CHEM 5200 - Exam 2 - October 17, 2017

INFORMATION PAGE (Use for reference and for scratch paper)

Constants and Conversion Factors:

R = 0.082 L-atm/mol-K = 8.31 J/mol-K = 8.31 kPa-L/mol-K

1 L-atm = 101 J

1 L-bar = 100 J

1 kPa-L = 1 J

1 bar = 100 kPa

1 bar = 750 torr

1 atm = 760 torr

Trouton's Rule: $\Delta_{vap}S^o$ = 85. J/mol-K

The relation between the Molar Mass (M), density (ρ) and Molar Volume (V_m) of a material is: $\rho = \frac{M}{V_m}$

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Name______________________________

(45) MULTIPLE CHOICE [3 points per question] (Circle the ONE correct answer)

For #1 - #2: Consider the reaction, 2 $N_2O_5(g) \rightarrow$ 4 $NO_2(g)$ + $O_2(g)$. Relevant thermodynamic data is given in the table below:

Compound	**S_m^o**	**$\Delta_f G^o$**
$NO_2(g)$	240. J/mol-K	+51. kJ/mol
$O_2(g)$	205.	
$N_2O_5(g)$	356.	+115.

1. The Gibbs Energy Change ($\Delta_r G^o$) for the above reaction at 25 ^oC (in kJ) is approximately:

   (A) -128. kJ (B) -26. kJ (C) +26. kJ

   (D) Insufficient data is given

2. The standard Enthalpy Change ($\Delta_r H^o$) for the above reaction at 25 ^oC (in kJ) is approximately:

   (A) -161 kJ (B) +109 kJ (C) -109. kJ

   (D) Insufficient data is given

3. When two (2) moles of $N_2(g)$ at 25 ^oC and 50 L are compressed reversibly and isothermally to a final volume of 20 L, the entropy change is

   (A) -7.6 J/K (B) +15.2 J/K (C) -4.5 kJ/K (D) -15.2 J/K

4. The **constant pressure** molar heat capacity of $CO_2(g)$ is 37.1 J/mol-K. What is ΔS when 5 moles of $CO_2(g)$ is heated at **constant volume** from 100 ^oC to 400 ^oC?

   (A) +25 J/K (B) +109 J/K (C) +85 J/K (D) +300 J/K

5. A sample of 2 moles of $N_2(g)$ at 50 kPa and 20 L is compressed **reversibly** and **adiabatically** to a final pressure of 400 kPa. What is ΔS for this process?

   (A) +34.6 J/K (B) 0 J/K (C) -34.6 J/K (D) -97.4 J/K

6. The normal boiling point of napthalene, $C_{10}H_8$, is 218 ^oC. An estimate of the Enthalpy of Vaporization of Napthalene using Trouton's Rule is:

   (A) 41.7 kJ/mol (B) 52.1 kJ/mol (C) 18.5 kJ/mol (D) 28.9 kJ/mol

7. The normal boiling point of methanol is 64 ^oC. The Enthalpy of Vaporization of methanol is 35.3 kJ/mol. What is the entropy change of the **system** when **two (2)** moles of liquid methanol are vaporized reversibly to the gas at 64 ^oC?

   (A) +210 J/K (B) +105 J/K (C) -105 J/K (D) -210 J/K

8. The normal melting point of mercury is -39 ^oC. The enthalpy of fusion of mercury is 2.3 kJ/mol. What is the entropy change of the **surroundings** when **4 (four)** moles of liquid mercury are crystallized to the solid reversibly at -39 ^oC?

   (A) +9.8 J/K (B) -39.3 J/K (C) -9.8 J/K (D) +39.3 J/K

9. The change in the Gibbs energy (**in kJ**) when the volume of **2.5 moles** of ethane gas [C_2H_6(g)] is increased from isothermally 0.50 Liters to 10 Liters at 300 ^oC is:

   (A) +35.7 kJ (B) +14.3 kJ (C) -35.7 kJ (D) -18.7 kJ

10. The density of liquid toluene, C_7H_8(l) [M=92], is 0.90 g/mL at 50 ^oC. Therefore, the change in the Gibbs energy [in J] of **one(1)** mole of liquid toluene when the pressure is **increased** isothermally from 100 kPa to 5,000 kPa at 50 ^oC is approximately

