1. The standard reaction enthalpy for hydrogenation of propene

$$CH_2 = CHCH_3(g) + H_2(g) \rightarrow CH_3CH_2CH_3(g)$$

is $-124 \ kJ/mol$. The standard reaction enthalpy for the combustion of propane

$$CH_3CH_2CH_3(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$$

is $-2220 \ kJ/mol$. The standard reaction enthalpy for the formation of water

$$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$$

is $-286 \ kJ/mol$. Answer the below questions about calculating the standard enthalpy of propene

(a) Write down the combustion reaction for propene?

(b) Name and state the the princple that is to be used to compute the standard enthalpy of propene

(c) Use the above stated principle and calculate the enthalpy of combustion of propene.

2. **(10 points)** Derive the following relations:

(a) Show that internal pressure $\pi_T = T\left(\frac{\partial p}{\partial T}\right)_V - p$; and hence $\pi_T = 0$ for ideal gas.

(b) For a real substance (not an ideal gas), using $U(T, V)$, find $\left(\frac{\partial U}{\partial T}\right)_p$. Then use the relation for π_T and find function f, where $C_p - C_v = f(T, V, \alpha, \kappa)$ where α is the thermal expansion coefficient, κ is the compressibility. In one sentence explain the significance of this relation.

3. Answer the following questions:

(a) A liquid (one component, example pure water) experiences a change in its external pressure (ΔP) at constant temperature T. What is the change in its chemical potential, if we assume its molar volume (V_m) does not change significantly?

(b) In an experiment on a one component system at fixed volume and at constant temperature, at equilibrium the system had liquid phase and gas phase (example, water) with measured pressure p^*. An inert gas which is insoluble in liquid phase (example, nitrogen gas) is introduced into the system, leading to change in pressure by ΔP. Find the relation for the partial vapor pressure p in terms of p^*, ΔP, V_m, and T.

4. Consider an experiment where the temperature and pressure remain fixed in the system (at equilibrium with surroundings maintained at pressure p & temperature T)

(a) Derive the condition for spontaneity of processes in the system. Above condition for spontaneity will involve some thermodynamic function, which one? Remainder of the sub-questions will be referencing this thermodynamic function.

(b) Using the First Law of thermodynamics write the mathematical formula for the infinitesimal change of this thermodynamic function.

(c) When p and T is fixed (as in this experiment), why does this function change its value?

(d) Change in the value of some kind of work is related to change in this thermodynamic function. Derive and identify the kind of work. Comment.

5. The four stages of the Carnot cycle can equally well represented on a temperature-entropy diagram with horizontal axis being entropy and vertical axis being temperature (instead of standard pressure-volume diagram). Assume that temperature of hot source is T_h, that of cold sink is T_c, and that the volume of working substance expands from V_A to V_B in first isothermal stage.

(a) Draw the Carnot Cycle in this temperature-entropy diagram.

(b) By considering the entropy change of each stage, derive the expression for the area enclosed by the cycle in this temperature-entropy diagram.

(c) Derive the expression for the work done over the cycle.

(d) Comment on the relation between your answers to (b) and (c) above.