Thermodynamics

Date Planned : __ / __ / __	**Daily Tutorial Sheet**	**Expected Duration : 90 Min**
Actual Date of Attempt : __ / __ / __	**Level-0**	**Exact Duration :________**

Very Short Answer Type (1 Mark)

1. The internal energy change (ΔU) for the reaction $CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(\ell)$ is $-885\,\text{kJ mol}^{-1}$ at 298 K. What is ΔH at 398 K?

2. When $0.532\,g$ of benzene (C_6H_6), boiling point $353\,K$, is burnt with excess of oxygen in a constant volume system. $22.3\,kJ$ of heat is given out. Calculate ΔH for the combustion process $(R = 8.31\,J\,K^{-1}\,mol^{-1})$.

3. $\Delta U^{\ominus}$ of combustion of methane is $-X\,kJ\,mol^{-1}$. The value of $\Delta H^{\ominus}$ is :

(i) $= \Delta U^{\ominus}$ **(ii)** $> \Delta U^{\ominus}$ **(iii)** $< \Delta U^{\ominus}$ **(iv)** $= 0$

4. Calculate the enthalpy change on freezing of 1.0 mole. of water at 10.0°C to ice at $-10°C$. $\Delta_{fus}H = 6.03\,kJ\,mol^{-1}$ at 0°C.

$$C_p\left[H_2O(\ell)\right] = 75.3\,J\,mol^{-1}\,K^{-1};\; C_p\left[H_2O(s)\right] = 36.8\,J\,mol^{-1}\,K^{-1}$$

5. Calculate the entropy change in surroundings when 1.00 mole $H_2O(\ell)$ is formed under standard conditions. $\Delta_f H° = -286\,kJ\,mol^{-1}$

6. Although heat is a path function but heat absorbed by the system under certain specific conditions is independent of path. What are those conditions? Explain.

Short Answer Type-I (2 Marks)

7. **(a)** A cylinder of gas is assumed to contain 11.2 kg of butane. If a normal family needs 20,000 kJ of energy per day for cooking, how long will the cylinder last? Given that the heat of combustion of butane is $2658\,kJ\,mol^{-1}$.

(b) If the air supply of the burner is insufficient (i.e., you have a yellow instead of a blue flame), a portion of the gas escapes without combustion. Assuming that 33% of the gas is wasted due to this inefficiency, how long would the cylinder last?

8. 18.0 gm of water completely vaporizes at 100°C and 1 bar pressure and then enthalpy change in the process is 40.79 kJ mol^{-1}. What will be the enthalpy change for vaporizing two moles of water under the same conditions? What is the standard enthalpy of vaporization for water?

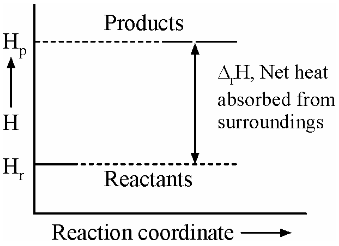
Standard enthalpy of vaporization at 100°C and 1 bar pressure $\Delta_{vap}H^{o} = +40.79\,kJ\,mol^{-1}$

9. The difference between C_p and C_v can be derived using the empirical relation $H = U + pV$. Calculate the difference between C_p and C_v for 10 moles of an ideal gas.

10. An ideal gas is allowed to expand against a constant pressure of 2 bar from 10 L to 50 L in one step. Calculate the amount of work done by the gas. If the same expansion were carried out reversibly, will the work done be higher or lower than the earlier case? (Given that, $1\,\text{L bar} = 100\,\text{J}$)

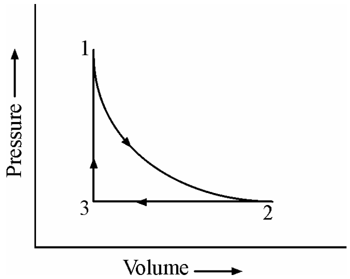
11. How will you calculate work done on an ideal gas in a compression, when change in pressure is carried out in infinite steps?

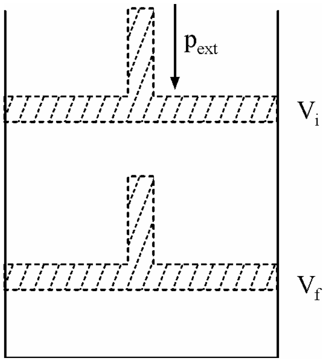
12. Enthalpy diagram for a particular reaction is given in figure. Is it possible to decide spontaneity of a reaction from given diagram. Explain.



13. **(a)** A sample of 1.0 mol of a monoatomic ideal gas is taken through a cyclic process of expansion and compression as shown in figure. What will be the value of ΔH for the cycle as a whole?

(b) Which quantity out of $\Delta_r G$ and $\Delta_r G^{\ominus}$ will be zero at equilibrium?





