

# ABE 303 – Applications of Physical Chemistry to Biological – Fall 2017

## Homework 2 – 100 marks

Deadline Thursday September 14

### Problem 1

Prepacked ready meals are to be cooled to a chill storage temperature of  $-1.5^{\circ}\text{C}$  following in-pack microwave pasteurization. The meals leave the pasteurizer at  $90^{\circ}\text{C}$ . Each meal consists of:

Potato	250 g
Peas	180 g
Pork	150 g
Butter	30 g
Total	610 g

The compositions of the four meal components are as follows:

	Potato	Peas	Pork	Butter
Water (%)	80	75	45	12
Fat (%)	0	0	29	88
SNF (%)	20	25	26	0

The freezing points of all four components are all less than  $-1.5^{\circ}\text{C}$ .

Using the data given below, calculate how much energy (in MJ/day) the chilling system must be capable of removing from the meals if they are being produced at the rate of 900 per day.

**Hint:** unless a meal is considered as one composite material, this problem will take a long time to solve.

### DATA

Specific heat of water =  $4.2 \text{ kJ/kg.K}$

Enthalpy data for butterfat and port fat:

Temperature ( $^{\circ}\text{C}$ )	Enthalpy, $h$ (kJ kg), relative to $h=0$ at $-50^{\circ}\text{C}$	
	Butter Fat	Pork Fat
-5	86.3	77.1
0	101.7	86.15
10	141.4	112.9
30	223.9	182.6
60	294.2	301.0
90	355.3	361.5

For a fatty material containing more than one type of fat:

$$\Delta h_{\text{fattymaterial}} = x_{\text{non-fat}} \Delta h_{\text{non-fat}} + x_{\text{fat}_1} \Delta h_{\text{fat}_1} + \dots + x_{\text{fat}_n} \Delta h_{\text{fat}_n}$$

where:

$$x_{\text{non-fat}} + x_{\text{fat}_1} + \dots + x_{\text{fat}_n} = 1$$

[50 marks]

## **Problem 2**

A non-fatty protein based biomaterial has the following composition (%w/w):

Water 82%

Protein 16.5%

Salt (NaCl) 1.5%

Mass fraction of solids non-fat includes the salt and the protein, so it is 18%. The biomaterial has to be cooled from room temperature 25°C to -2.5°C to slow chemical and microbiological deterioration. In addition of affecting the quality of the biomaterial freezing is an expensive process so it needs to be avoided. The freezing point of the biomaterial is -1°C, so more salt has to be added to depress its freezing point to -3.5°C and the biomaterial can be cooled at -2.5°C without freezing.

- Calculate the mass of salt (in kg) per kg of biomaterial to add to have an initial freezing point of -3.5°C. To facilitate your calculations, you could use 1 kg (or 100 g) of the biomaterial as a basis for your calculation.
- Calculate the new composition of the salted biomaterial in terms of percentage of water and percent solids non-fat (SNF)
- Calculate the additional (i.e. difference between salted and non-salted biomaterial) energy removal (in kJ/kg) that would be required to cool the biomaterial to -3.5°C if salt was not added. Assume no bound water.
- Explain briefly why this additional energy removal would be necessary.

## **DATA**

Specific heat of water = 4.2 kJ/kg.K

Specific heat of SNF (protein plus salt) = 1.9 kJ/kg.K

Specific heat of ice = 2.1 kJ/kg.K

Latent heat of fusion of water = 331 kJ/kg

Freezing point data for salt solutions

Salt concentration in the brine solution (%)	Freezing Point °C
1.7	-1.0°C
3.3	-2.0°C
5.2	-3.0°C
6.8	-4.5°C

[50 marks]

Problem)Food

$$m_p = 250 \text{ g}$$

$$m_{\text{peas}} = 180$$

$$m_{pk} = 150$$

$$m_B = 30 \text{ g}$$

$$m_T = 610 \text{ g}$$

$$X_p = \frac{m_p}{m_T} \quad [\text{Fraction of } P.]$$

$$X_{\text{peas}} = \frac{m_{\text{peas}}}{m_T}$$

$$X_w = X_p \times 0.9 + X_{\text{peas}} \times 0.75 + X_{pk} \times 0.45 + X_B \times 0.12$$

(2)

NO SALT  
ADDED

Diagram illustrating the enthalpy change ( $\Delta h$ ) for the fusion of a biomaterial at different temperatures relative to its freezing point ( $-1^\circ\text{C}$ ).

The diagram shows a horizontal line representing the freezing point at  $-1^\circ\text{C}$ . The vertical axis represents enthalpy change ( $\Delta h$ ).

Key points and labels:

- Biomaterial** (at the top of the vertical axis)
- Freezing Point** (at  $-1^\circ\text{C}$ )
- Below Freezing Point** (at  $-2.5^\circ\text{C}$ )
- Above FP** (at  $-1^\circ\text{C}$ )
- Below FP** (at  $-2.5^\circ\text{C}$ )

Enthalpy change calculations:

- For fusion at  $-1^\circ\text{C}$ :  $\Delta h_{-1^\circ\text{C} - 25}$
- For fusion at  $-2.5^\circ\text{C}$ :  $\Delta h_{-2.5 - 25}$
- For fusion at  $-1^\circ\text{C}$  (above FP):  $\Delta h_{-1 - 25}$
- For fusion at  $-2.5^\circ\text{C}$  (below FP):  $\Delta h_{-2.5 - 25}$

The diagram shows that the enthalpy change for fusion is greater (more negative) when the material is heated from below the freezing point compared to heating from above the freezing point.

ADD SALT

CASE 2

ADD SALT

$\Delta H_{2.5}$

25

2.5°C

Freezing point: -3.5

The diagram consists of a vertical line with arrows at both ends. To the right of the top of the line is the number '25'. To the left of the line, between two horizontal tick marks, is the label 'ΔH\_{2.5}'. Below the lower tick mark is the label '2.5°C'. To the left of the bottom of the line is the text 'Freezing point:'. To the right of the bottom of the line, between two horizontal tick marks, is the number '-3.5'.

From Interpolation in the table

$X = 5.5\%$   
Salt



(3)

82% water  
16.5 protein  
1.5% salt } SNF 18%

- 1.0°C

check!!

interpolate salt (5.5%)

$$1 \text{ Kg} = 1000 \text{ g}.$$

0.82 g water

0.165 protein

X salt.

$$\frac{X}{0.82 + 0.165 + X} \times 100 = 5.5 \Rightarrow X$$

$$\text{salt to add} = X - 1.5$$

## Units in Problem 1

(4)

$$\text{Result } \frac{\text{KJ}}{\text{kg}} \times \frac{900 \text{ meol}}{\text{day}} \times \frac{0.610 \text{ kg}}{\text{meol}} = \frac{\text{KJ}}{\text{day}} \times \frac{1 \text{ MJ}}{10^3 \text{ J}}$$

$$\frac{\text{KJ}}{\text{kg}} \xrightarrow{\%} 1000 \times 900 \times 0.610$$

$$\boxed{\frac{\text{MJ}}{\text{kg day}}}$$