From that standpoint frozen materials will conduct heat better than unfrozen materials.

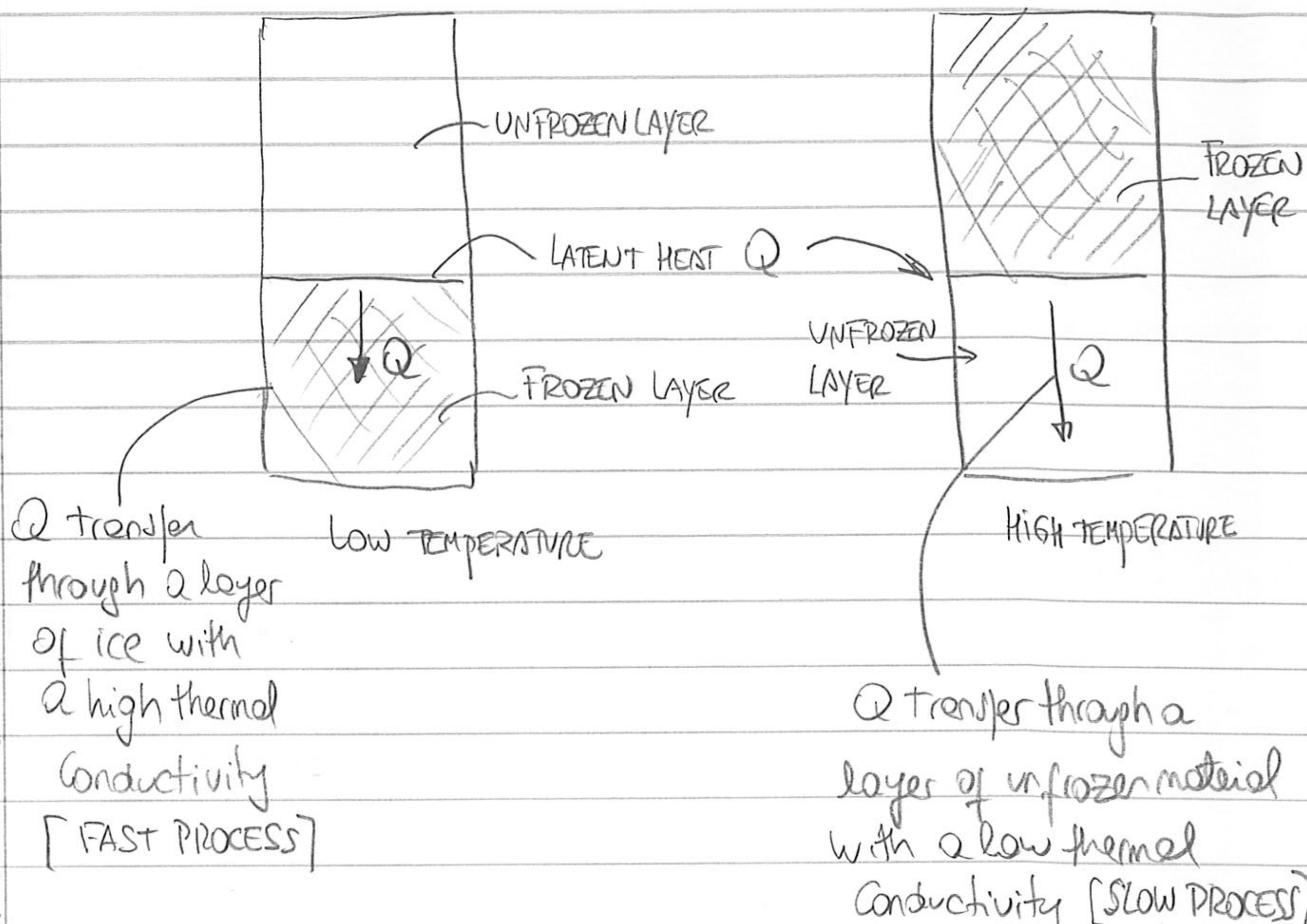
(ii) Heat capacity



Heat capacity is the ability of a material to store or lose energy. As shown in the plot above there is a large variation in the heat capacity of the material close to the initial freezing point due to the mixture of latent heat (due to freezing or melting) and sensible heat. Far from the initial freezing point the heat capacity approaches that of the ice (at very low temperatures) or the material at high temperatures.

