

CHEM 5200 - Exam 2 - October 11, 2018

INFORMATION PAGE (Use for reference and for scratch paper)

Constants and Conversion Factors:

$$R = 0.082 \text{ L-atm/mol-K} = 8.31 \text{ J/mol-K} = 8.31 \text{ kPa-L/mol-K}$$

$$1 \text{ L-atm} = 101 \text{ J}$$

$$1 \text{ L-bar} = 100 \text{ J}$$

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

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

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

$$1 \text{ atm} = 760 \text{ torr}$$

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

The relation between the Molar Mass (M), density (ρ) and Molar Volume (V_m)

of a material is: $\rho = \frac{M}{V_m}$

NOTE: if a question asks for the value of ΔS (without stating it's the "surroundings"), it is asking for the value of ΔS for the system.

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

1. The entropy change is +237 J/K for the reaction: $2 \text{HgO}(s) \rightarrow 2 \text{Hg}(l) + \text{O}_2(g)$. The standard molar entropies of $\text{HgO}(s)$ and $\text{O}_2(g)$ are 70 J/mol-K and 205 J/mol-K. Therefore, the standard molar entropy of $\text{Hg}(l)$ is:

(A) 86 J/mol-K (B) 0 J/mol-K (C) 51 J/mol-K (D) 102 J/K

For #2: Consider the reaction, $2 \text{SO}_2(g) + \text{O}_2(g) \rightarrow 2 \text{SO}_3(g)$. Relevant thermodynamic data is given in the table below:

Compound	S_m°	$\Delta_f G^\circ$
$\text{SO}_2(g)$	248 J/mol-K	-350 kJ/mol
$\text{O}_2(g)$	205	
$\text{SO}_3(g)$	257	-371

2. The Enthalpy change (ΔH°) change for the above reaction at 25 °C is:
- (A) +13.7 kJ (B) -46.7 kJ (C) -97.7 kJ
(D) There is insufficient data
3. A sample of 0.5 moles of $\text{O}_2(g)$ 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) +4030 J/K (D) +6.7 J/K
4. The **constant volume** molar heat capacity of $\text{Ar}(g)$ is 12.5 J/mol-K. What is ΔS when 3 moles of $\text{Ar}(g)$ is cooled at **constant pressure** from 500 °C to 100 °C?
- (A) +27.3 J/K (B) -45.5 J/K (C) -100.5 J/K (D) -27.3 J/K
5. A sample of 3 moles of $\text{O}_2(g)$ at an initial temperature of 100 °C and initial volume of 60 L is expanded **reversibly** and **adiabatically** to a final volume of 200 L. What is ΔS for this process?
- (A) -30 J/K (B) +11.2 kJ/K (C) 0 kJ/K (D) +30 J/K

For #6 - #8: The normal boiling point of methanol [CH₃OH, M=32] is 65 °C. The Enthalpy of Vaporization of methanol is 35.2 kJ/mol.

80 grams of methanol gas are condensed to the liquid at 65 °C and 1 bar pressure.

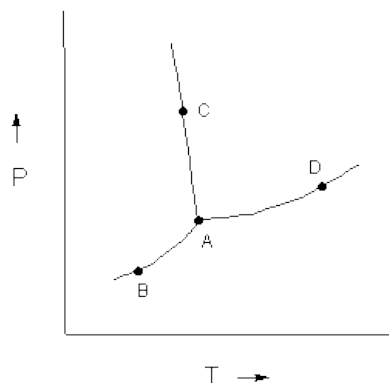
Calculate the following quantities for this condensation:

6. The Entropy Change, ΔS , for this process is approximately
(A) +260 J/K (B) -104 J/K (C) -260 J/K
(D) None of the above
7. The work, w , for this process is approximately
(A) +7.0 kJ (B) +8.8 kJ (C) -7.0 kJ
(D) None of the above
8. The Internal Energy change, ΔU for this process is approximately
(A) -95 kJ (B) -81 kJ (C) -88 kJ
(D) None of the above
9. The normal boiling point of toluene is 111 °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 °C?
(A) +102 J/mol-K (B) +35.3 J/mol-K (C) -102 J/mol-K (D) -353 J/mol-K
10. The Enthalpy of Vaporization of cyclooctane, C₈H₁₆, is 37.0 kJ/mol. An estimate of the normal boiling point (**in °C**) of cyclooctane using Trouton's Rule is:
(A) 128 °C (B) 435 °C (C) 294 °C (D) 162 °C
11. The change in the Gibbs Energy for a certain constant pressure process is given by:
 $\Delta G = a + bT^2$, $a = 4,000 \text{ J}$, $b = 5. \times 10^{-2} \text{ J/K}^2$. The value of ΔS for this process at 50 °C is approximately:
(A) -16 J/K (B) -32 J/K (C) 0 J/K (D) +32 J/K
12. The density of liquid benzene, C₆H₆(l) [M=78], is 0.85 g/mL at 50 °C. Therefore, the change in the Gibbs energy [in J] of **one(1)** mole of benzene when the pressure is **increased** isothermally from 100 kPa to 10,000 kPa at 50 °C is approximately
(A) 910 J (B) $9.1 \times 10^4 \text{ J}$ (C) $1.2 \times 10^4 \text{ J}$ (D) 770 J

