

CHEM 5200 - Exam 1 - September 20, 2018

INFORMATION PAGE (Use for reference and for scratch paper)

Constants and Conversion Factors:

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

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

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

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

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

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

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

$$1 \text{ atm} = 1.013 \text{ bar} = 1.013 \times 10^5 \text{ Pa}$$

Relations for Adiabatic Expansions and Compressions of a Perfect Gas

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2} \right)^{R/C_{v,m}} \quad \text{or} \quad \frac{p_2}{p_1} = \left(\frac{V_1}{V_2} \right)^{C_{p,m}/C_{v,m}} = \left(\frac{V_1}{V_2} \right)^\gamma \quad \gamma = \frac{C_{p,m}}{C_{v,m}}$$

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Name _____

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

1. What are q and ΔU when 1.5 moles of a perfect gas is expanded reversibly and isothermally from 3.0 L to 20 L at 30 °C?
(A) $q = +7.2$ kJ and $\Delta U = 0$ (B) $q = +7.2$ kJ and $\Delta U = -7.2$ kJ
(C) $q = 0$ and $\Delta U = -7.2$ kJ (D) $q = -7.2$ kJ and $\Delta U = 0$
2. The molar **constant volume** heat capacity of $O_2(g)$ is constant at $C_{V,m} = 24.5$ J/mol-K. You can assume that $O_2(g)$ is a Perfect Gas. When 5. moles of $O_2(g)$ is heated **at constant pressure** from 100 °C to 300 °C,
(A) $\Delta H = +24.5$ kJ & $w = +8.3$ kJ (B) $\Delta H = +24.5$ kJ & $w = -8.3$ kJ
(C) $\Delta H = +32.8$ kJ & $w = -8.3$ kJ (D) $\Delta H = +32.8$ kJ & $w = +8.3$ kJ
3. For the reaction of one(1) mole of gaseous pentane, $C_5H_{12}(gas)$, with $O_2(gas)$ to form $CO_2(gas)$ and $H_2O(liq)$, at 75 °C, the internal energy change is $\Delta U = -3524$ kJ. ΔH for this reaction at 75 °C is approximately.
(A) -3512 kJ (B) -3518 kJ (C) -3530 kJ (D) -3536 kJ
4. Consider the non-linear molecule, Ethylene ($CH_2=CH_2$) . What is the **constant pressure molar heat capacity**, $C_{p,m}$, of Ethylene, assuming that the molecules are free to translate C, rotate and vibrate?
(A) 15.0 R (B) 15.5 R (C) 16.0 R (D) 16.5 R
5. Sodium metal reacts with hydrochloric acid according to the equation:
 $2 Na(s) + 2 HCl(aq) \rightarrow 2 NaCl(aq) + H_2(g)$.
What is the work, w , when five(5) moles of $Na(s)$ reacts with $HCl(aq)$ at 25 °C and 1 atm. pressure?
(A) -0.5 kJ (B) -6.2 kJ (C) -12.4 kJ (D) +6.2 kJ
6. Consider the following Thermochemical equations:
 $2 SO_2(g) + O_2(g) \rightarrow 2 SO_3(g) \quad \Delta H = -196$ kJ
 $4 S(s) + 6 O_2(g) \rightarrow 4 SO_3(g) \quad \Delta H = -1580$ kJ
Use these equations to determine ΔH for the reaction, $S(s) + O_2(g) \rightarrow SO_2(g)$.
(A) -297 kJ (B) -493 kJ (C) -692 kJ (D) +493 kJ

7. 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) -111 kJ/mol (B) -166.5 kJ/mol (C) -127 kJ/mol
 (D) Cannot be determined without the Enthalpy of Formation of $\text{Fe}(\text{s})$

8. The isothermal compressibility of a substance is defined by: $\pi_T = -\frac{1}{V} \left(\frac{\partial V}{\partial p} \right)_T$

Consider a hypothetical gas which follows the Equation of State: $p^2V = nRT$
 The isothermal compressibility of this hypothetical gas is given by:

- (A) $\frac{1}{T}$ (B) $\frac{1}{p}$ (C) $\frac{2V}{p}$ (D) $\frac{2}{p}$

9. The derivative, $\left(\frac{\partial U}{\partial p} \right)_T$, is a measure of the change in Internal Energy when the pressure is varied at constant temperature. For a gas in which **repulsive** interactions between molecules predominate, when the pressure on one mole of the gas is **decreased** isothermally from 5.bar to 1. bar then:

- (A) $\left(\frac{\partial U}{\partial p} \right)_T < 0$, $\Delta U < 0$ (B) $\left(\frac{\partial U}{\partial p} \right)_T < 0$, $\Delta U > 0$
 (C) $\left(\frac{\partial U}{\partial p} \right)_T > 0$, $\Delta U < 0$ (D) $\left(\frac{\partial U}{\partial p} \right)_T > 0$, $\Delta U > 0$

FIVE(5) PROBLEMS on following pages:

NOTE: You Must show your work to receive credit.

(12) 1. Starting with the differential form of the First Law, applied to a Perfect Gas:

$$dU = dq + dw \quad \text{or} \quad nC_{V,m}dT = dq - pdV,$$

Prove that for a reversible adiabatic expansion (or compression) of a Perfect Gas,

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2} \right)^{R/C_{V,m}}$$

You MUST show all steps to receive credit on this derivation.

- (15) 2. Three (3) moles of a perfect gas, originally at a pressure of 80 kPa and volume of 100 L is compressed adiabatically and reversibly until the volume has decreased to 25 L. The constant volume molar heat capacity of the gas is $C_{V,m} = 26.5 \text{ J/mol-K}$

Calculate ΔU , ΔH and w for this compression (in kJ).

- (14) 3. Solid Carbon Dioxide (CO_2) sublimes directly to the gas at $-78\text{ }^\circ\text{C}$. The Enthalpy of Sublimation of CO_2 is 25.2 kJ/mol .

Calculation w , q , and ΔU (all in kJ) when five(5) moles of gaseous CO_2 is converted to the solid (i.e. deposited) at $-78\text{ }^\circ\text{C}$ and 1 bar pressure.

(18) 4. A Perfect Gas has a temperature dependent **constant volume** molar heat capacity,

$$C_{v,m} = a - \frac{b}{T^2}, \text{ with } a = 65. \text{ J/mol-K and } b = 2.5 \times 10^6 \text{ J}\cdot\text{K/mol.}$$

1.5 moles of this gas, originally at a temperature of 900 K and volume of 50. L is cooled reversibly at **constant volume** to 300 K.

Calculate q , w , ΔU and ΔH for this process, in kJ.

(14) 5. Consider one mole of a gas which obeys the equation of state,

$$p\left(V - \frac{A}{p^2}\right) = RT \text{ with } A = 25. \text{ L-atm}^2$$

It can be shown that the dependence of enthalpy on pressure is given by:

$$\left(\frac{\partial H}{\partial p}\right)_T = V - T\left(\frac{\partial V}{\partial T}\right)_p$$

Calculate the change in enthalpy, ΔH (in in kJ) when one mole of this gas is compressed reversibly and isothermally from $p_1 = 2.0$ atm. to $p_2 = 5.0$ atm. at 25°C .

Notes: 1. $\Delta H \neq 0$ because this is **NOT** a Perfect Gas
2. 1 L-atm = 101 J