(b)

Freezing Process. Thawing Process.



(c) Salt is a small molecule when compared with larger molecules (macromolecules) such as carbohydrate, proteins, etc., so its effect on water activity is very drastic, so little addition of salt (NaCl) results in large decreases in a_w, so products with low water activity are not effected by microbial growth.

Question 2

(a) Both temperatures are below the initial freezing point so we will use the equation to calculate enthalpy changes below the freezing point. Let's assume fish is non-fatty

$$\Delta H_{-25\rightarrow -1} = C_{SNF}(1-X_w)(\theta_{if}-\theta) + C_{ice}X_{BW}(\theta_{if}-\theta) + C_w X_w' \theta_{if} \ln \theta_{if}/\theta + C_{ice}X_w'(\theta_{if}-\theta) - C_{ice}X_w'\theta_{if}\ln\frac{\theta_{if}}{\theta} - LX_w'(\theta_{if}/\theta - 1) \quad (1)$$

$X_w = 0.77$

$\theta_{if} = -1°C$

$BW = 0.33 \frac{\text{kg water}}{\text{kg dry solids}}$ $\qquad X_{WB} = BW \times X_{SNF}$

$C_{SNF} = 1.9 \frac{kJ}{kg K}$ $\qquad X_{SNF} = 1 - X_w = 0.23$

$X_{BW} = 0.33 \times 0.23 = 0.08$

$C_w = 4.2 \frac{kJ}{kg K}$ $\qquad X_w' = X_w - X_{BW} = 0.77 - 0.08$

$C_{ice} = 2.1 \frac{kJ}{kg.K}$ $\qquad X_w' = 0.69$

Substituting values into Eq. (1)

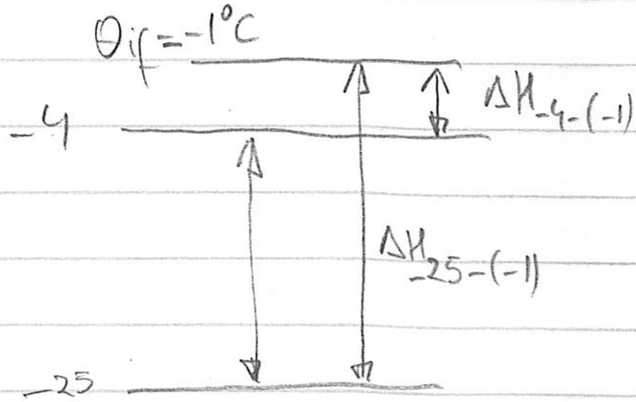
$$\Delta H_{-25 - -1} = 1.9 \times (1 - 0.77)\left[-1 - (-25)\right]$$
$$+ 2.1 \times 0.08 \times \left[-1 - (-25)\right]$$
$$+ 4.2 \times 0.69 (-1) \ln\left(\frac{-1}{-25}\right)$$
$$+ 2.1 \times 0.69 \left[-1 - (-25)\right]$$
$$- 2.1 \times 0.69 \times (-1) \ln\left(\frac{-1}{-25}\right)$$
$$- 320 \times 0.69 \left(\frac{(-1)}{-25} - 1\right)$$

$$\Delta H_{-25 - -1} = 10.\ldots$$
$$+ 4.03$$
$$+ 9.33$$
$$+ 34.8$$
$$+ 4.7$$
$$- (-212) \ \frac{KJ}{Kg}.$$

$$\boxed{\Delta H_{-25 - -1} = 275.4 \ \frac{KJ}{Kg}}$$

$$\Delta H_{-4--1} = 1.9(1-0.77)(-1-(-4)) + 2.1\times 0.08[-1-(-4)] + 4.2\times 0.69(-1)\left[\ln\left(\frac{-1}{-4}\right)\right] + 2.1\times 0.69[-1-(-4)] - 2.1\times 0.69(-1)\ln\left(\frac{-1}{-4}\right) - 320\times 0.69\left(\frac{-1}{-4}-1\right)$$

