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 atm = 760 torr

1 atm = 1.013 bar = 1.013×10^5 Pa

Relations for Adiabatic Expansions and Compressions of a Perfect Gas

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

Name_____

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

1. What are w and ΔU when 3. moles of a gas is compressed isothermally and reversibly from 30 L to 2 L at 50 °C?

    (A) w= 0 and ΔU= +21.8 kJ   (B) w= -21.8 kJ and ΔU=0

    (C) w= +21.8 kJ and ΔU= -21.8 kJ   (D) w=+21.8 kJ and ΔU= 0

2. When a gas is cooled at constant volume,

    (A) ΔU<0 & w<0   (B) ΔU<0 & w>0   (C) ΔU>0 & w=0   (D) ΔU<0 & w=0

3. Solid Nickel reacts with gaseous carbon monoxide to form solid nickel tetracarbonyl according to the equation. $Ni(sol) + 4\ CO(gas) \rightarrow Ni(CO)_4(liq)$. What is the work involved when 3. moles of Ni(sol) react with CO(gas) to form $Ni(CO)_4$(liq) at 100 °C and 1 bar pressure?

    (A) +12.4 kJ   (B) +37.2 kJ   (C) -12.4 kJ   (D) -37.2 kJ

4. The molar constant volume heat capacity of CO_2(g) is constant at $C_{V,m}$ = 28.2 J/mol-K. You can assume that CO_2(g) is a Perfect Gas. When 4. moles of CO_2(g) is heated from 100 °C to 250 °C,

    (A) ΔH = +11.9 kJ & ΔU = +16.9 kJ   (B) ΔH = +16.9 kJ & ΔU = +21.9 kJ

    (C) ΔH = +5.5 kJ & ΔU = +4.2 kJ   (D) ΔH = +21.9 kJ & ΔU = +16.9 kJ

5. The **constant pressure** molar heat capacity of a Perfect Gas is: $C_{p,m}$ = 21.0 J/mol-K. When a sample of this gas originally at a pressure of 2. bar and volume of 50. L is **compressed adiabatically and reversibly** to a final volume of 20. L. What is the approximate final pressure of the gas?

    (A) 4.6 bar   (B) 5.0 bar   (C) 7.2 bar   (D) 9.1 bar

6. For the reaction, $2\ SO_3(g) \rightarrow 2\ SO_2(g) + O_2(g)$, $\Delta H°$ = +200 kJ. The Enthalpy of Formation of SO_3(g) is −397 kJ/mol. What is the Enthalpy of Formation of SO_2(g)?

    (A) -297 kJ   (B) +497 kJ   (C) -497 kJ   (D) +297 kJ

7. What is the work involved when five(5) moles of liquid chlorobenzene vaporizes to the gas at its boiling point, 131 °C ?

    (A) -16.8 kJ   (B) +3.4 kJ   (C) -3.4 kJ   (D) +16.8 kJ

8. The thermal expansion coefficient of a substance is defined by:

$$\alpha = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_p$$ Consider a hypothetical gas which follows the Equation of State:

$$pV = nRT^2$$

The thermal expansion coefficient of this hypothetical gas is given by:

(A) $\dfrac{2nRT}{p}$ (B) $\dfrac{2}{T}$ (C) $\dfrac{2}{p}$ (D) $\dfrac{3}{T}$

9, The internal pressure is defined by, $\pi_T = \left(\dfrac{\partial U}{\partial V}\right)_T$, and is a measure of attractive or repulsive forces between molecules in real gases. Consider a gas in which **attractive** interactions between molecules predominate. When one mole of this gas is compressed isothermally from 1 bar pressure to 10 bar pressure:

(A) $\pi_T > 0$, $\Delta U > 0$ (B) $\pi_T < 0$, $\Delta U > 0$

(C) $\pi_T > 0$, $\Delta U < 0$ (D) $\pi_T < 0$, $\Delta U < 0$
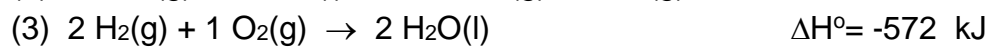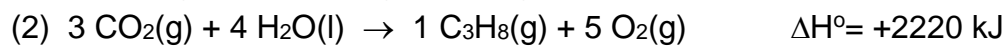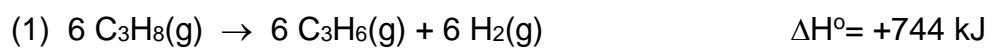
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FIVE(5) PROBLEMS on following pages:

NOTE: You Must show your work to receive credit.

(11) 1. Starting with the total differential for V(p,T), prove that: $\left(\dfrac{\partial p}{\partial T}\right)_V = \dfrac{\alpha}{\kappa_T}$,

where $\alpha = \dfrac{1}{V}\left(\dfrac{\partial V}{\partial T}\right)_p$ and $\kappa_T = -\dfrac{1}{V}\left(\dfrac{\partial V}{\partial p}\right)_T$

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

(14) 2. From the following enthalpies of reaction,

(1) $6\ C_3H_8(g) \rightarrow 6\ C_3H_6(g) + 6\ H_2(g)$ $\qquad\qquad\qquad$ $\Delta H° = +744\ kJ$

(2) $3\ CO_2(g) + 4\ H_2O(l) \rightarrow 1\ C_3H_8(g) + 5\ O_2(g)$ $\qquad$ $\Delta H° = +2220\ kJ$

(3) $2\ H_2(g) + 1\ O_2(g) \rightarrow 2\ H_2O(l)$ $\qquad\qquad\qquad\quad$ $\Delta H° = -572\ kJ$

Calculate $\Delta H°$ for the reaction, $2\ C_3H_6(g) + 9\ O_2(g) \rightarrow 6\ CO_2(g) + 6\ H_2O(l)$

(16) 3. The Enthalpy of Vaporization of Napthalene is 56.0 kJ/mol and the normal boiling point is 218 °C.

Calculation w, q, ΔU and ΔH (all in kJ) when four (4) moles of gaseous Napthalene are condensed to the liquid at 218 °C and 1 atm pressure. Nap (gas) $\rightarrow$ Nap (liq)

(18) 4.   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-K⁴).

Two (2) moles of this gas, originally at a temperature,of 300 K and volume of 20. L is heated reversibly at **constant pressure** to a temperature of 800 K.

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

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

$$\left(p + \frac{A}{V^3}\right)V = RT \quad \text{with } A = 2.5 \text{ L}^3 \text{ atm}$$

It can be shown that the dependence of internal energy on volume is:

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

Calculate the change in internal energy, ΔU (in in J) when one mole of this gas is expanded reversibly and isothermally from $V_1 = 0.50$ L to $V_2 = 0.90$ L.

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