There are Five more MC questions on the following page

13. A solid has two crystalline forms, A(s) and B(s). For the transition $A(s) \rightarrow B(s)$, $\Delta G^\circ = +10. \text{ kJ/mol}$ (i.e. at 1 bar pressure). The difference in molar volumes of the two forms is $V_m(B) - V_m(A) = \Delta V_m = -25. \text{ mL/mol}$. This transition will be **spontaneous** at pressures _____ a pressure of _____ bar.
- (A) above , 4×10^5 bar (B) below , 4000 bar
 (C) above , 4000 bar (D) Not spontaneous at any pressure

For #14 - #17, consider the phase diagram on the right.



14. The Triple Point in the diagram is represented by
 (A) Point A (B) Point B (C) Point C (D) Point D
15. The slope of curve A-B is steeper than the slope of curve A-D because
 (A) $\Delta_{\text{vap}}S > \Delta_{\text{sub}}S$ (B) $\Delta_{\text{sub}}S > \Delta_{\text{vap}}S$
 (C) $\Delta_{\text{sub}}V > \Delta_{\text{vap}}V$ (D) $\Delta_{\text{sub}}V < \Delta_{\text{vap}}V$
16. The slope of curve A-C is negative because
 (A) $\Delta_{\text{fus}}S^\circ > 0$ (B) $\Delta_{\text{fus}}S^\circ < 0$
 (C) $V_m(\text{liq}) > V_m(\text{sol})$ (D) $V_m(\text{sol}) > V_m(\text{liq})$
17. If the pressure on this substance is increased from 1 bar to 500 bar, the boiling point will _____ and the melting point will _____.
- (A) decrease, increase
 (B) increase, increase
 (C) increase, decrease
 (D) increase/ increase or decrease depends on relative solid and liquid entropies

There are Three (3) Problems on following pages.

(18) 1. A Perfect Gas has a temperature dependent **constant pressure** molar heat capacity, $C_{p,m} = a - \frac{b}{T^2}$, with $a = 75. \text{ J/mol-K}$ and $b = 3.0 \times 10^6 \text{ J}\cdot\text{K/mol}$.

3 moles of this gas, originally at a temperature of $100 \text{ }^\circ\text{C}$ and volume of $75. \text{ L}$ is heated reversibly at **constant pressure** to $400 \text{ }^\circ\text{C}$.

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

Part (b) is on following page

(18) 1. **CONT'D.**

A Perfect Gas has a temperature dependent **constant pressure** molar heat

capacity, $C_{p,m} = a - \frac{b}{T^2}$, with $a = 75. \text{ J/mol-K}$ and $b = 3.0 \times 10^6 \text{ J}\cdot\text{K/mol}$.

3 moles of this gas, originally at a temperature of $100 \text{ }^\circ\text{C}$ and volume of $75. \text{ L}$ is heated reversibly at **constant pressure** to $400 \text{ }^\circ\text{C}$.

(9) (b) Calculate the heat (q) and work (w) for this process (in kJ).

- (16) 2. The normal melting point of CHCl_3 is $-63\text{ }^\circ\text{C}$.
The Enthalpy of Fusion of CHCl_2 at $-63\text{ }^\circ\text{C}$ is 8.80 kJ/mol
The constant pressure heat capacity of liquid CHCl_3 is 116 J/mol-K
The constant pressure heat capacity of solid CHCl_3 is 96 J/mol-K

Calculate the entropy change of the **system**, ΔS_{sys} , when one (1) mole of liquid trichloromethane freezes irreversibly to the solid at $-90\text{ }^\circ\text{C}$.

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

$$(p + BV^2)V = RT, \text{ where } B \text{ is a constant}$$

If this gas undergoes an isothermal expansion from V_1 to V_2 , develop **INTEGRATED** expressions for ΔU , ΔH and ΔG in terms of B , R , T , V_1 and V_2 .