



THERMOCHEMISTRY

Exercise-1

PART - I : SUBJECTIVE QUESTIONS

Section (A) : Calculation ΔU , ΔH & W for chemical reaction

- A-1. For the reaction : $C_2H_5OH(\ell) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(g)$
if $\Delta U^\circ = -1373 \text{ kJ mol}^{-1}$ at 298 K. Calculate ΔH°
- A-2. 2 mole of zinc is dissolved in HCl at 25°C. Calculate the work done in open vessel.

Section (B) : Basics & Kirchoff's law

- B-1. Diborane is a potential rocket fuel which undergoes combustion according to the reaction
 $B_2H_6(g) + 3O_2(g) \longrightarrow B_2O_3(s) + 3H_2O(g)$
 From the following data, calculate the enthalpy change for the combustion of diborane
 $2B(s) + (3/2) O_2(g) \longrightarrow B_2O_3(s) \Delta H = -1273 \text{ kJ mol}^{-1}$
 $H_2(g) + (1/2)O_2(g) \longrightarrow H_2O(l) \quad \Delta H = -286 \text{ kJ mol}^{-1}$
 $H_2O(l) \longrightarrow H_2O(g) \quad \Delta H = 44 \text{ kJ mol}^{-1}$
 $2B(s) + 3H_2(g) \longrightarrow B_2H_6(g) \quad \Delta H = 36 \text{ kJ mol}^{-1}$
- B-2. Predict the standard reaction enthalpy of $2 NO_2(g) \rightarrow N_2O_4(g)$ at 100°C. ΔH° at 25°C is $-57.2 \text{ kJ mol}^{-1}$
 $C_p(NO_2) = 37.2 \text{ J mol}^{-1} K^{-1}$ $C_p(N_2O_4) = 77.28 \text{ J mol}^{-1} K^{-1}$.

Section (C) : Enthalpy of formation & combustion

- C-1. The heat of combustion of ethyl alcohol is -300 kcal . If the heats of formation of $CO_2(g)$ and $H_2O(\ell)$ are -94.3 and -68.5 kcal respectively, calculate the heat of formation of ethyl alcohol.
- C-2. If $H_2 + 1/2 O_2 \longrightarrow H_2O$, $\Delta H = -68 \text{ kcal}$
 $K + H_2O + \text{water} \longrightarrow KOH(aq) + 1/2 H_2$, $\Delta H = -48 \text{ kcal}$
 $KOH + \text{water} \longrightarrow KOH(aq)$, $\Delta H = -14 \text{ kcal}$
 Find the heat of formation of KOH.
- C-3. The standard enthalpy of decomposition of the yellow complex H_3NSO_2 into NH_3 and SO_2 is $+40 \text{ kJ mol}^{-1}$. Calculate the standard enthalpy of formation of H_3NSO_2 . $\Delta H_f^\circ(NH_3) = -46.17 \text{ kJ mol}^{-1}$, $\Delta H_f^\circ(SO_2) = -296.83$.
- C-4. When 12.0 g of carbon (graphite) reacted with oxygen to form CO and CO_2 at 25°C and constant pressure, 252 kJ of heat was released and no carbon remained. If $\Delta H_f^\circ(CO, g) = -110.5 \text{ kJ mol}^{-1}$ and $\Delta H_f^\circ(CO_2, g) = -393.5 \text{ kJ mol}^{-1}$, calculate the mass of oxygen consumed.

Section (D) : Bond enthalpy method & Resonance energy

- D-1. Calculate the bond energy of Cl-Cl bond from the following data :
 $CH_4(g) + Cl_2(g) \longrightarrow CH_3Cl(g) + HCl(g)$; $\Delta H = -100.3 \text{ kJ}$. Also the bond enthalpies of C-H, C-Cl, H-Cl bonds are 413, 326 and 431 kJ mol^{-1} respectively.
- D-2. Calculate ΔH_r° for the reaction $CH_2Cl_2(g) \longrightarrow C(g) + 2H(g) + 2Cl(g)$. The average bond enthalpies of C-H and C-Cl bonds are 414 kJ mol^{-1} and 330 kJ mol^{-1} .
- D-3. Calculate the enthalpy change (ΔH) of the following reaction $2C_2H_2(g) + 5O_2(g) \longrightarrow 4CO_2(g) + 2H_2O(g)$ given average bond enthalpies of various bonds, i.e., C-H, C=C, O=O, C=O, O-H as 414, 814, 499, 724 and 640 kJ mol^{-1} respectively.



- D-4.** Calculate change in enthalpy for the reaction at 27°C

$$\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \longrightarrow 2\text{H-Cl}(\text{g})$$
 by using the bond energy and energy data
 Bond energies of H-H, Cl-Cl and H-Cl bonds are 435 kJ mol⁻¹, 240 kJ mol⁻¹ and 430 kJ mol⁻¹ respectively.
- D-5.** Estimate the average S-F bond enthalpy in SF₆. The values of standard enthalpy of formation of SF₆(g), S(g) and F(g) are : -1100, 274 and 80 kJ mol⁻¹ respectively.

Section (E) : Enthalpy of solution & Born Haber's cycle

- E-1.** Calculate the standard enthalpy of solution of AgCl(s) in water $\Delta H^\circ_f(\text{AgCl}, \text{s}) = -127.07 \text{ kJ mol}^{-1}$, $\Delta H^\circ_f(\text{Ag}^+, \text{aq}) = 105.58 \text{ kJ mol}^{-1}$, $\Delta H^\circ_f(\text{Cl}^-, \text{aq}) = -167.35 \text{ kJ mol}^{-1}$.
- E-2.** Enthalpies of solution of BaCl₂(s) and BaCl₂.2H₂O(s) are -20 kJ/mole and 8.0 kJ/mole respectively. Calculate heat of hydration of BaCl₂(s).
- E-3.** Setup of Born-Haber cycle; calculate lattice energy of MgO(s). The given that - enthalpy of formation of MgO(s) = -602, sublimation of Mg(s) = 148 ; 1st & 2nd ionization energy of Mg = 738 & 1450 respectively. For Oxygen bond dissociation energy = 498; 1st & 2nd electron gain enthalpy = -141 & 844 respectively (all unit in kJmole⁻¹).

