

**Answer the following multiple choice questions for 10 points each.  
 Must show complete work for full credit to be given:**

- To design a particular kind of refrigerator we need to know the temperature reduction brought about by the adiabatic expansion of the freon. One type of freon has  $\mu_{JT} = 1.5 \text{ K atm}^{-1}$ . What pressure difference is needed to produce a temperature drop of 4.5 K?  
 A) 0.333 atm      B) 1.333 atm      C) 3.000 atm      D) 4.000 atm      E) 5.000 atm
- For a gas at constant pressure and temperature, if the intermolecular attractions are significantly increased, the effect on the molar volume ( $V_m$ ) and compression factor ( $Z$ ) are:  
 A) Both unchanged      C) Both increase      E) Both decrease  
 B)  $Z$  increases and  $V_m$  decreases      D)  $Z$  decreases and  $V_m$  increases
- For the reaction  $3 \text{ O}_2 (\text{g}) \rightarrow 2 \text{ O}_3 (\text{g})$ ,  $H_{\text{rxn}} = +285.4 \text{ kJ mol}^{-1}$  at 300K and 1 atm pressure. The  $C_{p,m}$  for  $\text{O}_2$  and  $\text{O}_3$  are 29.35 and 39.20  $\text{J mol}^{-1} \text{ K}^{-1}$  respectively and are roughly constant from 200 to 600 K. Calculate the  $H_{\text{rxn}}$  at 550 K and 1 atm pressure.  
 A) +283.0  $\text{kJ mol}^{-1}$     B) +285.4  $\text{kJ mol}^{-1}$     C) +287.8  $\text{kJ mol}^{-1}$     D) +268.3  $\text{kJ mol}^{-1}$     E) +302.5  $\text{kJ mol}^{-1}$

**Choose one of the following three exercises for 20 points:**

- When 0.2715 g of fructose ( $\text{C}_6\text{H}_{12}\text{O}_6$ ) was burned in a bomb calorimeter of calorimeter constant 437  $\text{J K}^{-1}$  the temperature rose by 9.69 K. Calculate the heat of combustion, the internal energy change of combustion and the heat of formation for fructose. The heats of formation for  $\text{CO}_2 (\text{g})$  and  $\text{H}_2\text{O} (\text{l})$  are  $-393 \text{ kJ mol}^{-1}$  and  $-285 \text{ kJ mol}^{-1}$  respectively.
- By direct differentiation of  $H = U + pV$ , obtain a relation between  $(H/U)_p$  and  $(U/V)_p$ .
- Calculate the final temperature of a sample of Ar of mass 12.0 g that is expanded reversibly and adiabatically from 1.0 L at 273 K to 3.0 L. Assume perfect gas behavior and  $C_{v,m} = 3 R / 2$ .

**Choose two of the following three problems for 45 points each:**

- Using the equation of state given below, show that this equation leads to critical behavior. Find the critical constants of the gas in terms of B and C and an expression for the critical compression factor,  $Z_c$ .

$$p = \frac{RT}{V_m} - \frac{B}{V_m^2} + \frac{C}{V_m^3}$$

- With reference to the figure to the right, and assuming perfect gas behavior, calculate: (a) the amount of gas molecules (in moles) in the system when  $T = 313 \text{ K}$  at A and B, (b) the work done on the gas along the paths ACB and ADB, (c) the work done on the gas along the isotherm AB, (d)  $\Delta T$ ,  $q$  and  $\Delta U$  for each of the three paths using  $C_{v,m} = 3 R / 2$ .
- Calculate the isothermal compressibility ( $\kappa_T$ ) and the expansion coefficient ( $\alpha$ ) of a van der Waals gas. Show, using Euler's chain relation, that  $\kappa_T R = (V_m - b)$ .