$$\Delta H_{-4--1} = 1.31 + 0.50 + 4.02 + 4.35 - (-2.01) - (-165.6)$$



$$\Delta H_{-4-(-1)} = 175.8 \text{ kJ/kg}$$

$$\Delta H_{-25-(4)} = \Delta H_{-25-(-1)} - \Delta H_{-4-(-1)} = 275.4 - 175.8 \cong 100 \frac{\text{kJ}}{\text{kg}}$$

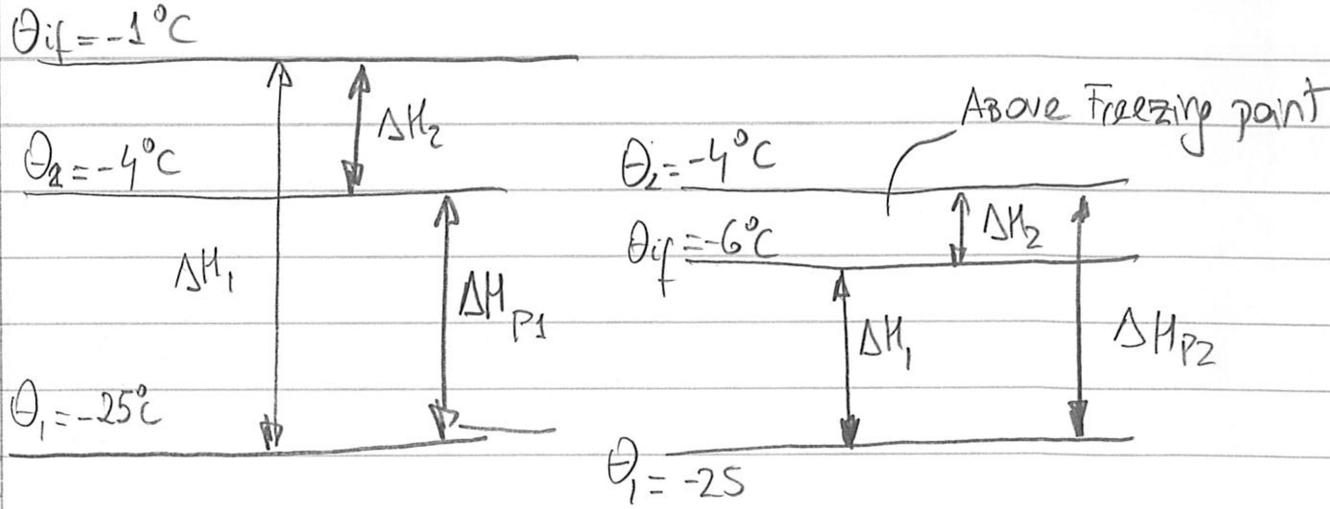
$$\text{THROUGHPUT} = \frac{32\text{ kW}}{100\frac{\text{kJ}}{\text{kg}}} = 0.32\frac{\text{kg}}{\text{s}} \times \frac{3600\text{ s}}{1\text{ h}}$$

$$\boxed{\text{THROUGHPUT} = 1{,}152 \frac{\text{kg}}{\text{h}}}$$

(b) (7)

In case the freezing point is decreased to $-6°C$ the calculation will change to the following.

Freezing Point $-1°C$ Freezing Point $-6°C$



Freezing Point $-1°C$ $\Delta H_{P1} = \Delta H_1 - \Delta H_2$

Freezing point $-6°C$ $\Delta H_{P2} = \Delta H_1 + \Delta H_2$

Hard to define without calculation, but when the Freezing point is $-6°C$ part of the calculation will involve the enthalpy above the initial freezing point that is probabley less, so that will save some energy, Quality perhaps is negatively affected. I would use salt or Sugar to decrease the initial freezing point of the fish.