Chem E-1a
Friday Review Problems
Chapter 6: Energy Relationships in Chemical Reactions

1. a) Write a complete balanced equation for the combustion of **one mole** of solid sucrose, $C_{12}H_{22}O_{11}$. Include state symbols such as (*s*) and (*g*).

$$C_{12}H_{22}O_{11}(s) + 12\,O_2(g) \longrightarrow 12\,CO_2(g) + 11\,H_2O(l)$$

b) A bomb calorimeter and its contents has a total heat capacity of 10.73 kJ/°C. When 1.243 g of sucrose are completely combusted in this calorimeter, the temperature increases by 1.91°C. Use this information to calculate the standard enthalpy change $\Delta H°$ for the combustion of sucrose in kJ/mol. ← $\Delta H°_{COMB}$

CALORIMETER PROBLEM:

$$q_{CAL} + q_{COMB} = 0$$

$$C_{CAL}\Delta T + n\Delta H°_{COMB} = 0$$

$$(10.73\ kJ/°C)(1.91°C) + (0.00363\ mol)\Delta H° = 0$$

$$(0.00363)\Delta H° = -(10.73\ kJ/°C)(1.91°C)$$

$$\boxed{\Delta H° = -5646\ kJ/mol}$$

FIND n:

n = # OF MOLES OF SUCROSE THAT COMBUSTS

$$1.243\ g\ Suc. \times \frac{1\ mol}{342\ g} = 0.00363\ mol\ Suc = n$$

c) Now use the information provided below to calculate the standard enthalpy change $\Delta H°$ for the combustion of solid sucrose.

$\Delta H°_f\,(CO_2\,(g))$ = –393.5 kJ/mol $\qquad$ $\Delta H°_f\,(H_2O\,(l))$ = –285.8 kJ/mol

$\Delta H°_f\,(C_{12}H_{22}O_{11}\,(s))$ = –2221.7 kJ/mol

$$\Delta H_{RXN} = \Sigma m\Delta H°_f\ PROD - \Sigma m\Delta H_f\ REACT$$

$$\Delta H_{COMB} = 12\,\Delta H°_f\,CO_2(g) + 11\,\Delta H°_f\,H_2O(l) - (\Delta H°_f\,C_{12}H_{22}O_{11}(s) + 12\,\Delta H°_f\,O_2(g))$$

$$= 12(-393.5\ kJ/mol) + 11(-285.8\ kJ/mol) - (-2221.7\ kJ/mol + 0)$$

$$\boxed{\Delta H_{COMB} = -5644\ kJ/mol}$$

2. You wish to prepare a pitcher of iced tea by mixing some amount of ice at –10°C with 400 g of hot tea at 80°C. You want your final pitcher of iced tea to be at 10°C. Determine the mass of ice you should use. **Useful Info**: specific heat of ice = 2.09 J/g°C
specific heat of tea = specific heat of liquid water = 4.18 J/g°C
ΔH°_{fusion} (H_2O) = +6.01 kJ/mol

$$q_{ICE} + q_{TEA} = 0$$

ICE:

(s) @ -10°C ⟶ (l) @ 10°C

SOLID ⟶ LIQUID!!!

TEA:

(l) @ 80°C ⟶ (l) @ 10°C

PHASE CHANGES MUST OCCUR AT PHASE CHANGE TEMP.

