

CHEM 3530 - Exam 2 - March 2, 2018

Constants and Conversion Factors

$$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$$

$$R = 8.31 \text{ J/mol-K} = 8.31 \text{ kPa-L/mol-K}$$

$$1 \text{ bar} = 100 \text{ kPa} = 750 \text{ torr}$$

$$1 \text{ kPa} = 7.50 \text{ torr}$$

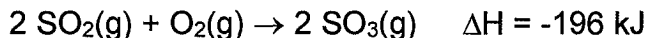
$$1 \text{ J} = 1 \text{ kPa-L}$$

Molar Masses

$$\text{C}_4\text{H}_{10} - 58.$$

(76) PART I. MULTIPLE CHOICE (Circle the ONE correct answer)

1. Consider the following Thermochemical equations:

Use these equations to determine ΔH for the reaction, $\text{S}(\text{s}) + \text{O}_2(\text{g}) \rightarrow \text{SO}_2(\text{g})$.

- (A) -297 kJ (B) -493 kJ (C) -692 kJ (D) +493 kJ

2. Consider the reaction:
- $2 \text{C}_2\text{H}_6 + 7 \text{O}_2 \rightarrow 4 \text{CO}_2 + 6 \text{H}_2\text{O} \quad \Delta H = -3122 \text{ kJ}$

Which of the following statements is/are **incorrect**?

- C ✓ i ΔH for forming one mole of C_2H_6 from and CO_2 and H_2O is -1561 kJ
 Inc. X ii ΔH for the combustion of 1.5 moles of C_2H_6 is -4163
 Inc. X iii The enthalpy of formation of C_2H_6 is +1561 kJ/mol
 ✓ iv The enthalpy of formation of $\text{O}_2(\text{g})$ is 0 kJ/mol

- (A) ii & iv (B) ii & iii (C) ii only (D) iii only

3. For the reaction
- $\text{Fe}_2\text{O}_3(\text{s}) + 3 \text{CO}(\text{g}) \rightarrow 2 \text{Fe}(\text{s}) + 3 \text{CO}_2(\text{g})$
- ,
- $\Delta H = -24 \text{ kJ}$
- . The Enthalpy of Formations of
- $\text{Fe}_2\text{O}_3(\text{s})$
- and
- $\text{CO}_2(\text{g})$
- are -825 kJ/mol and -394 kJ/mol, respectively. Therefore, the enthalpy of formation of
- $\text{CO}(\text{g})$
- is

- (A) -127 kJ/mol (B) -166.5 kJ/mol (C) -111 kJ/mol

(D) Cannot be determined without the Enthalpy of Formation of $\text{Fe}(\text{s})$

4. The Fuel Value (aka Specific Enthalpy) of butane,
- C_4H_{10}
- , is 50. kJ/g. Therefore, the enthalpy change to combust
- Two(2)**
- of butane in
- $\text{O}_2(\text{g})$
- to form
- $\text{CO}_2(\text{g})$
- and
- $\text{H}_2\text{O}(\text{l})$

- (A) -2900 kJ (B) -1450 kJ (C) +2900 kJ (D) -5800 kJ

5. The entropy change is +237 J/K for the reaction:
- $2 \text{HgO}(\text{s}) \rightarrow 2 \text{Hg}(\text{l}) + \text{O}_2(\text{g})$
- . The standard molar entropies of
- $\text{HgO}(\text{s})$
- and
- $\text{Hg}(\text{l})$
- are 70 J/mol-K and 86 J/mol-K. Therefore, the standard molar entropy of
- $\text{O}_2(\text{g})$
- is:

- (A) 205 J/mol-K (B) 0 J/mol-K (C) 221 J/mol-K (D) 269 J/K

6. The constant pressure molar heat capacity of
- $\text{N}_2(\text{g})$
- is 29.1 J/mol-K. What is the entropy change when 4 moles of
- N_2
- are cooled from 200 °C to 50 °C at 1 bar?

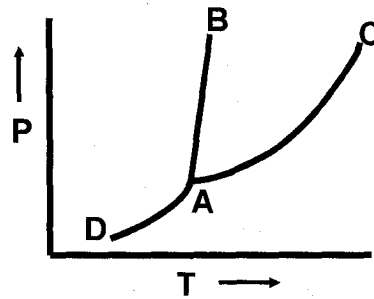
- (A) -23.2 J/K (B) -11.1 J/K (C) -161 J/K (D) -44.4 J/K

7. A sample of 0.5 moles of
- $\text{O}_2(\text{g})$
- originally at 500 kPa and 5 L is expanded reversibly and isothermally to a final pressure of 100 kPa. What is
- ΔS
- for this process?