Short Answer Type-II (3 Marks)

14. What will be the work done on an ideal gas enclosed in a cylinder, when it is compressed by a constant external pressure, p_{ext} in a single step as shown in figure? Explain graphically.

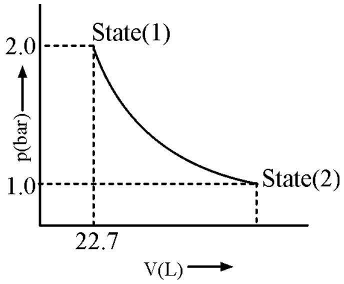
15. Represent the potential energy/enthalpy change in the following process graphically.

(a) Throwing a stone from the ground to roof.

(b) $\frac{1}{2}H_2(g) + \frac{1}{2}Cl_2(g) \rightleftharpoons HCl(g)\ \Delta_r H^o = -92.32\ \text{kJ mol}^{-1}$

In which of the processes potential energy/enthalpy change is contributing factor to the spontaneity?

16. 1.0 mol of a monoatomic ideal gas is expanded from state (1) to state (2) as shown in figure. Calculate the work done for the expansion of gas from state (1) to state (2) as 298 K.



17. One mole of an ideal gas ($C_v = \frac{3}{2}R$) is heated at constant pressure of 1 atmosphere from 25°C to 100°C. Calculate ΔE and ΔH.

(A) 223.51 cal and 372.56 cal **(B)** 356.76 cal and 356.46 cal
(C) 437.3 cal and 357.76 cal **(D)** 396.5 cal and 436.5 cal

18. A gas occupies 2 litre at STP. It is provided 300 joule heat so that its volume becomes 2.5 litre at 1atm. Calculate change in its internal energy.

(A) 300 J **(B)** 500 J **(C)** 356.9 J **(D)** 249.37 J

19. In an insulated contained 1 mole of a liquid, molar volume $100\,\text{mL}$ is at 1 bar. Liquid is steeply taken to 100 bar, when volume of liquid decreases by $1\,\text{mL}$. Find ΔE and ΔH for the process?

(A) 200 bar mL, 8000 bar mL **(B)** 300 bar mL, 7000 bar mL
(C) 100 bar mL, 9900 bar mL **(D)** 350 bar mL, 870 bar mL

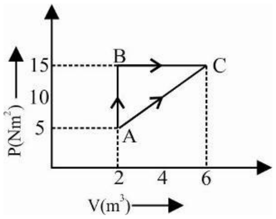
Long Answer Type (5 Marks)

20. 1 mole of an ideal gas undergoes reversible isothermal expansion from an initial volume V_1 to a final volume $10V_1$ and does 10 kJ of work. The initial pressure was $1 \times 10^7\,\text{Pa}$.

(i) Calculate V_1 **(ii)** If there were 2 moles of gas what must its temperature ?

(A) 0.003, 275 K **(B)** 0.00043, 261.13 K
(C) 0.0005, 300 K **(D)** 0.00049, 353 K

21. The given figure shows a change of state A to state C by two paths ABC and AC for an ideal gas. Calculate the



(a) Path along which work done is least.
(b) Internal energy at C if the internal energy of gas at A is 10 J and amount of heat supplied to change its state to C through the path AC is 200 J.
(c) Amount of heat supplied to the gas to go from A to B, if internal energy of gas at state B is 10 J.

22. 14 g of oxygen at 0°C and 10 atm are subjected to reversible adiabatic expansion to a pressure of 1 atm. Calculate the work done in

(i) Litre atm. **(ii)** Calorie (Given $\frac{C_p}{C_v} = 1.4$)

23. A sample of 3.0 mole of perfect gas at 200 K and 2.0 atm is compressed reversibly and adiabatically until the temperature reaches 250 K. Given that molar heat capacity at $27.5\,\text{JK}^{-1}\,\text{mol}^{-1}$ at constant volume, calculate q, W, ΔE, ΔH and the final pressure and volume.

24. Calculate the entropy change accompanying the conversion of 1 mole of ice at 273.1 K and 1 atm pressure into steam at 373.1 K and 1 atm pressure. At 273.1 K, the molar heat of fusion of ice, ΔH_f, is $6.00\ \text{kJ mol}^{-1}$ and at 373.1 K, the molar heat of vapourization of water, ΔH_v, is $40.6\ \text{kJ mol}^{-1}$. Also assume that the molar heat capacities, C_p, in the temperature range 373.1 to 273.1 K remains constant. Given that $C_p = 75.25\ \text{mol}^{-1}\text{K}^{-1}$ and log 13.66 = 1.1354.

25. A sample of argon gas at 1 atm pressure and 27°C expands reversibly and adiabatically from 1.25 dm^3 to 2.5 dm^3. Calculate the enthalpy change in the process. Given that C_V for Ar is 12.45 K^{-1} mol^{-1} and antilog (0.199) = 1.58.