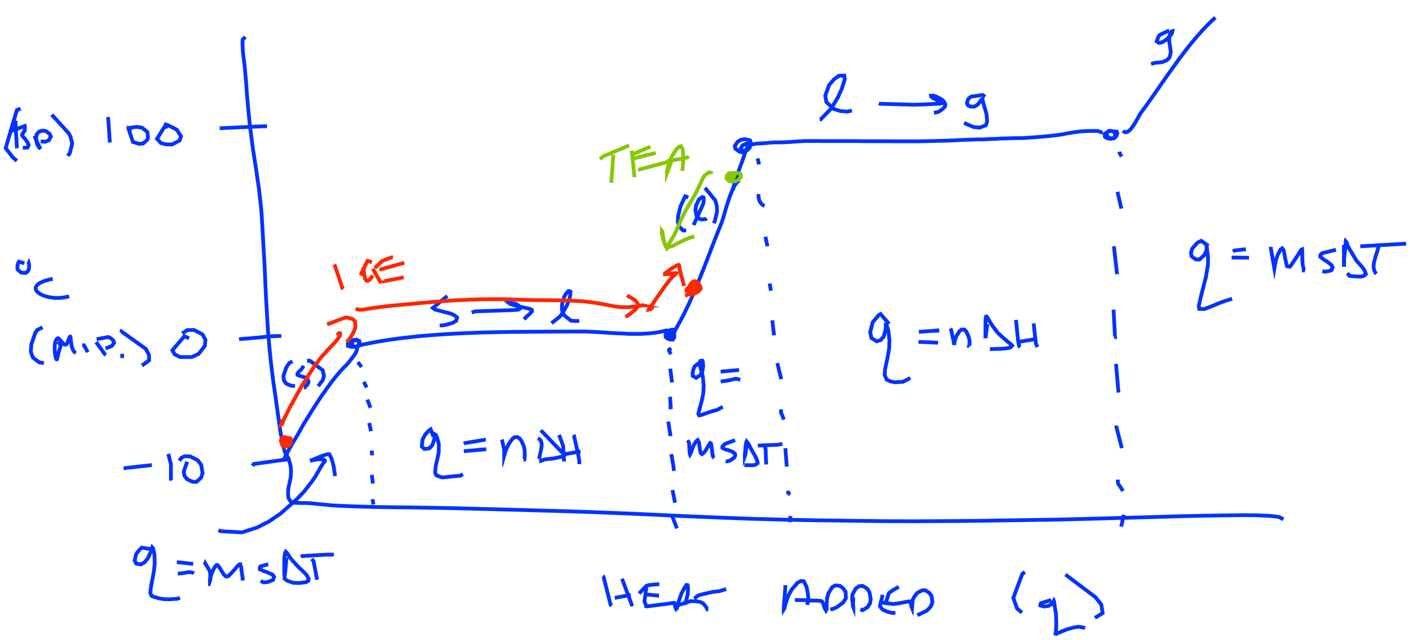
q FOR A PHASE CHANGE $= n\Delta H$

(s) ⟶ (l) ΔH_{fus} OCCURS AT MELTING POINT = FREEZING POINT

(l) ⟶ (s) $-\Delta H_{fus}$ " "

(l) ⟶ (g) ΔH_{vap} OCCURS AT BOILING POINT.

CONSIDER A HEATING CURVE: HEAT ICE FROM -10°C



2. (cont. – Additional space for work.)

$$\underbrace{q_{ICE}\quad +}\quad q_{TEA} = 0$$

(s) $-10 \to 0$ $\quad$ (s) $\to$ (l) $\quad$ (l) $0 \to 10$ $\quad$ (l) $80 \to 10$

$$msΔT + nΔH_{fus} + msΔT + msΔT = 0$$

$$m(2.09\ J/g°C)\overbrace{(0°C - -10°C)}^{T_f - T_i} + \cancel{n}^{\frac{m}{18}}(\cancel{6.01\ kJ/mol})(6010\ J/mol) + m(4.18\ J/g°C)\overbrace{(10°C - 0°C)}^{T_f - T_i}$$

$$+ (400\ g)(4.18\ J/g°C)\overbrace{(10°C - 80°C)}^{T_f - T_i} = 0$$

MASS OF ICE

MASS OF ICE

n = # OF MOLES OF ICE

$$m\ g\ ICE \times \frac{1\ MOL\ ICE}{18\ g\ ICE} = \frac{m}{18}\ MOL\ ICE = n$$

SOLVE : $\boxed{m = 295\ g\ ICE}$

SOLVING

$$20.9m + 333.9m + 41.8m + (-117040) = 0$$

3. a) Given the following information:

$$NO\ (g) + NO_2\ (g) \rightarrow N_2O_3\ (g) \qquad \Delta H° = -40\ kJ/mol$$

$$N_2O_4\ (g) \rightarrow 2\ NO_2\ (g) \qquad \Delta H° = 58\ kJ/mol$$

Calculate ΔH° for the following reaction:

$$2\ N_2O_3\ (g) \rightarrow 2\ NO\ (g) + N_2O_4\ (g) \qquad \Delta H = ??$$

$$2N_2O_3(g) \longrightarrow 2NO(g)\ \cancel{+2NO_2(g)} \qquad \Delta H° = -2(-40\ kJ/mol)$$

$$\cancel{2NO_2(g)} \longrightarrow N_2O_4(g) \qquad \Delta H° = -(58\ kJ/mol)$$

$$2N_2O_3(g) \longrightarrow 2NO(g) + N_2O_4(g) \qquad \Delta H° = 22\ kJ/mol$$

b) Calculate ΔU, q and w for the complete reaction of 5 moles of N_2O_3 (*g*) according to the above reaction at 25°C with a constant external pressure of 1.00 atm.

$$\Delta U = q + w$$

Find q: $q = n\Delta H = \left(\dfrac{5\ mol\ N_2O_3}{2}\right)(22\ kJ/mol)$

STOICH. COEFF. IN REACTION

$$\boxed{q = 55\ kJ}$$

Find w: $w = -P_{ext}\Delta V$

$$w = -(1.00\ atm)(V_f - V_i)$$

$$V_i = \frac{n_i RT}{P} = \frac{(5\ mol)(0.0821)(298\ k)}{(1.00\ atm)} = 122.3\ L$$

3. (cont. – Additional space for work.)

$$V_f = \frac{n_f RT}{P}$$

Find n_f:

# MOL	$2N_2O_3(g)$	$\rightarrow$	$2NO(g)$	+	$N_2O_4(g)$
I	5		0		0
C	$-2(2.5)$		$+2(2.5)$		$+2.5$
E	0		5		2.5

n_f TOTAL $= 7.5$ mol

$$V_f = \frac{(7.5\ \text{mol})(0.0821)(298\ \text{K})}{(1\ \text{atm})} = 183.5\ \text{L}$$

$$W = -P_{ext}(\Delta V) = -1\ \text{atm}\,(\overbrace{183.5\ \text{L} - 122.3\ \text{L}}^{V_f - V_i})$$

$$W = -61.2\ \text{L}\cdot\text{atm}$$

$$-61.2\ \text{L}\cdot\text{atm} \times \frac{101.3\ \text{J}}{1\ \text{L}\cdot\text{atm}} = -6195.6\ \text{J}$$

$$= \boxed{-6.2\ \text{kJ} = W}$$

$$\Delta U = q + W = 55\ \text{kJ} + -6.2\ \text{kJ}$$

$$\boxed{\Delta U = 48.8\ \text{kJ}}$$