- (A) +13.4 J/K (B) +6.7 J/K (C) -6.7 J/K (D) +4030 J/K

8. When a gas is expanded adiabatically and reversibly, then:
 (A) $\Delta H > 0$ & $\Delta S < 0$ (B) $\Delta H < 0$ & $\Delta S = 0$ (C) $\Delta H < 0$ & $\Delta S > 0$ (D) $\Delta H > 0$ & $\Delta S = 0$
9. The normal melting point of toluene is $-95\text{ }^\circ\text{C}$. The enthalpy of fusion of toluene is 6.6 kJ/mol . What is the entropy change of the **system** when one mole of liquid toluene crystallizes to solid toluene at $-95\text{ }^\circ\text{C}$?
 (A) $+69\text{ J/mol-K}$ (B) $+37\text{ J/mol-K}$ (C) -37 J/mol-K (D) -69 J/mol-K
10. The normal boiling point of toluene is $111\text{ }^\circ\text{C}$. The enthalpy of vaporization of toluene is 39.2 kJ/mol . What is the entropy change of the **surroundings** when one mole of toluene vaporizes at $111\text{ }^\circ\text{C}$?
 (A) -102 J/mol-K (B) $+35.3\text{ J/mol-K}$ (C) $+102\text{ J/mol-K}$ (D) -353 J/mol-K
11. The reaction, $A \rightarrow B$, is **endergonic** at $25\text{ }^\circ\text{C}$ and the entropy change is $+40\text{ J/K}$. What can be concluded about the enthalpy change for this reaction?
 (A) $\Delta H < -11.9\text{ kJ}$ (B) $\Delta H > +11.9\text{ kJ}$ (C) $\Delta H > 18.4\text{ kJ}$
 (D) No conclusion can be made about ΔH
12. For the **exergonic** reaction, $C \rightarrow D$, $\Delta H = +25\text{ kJ}$. For this reaction,
 (A) $\Delta G < 0$ & $\Delta S < 0$ (B) $\Delta G > 0$ & $\Delta S > 0$ (C) $\Delta G > 0$ & $\Delta S < 0$ (D) $\Delta G < 0$ & $\Delta S > 0$
13. The Enthalpy of Fusion of acetone is 5.7 kJ/mol . The Entropy of Fusion of Acetone is 32.0 J/mol-K . What is ΔG when 1 mole of liquid acetone is crystallized to the solid at $20\text{ }^\circ\text{C}$?
 (A) $+3.7\text{ kJ}$ (B) 0 kJ (C) -3.7 kJ (D) -15.1 kJ
14. The enthalpy and entropy changes for the denaturation of one mole of a protein, Native \rightarrow Random Coil, are $+280\text{ kJ/mol}$ and $+800\text{ J/mol-K}$, respectively. Over what temperature range, **in degrees Celsius**, is this transition spontaneous?
 (A) Below $77\text{ }^\circ\text{C}$ (B) Below $350\text{ }^\circ\text{C}$ (C) Above $77\text{ }^\circ\text{C}$ (D) Above $350\text{ }^\circ\text{C}$
15. The pairing of bases in the formation of doubly stranded DNA is
 (A) Favored by both ΔH and ΔS (B) Favored by ΔH , but not by ΔS
 (C) Favored by ΔS , but not by ΔH (D) Not favored by either ΔH or ΔS
16. Spooky McSchwartz (aka "The Spookman") recently developed a new, high efficiency, cycle for the metabolism of Swanson Chunk Tuna. In the MM cycle, ΔG° for the metabolism of one mole of Tuna is -1100 kJ and the cycle converts 25 moles of ADP to ATP. If $\Delta G^\circ = 30\text{ kJ}$ for the conversion of one mole of ADP to ATP, then the energy storage efficiency of Spooky's cycle is:
 (A) 83% (B) 41% (C) 28% (D) 68%

For #17 - #19, consider the phase diagram to the right



17. At temperatures below the triple point temperature, this substance can exist as:
- (A) vapor only (B) solid or liquid or vapor
(C) liquid or vapor only (D) solid or vapor only
18. The slope of curve A-D is steeper than the slope of curve A-C because
- (A) $\Delta_{\text{sub}}S > \Delta_{\text{vap}}S$ (B) $\Delta_{\text{vap}}S > \Delta_{\text{sub}}S$ (C) $\Delta_{\text{sub}}V > \Delta_{\text{vap}}V$ (D) $\Delta_{\text{sub}}V < \Delta_{\text{vap}}V$
19. If the pressure on this substance is increased from 1 bar to 500 bar, the melting point will _____ and the boiling point will _____.
- (A) decrease, increase (B) increase, increase (C) increase, decrease
(D) increase/decrease depends on relative solid and liquid entropies, increase

PART II. TWO (2) PROBLEMS ON FOLLOWING PAGES (Show work for partial credit)

- (10) 1. The normal boiling point of liquid pyridine is $116\text{ }^{\circ}\text{C}^*$, and the Enthalpy of Vaporization of pyridine is 40.3 kJ/mol .