    (A) 1.6×10^3 J (B) 5.0×10^2 J (C) 1.1×10^4 J (D) 5.0×10^5 J

11. A solid has two crystalline forms, A(s) and B(s). For the transition A(s) $\rightarrow$ B(s), ΔG^o = -9.0 kJ/mol (i.e. at 1 bar pressure). The difference in molar volumes of the two forms is $V_m(B) - V_m(A) = \Delta V_m = +2.0 \times 10^{-2}$ L/mol. This transition will be **spontaneous** at pressures _______ a pressure of _____bar.

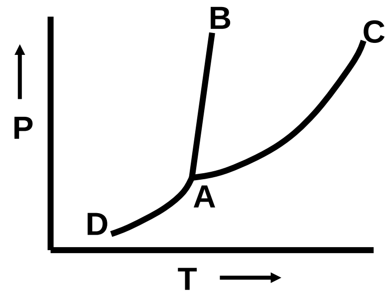
    (A) above , 4.5×10^5 bar (B) above , 4500 bar

    (C) below , 4500 bar (D) Spontaneous at all pressures

There are Four more MC questions on the following page

MULTIPLE CHOICE QUESTIONS (Continued)

For #12 - #15, consider the phase diagram to the right



12. The Critical Point of the substance is represented by:

    (A) Point A (B) Point B (C) Point C (D) Point D

13. The slope of curve A-D is **greater** than the slope of curve A-C because

    (A) $\Delta_{sub}V > \Delta_{vap}V$ (B) $\Delta_{vap}S > \Delta_{sub}S$

    (C) $\Delta_{sub}S > \Delta_{vap}S$ (D) $\Delta_{sub}V < \Delta_{vap}V$

14. The slope of curve A-B is **much greater** than the slope of curve A-C because

    (A) $\Delta_{fus}V < 0$ (B) $\Delta_{fus}V << \Delta_{vap}V$

    (C) $\Delta_{fus}S << \Delta_{vap}S$ (D) $\Delta_{fus}S >> \Delta_{vap}S$

15. If the pressure on this substance is **decreased** from 2000. bar to 1. bar, the melting point temperature will _______ and the boiling point temperature will _______

    (A) Decrease, Decrease (B) Increase, Decrease

    (C) Decrease, Increase (D) Increase, Increase

Four (4) Problems on following pages.

(12) 1. A Perfect Gas has a temperature dependent molar constant pressure heat capacity, $C_{p,m} = a + bT^3$ with a = 30 J/mol-K and b = 8x10^{-8} J/(mol-K^4).

Two (2) moles of this gas, originally at a temperature,of 250 ^oC and volume of 30. L is heated reversibly at **constant pressure** to a temperature of 600 ^oC.

Calculate the Entropy change, ΔS, for this process (in J/K)

(15) 2. Consider a hypothetical gas that obeys the equation of state:

$p(V-Ap) = nRT$ **Note: A** is an arbitrary constant, and NOT the Helmholtz Energy.

If this gas undergoes an isothermal compression from p_1 to p_2, develop **INTEGRATED** expressions for ΔU, ΔH and ΔA in terms of n, R, T, A, p_1 and p_2.

(16) 3. The normal boiling point of Bromine liquid, Br_2(liq) is 59 ^oC.
The Enthalpy of Vaporization is 29.5 kJ/mol at 59 ^oC.
The constant pressure molar heat capacity of bromine liquid, Br_2(liq) is 76. J/mol-K
The constant pressure molar heat capacity of bromine gas, Br_2(gas), is 36. J/mol-K.

Calculate the entropy change of the **Surroundings**, $\boldsymbol{\Delta S_{surr}}$, (in J/mol-K) when one (1) mole of supercooled Br_2(gas) condenses to Br_2(liq) at 35 ^oC.

(12) 4 The densities of solid and liquid copper [Cu, M = 63.5] are 8.9 g/mL and 8.0 g/mL, respectively. The normal melting point of copper is 1085 ^{o}C. The enthalpy of fusion of copper is 13.3 kJ/mol.

What pressure must be applied (in bar) to increase melting point of Cu to 1100 ^{o}C?