GJ

## The University of Calgary
## Department of Chemical & Petroleum Engineering

**ENCH 501: Transport Processes Quiz #3** **October 2, 2007**

**Time Allowed: 35 mins.** **Name:**

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**1)** Tea is made in a ceramic mug, empty mass of 301g. The mass of the tea and mug is 501g and the temperature of both is 92°C - that is the tea is too hot to drink. (The mug is insulated on the outside with felt.) For each of the following schemes to cool the tea, ***estimate the final condition*** of the tea which was continuously stirred and show all your steps;

a) (2 pts) 50g of water at 2°C is added,
b) (2 pts) 50g of ice at 0°C is added,
c) (4 pts) For this case, the initial mass of the mug and tea was 611g, with the initial temperature and the empty mass of the mug unchanged (from above). The mug and tea are placed in a temperature controlled vacuum chamber. The temperature of the chamber is always exactly equal to the temperature of the object within and water is steadily evaporated from the mug. The mug is taken out when exactly 60g of water has been evaporated.

**Data:** Properties of material, assumed constant
water, $C_p$ = 4.186 kJ/kg K ; $\Delta H_{vap}$ = 2260 kJ/kg ; $\Delta H_{fusion}$ = 334 kJ/kg
ceramic, $C_p$ = 0.82 kJ/kg K . Assume tea has the same themal properties as water.

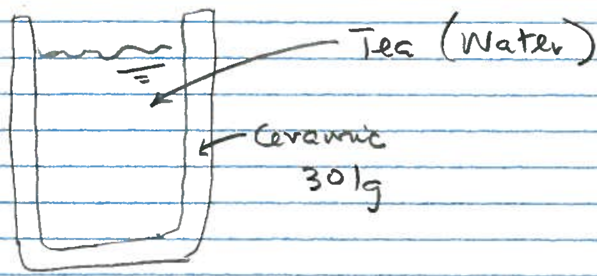
**2)** (2 pts) Show that, for a binary mixture of A and B,

$$\omega_A = \frac{x_A M_A}{x_A M_A + x_B M_B}$$

where $x$ denote mole fraction, $M$ molar mass and ω mass fraction.

ENCH 501 Quiz #3 Solution Oct. 2, 2007

Problem #1




(a) Mass Tea = 200 g

On adding 50 g water at 2°C, we have energy balance →

Heat gain by 50 g water = Heat loss by tea and mug

$$\frac{50}{1000}(4.186)(T_f - 2) = \left[\frac{200}{1000}(4.186) + \frac{301}{1000}(0.82)\right] \times (92 - T_f)$$

The final temperature of mug and tea,

$T_f = 77.4$ °C, still too hot

(b) Add 50 g ice. Ice melts first, gaining latent heat and then warms up.

Energy balance

$$\frac{50}{1000}\left[334 + 4.186(T_f - 0)\right] = \left[\frac{200}{1000}(4.186) + \frac{301}{1000}(0.82)\right](92 - T_f)$$

Final temp., $T_f = 64.2$ °C, still hot.

(c) Initial mass of tea = 310 g and 60 g is evaporated. The latent heat of evaporation is extracted from both the tea and the mug.

Perform energy balance

$$\frac{60}{1000}(2260) = [250(4.186) + 301(0.82)](92 - T_f)$$

$$T_f = -12.9\,^\circ C$$

This is below the freezing point of water. Hence the process must occur in 2 stages — first cool the tea to 0°C; then extract latent heat and form ice.

Let m be the mass of water vaporized (in grams) when the tea attains 0°C. Then

$$\frac{m}{1000}(2260) = \left[\frac{(310-m)(4.186)}{1000} + \frac{301(0.82)}{1000}\right](92)$$

$$m = 53.7188\ g$$

Evaporation of the balance, i.e. 60 − 53.7188 or 6.2812 g just produces ice at 0°C.

or

$$\frac{(6.2812)(2260)}{1000} = \frac{W}{1000}(334)$$

∴ mass of ice produced

$$W = 42.5\ g$$

The tea will have 42.5 g ice and 207.5 g liquid at 0°C

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Problem # 2

By definition

mass fraction of A $\quad \omega_A = \dfrac{\text{Mass } A}{\text{Mass } A + \text{Mass } B}$ (1)

and $\quad x_A = \dfrac{\text{moles } A}{\text{Total Moles A and B}} = \dfrac{\Omega_A}{\Omega_A + \Omega_B}$

moles A, $\Omega_A = x_A(\Omega_A + \Omega_B)$

mass A = moles A × Molar Mass A $= \Omega_A M_A$

$= x_A M_A(\Omega_A + \Omega_B)$ (2)

Similarly Mass B $= x_B M_B(\Omega_A + \Omega_B)$ (3)

Substitute (2) and (3) into (1)

$$\omega_A = \frac{x_A M_A}{x_A M_A + x_B M_B}$$

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Q.E.D.