Calculate the temperature, in $^{\circ}\text{C}$, at which the vapor pressure of pyridine is 20 kPa .

*This is the temperature at which the vapor pressure of the liquid is 1.0 bar

$$\Delta_{\text{vap}} H = 40.3\text{ kJ/mol} \quad P_1 = 1\text{ bar} = 100\text{ kPa} \quad P_2 = 20\text{ kPa}$$

$$= 4.03 \times 10^4\text{ J/mol} \quad T_1 = 116^{\circ}\text{C} = 389\text{ K} \quad T_2 = ?$$

$$\ln\left(\frac{P_2}{P_1}\right) = -\frac{\Delta_{\text{vap}} H}{R} \left[\frac{1}{T_2} - \frac{1}{T_1}\right] \rightarrow \frac{1}{T_2} - \frac{1}{T_1} = \frac{-R}{\Delta_{\text{vap}} H} \ln\left(\frac{P_2}{P_1}\right)$$

$$\frac{1}{T_2} = \frac{1}{T_1} - \frac{R}{\Delta_{\text{vap}} H} \ln\left(\frac{P_2}{P_1}\right)$$

$$= \frac{1}{389\text{ K}} - \frac{8.31\text{ J/mol}\cdot\text{K}}{4.03 \times 10^4\text{ J/mol}} \ln\left(\frac{20}{100}\right)$$

$$\frac{1}{T_2} = 2.903 \times 10^{-3}\text{ K}^{-1}$$

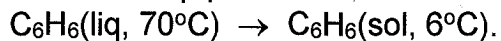
$$T_2 = \frac{1}{2.903 \times 10^{-3}\text{ K}^{-1}} = 345\text{ K} - 273$$

$$= \boxed{72^{\circ}\text{C}}$$

$$T_1 = 70^\circ\text{C} = 343\text{ K} \quad T_2 = 6^\circ\text{C} = 279\text{ K}$$

- (14) 2. The constant pressure molar heat capacity of benzene liquid [$\text{C}_6\text{H}_6(\text{liq})$] is $135\text{ J/mol}\cdot\text{K}$. The melting point of benzene is 6°C . The Enthalpy of Fusion of benzene is 9.8 kJ/mol . Consider the process in which **three (3)** moles of liquid benzene are (1) cooled from 70°C to the melting point, and (2) is crystallized to the solid:

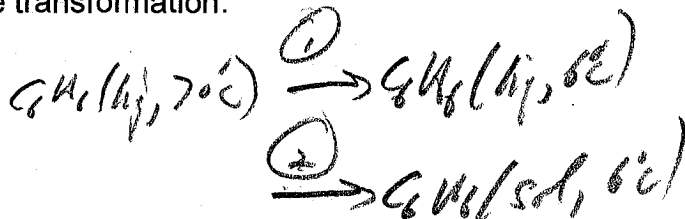
This two step process results in the transformation:



For this process, calculate:

(9) (a) ΔS (in J/K)

(5) (b) ΔH (in kJ)



$$\textcircled{a} \Delta S_1(\text{cool}) = n C_{p,m} \ln\left(\frac{T_2}{T_1}\right) = 3(135) \ln\left(\frac{279}{343}\right) = \boxed{-83.6} \text{ J/K}$$

$$\Delta_{\text{cool}} H = -\Delta_{\text{fus}} H = -9.8 \text{ kJ/mol} = -9800 \text{ J/mol}$$

$$\Delta S_2(\text{crys}) = \frac{n \Delta_{\text{cool}} H}{T} = \frac{3(-9800)}{279} = \boxed{-105.4} \text{ J/K}$$

$$\Delta S = -83.6 - 105.4 = \boxed{-189} \text{ J/K}$$

$$\textcircled{b} \Delta H_1(\text{cool}) = n C_{p,m} (T_2 - T_1) = 3(135)(279 - 343)$$

$$= -2.59 \times 10^4 \text{ J} = \boxed{-25.9} \text{ kJ}$$

$$\Delta H_2(\text{crys}) = n(\Delta_{\text{cool}} H) = 3(-9.8 \text{ kJ}) = \boxed{-29.4} \text{ kJ}$$

$$\Delta H = -25.9 - 29.4 = \boxed{-55.3} \text{ kJ}$$