Section (F) : Enthalpy of neutralization

- F-1.** 10 mL of each 1 M HCl and 1M H₂SO₄ are neutralized by 1 M NaOH solution that liberate the heat of a & b kJ/mol respectively. What is relation between a and b ?
- F-2.** The enthalpy of neutralization of 1M HCl by 1M NaOH is -57 kJ/mole. The enthalpy of formation of water is -285 kJ/mole. The enthalpy of formation of OH⁻ ion is :
- F-3.** The standard enthalpy of neutralization of KOH with HCN and HCl in dilute solution is -2480 cal.mol⁻¹ and -13.68 kcalmol⁻¹ respectively. Find the enthalpy of dissociation of HCN at the same temperature.

PART - II : ONLY ONE OPTION CORRECT TYPE

Section (A) : Calculation ΔU , ΔH & W for chemical reaction

- A-1.** The free energy change for a reversible reaction at equilibrium is :
 (A) Positive (B) Negative (C) Zero (D) Cannot say
- A-2.** ΔH° for the reaction $\text{X}(\text{g}) + \text{Y}(\text{g}) \rightleftharpoons \text{Z}(\text{g})$ is -4.6 Kcal, the value of ΔU° of the reaction at 227°C is (R = 2 cal.mol⁻¹ K⁻¹) :
 (A) -3.6 kcal (B) -5.6 kcal (C) -4.6 kcal (D) -2.6 kcal
- A-3.** Determine which of the following reactions at constant pressure represent surrounding that do work on the system :
 I. $4\text{NH}_3(\text{g}) + 7\text{O}_2(\text{g}) \longrightarrow 4\text{NO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{g})$
 II. $\text{CO}(\text{g}) + 2\text{H}_2(\text{g}) \longrightarrow \text{CH}_3\text{OH}(\ell)$
 III. $\text{C}(\text{s, graphite}) + \text{H}_2\text{O}(\text{g}) \longrightarrow \text{CO}(\text{g}) + \text{H}_2(\text{g})$
 IV. $\text{H}_2\text{O}(\text{s}) \longrightarrow \text{H}_2\text{O}(\ell)$
 (A) III, IV (B) II and III (C) II, IV (D) I and II, IV
- A-4.** Consider the reaction at 300 K

$$\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \longrightarrow 2\text{HCl}(\text{g}); \quad \Delta H^\circ = -185 \text{ kJ}$$
 If 2 mole of H₂ completely react with 2 mole of Cl₂ to form HCl. What is ΔU° for this reaction ?
 (A) 0 (B) -185 kJ (C) 370 kJ (D) -370 kJ
- A-5.** A mixture of 2 mole of CO and 1 mole of O₂, in a closed vessel is ignited to convert the CO to CO₂. If ΔH is the enthalpy change and ΔU is the change in internal energy then :
 (A) $\Delta H < \Delta U$ (B) $\Delta H > \Delta U$ (C) $\Delta H = \Delta U$ (D) $\Delta H = 2\Delta U$





Section (B) : Basics & Kirchoff's law

- B-1.** For which of the following change $\Delta H \neq \Delta E$?
 (A) $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \longrightarrow 2\text{HI}(\text{g})$ (B) $\text{HCl}(\text{aq}) + \text{NaOH}(\text{aq}) \longrightarrow \text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\text{l})$
 (C) $\text{C}(\text{s}) + \text{O}_2(\text{g}) \longrightarrow \text{CO}_2(\text{g})$ (D) $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \longrightarrow 2\text{NH}_3(\text{g})$
- B-2.** Calculate the Standard internal energy of formation of liquid methyl acetate ($\text{CH}_3\text{COOCH}_3$) from its standard enthalpy of formation, which is $-442.91 \text{ kJ mole}^{-1}$ at 25°C .
 (A) -433 (B) $+433$ (C) -452.82 (D) 452.82
- B-3.** $2\text{C} + \text{O}_2 \longrightarrow 2\text{CO}$; $\Delta H = -220 \text{ kJ}$
 Which of the following statement is correct for this reaction
 (A) Heat of combustion of carbon is 110 kJ (B) Reaction is exothermic
 (C) Reaction needs no initiation (D) All of these are correct
- B-4.** $\text{C}(\text{s}) + \text{O}_2(\text{g}) \longrightarrow \text{CO}_2(\text{g})$; $\Delta H = -94.3 \text{ kcal/mol}$
 $\text{CO}(\text{g}) + \frac{1}{2}\text{O}_2(\text{g}) \longrightarrow \text{CO}_2(\text{g})$; $\Delta H = -67.4 \text{ kcal/mol}$
 $\text{O}_2(\text{g}) \longrightarrow 2\text{O}(\text{g})$; $\Delta H = 117.4 \text{ kcal/mol}$
 $\text{CO}(\text{g}) \longrightarrow \text{C}(\text{g}) + \text{O}(\text{g})$; $\Delta H = 230.6 \text{ kcal/mol}$
 Calculate ΔH for $\text{C}(\text{s}) \longrightarrow \text{C}(\text{g})$ in kcal/mol .
 (A) 171 (B) 154 (C) 117 (D) 145

Section (C) : Enthalpy of formation & combustion

- C-1.** In the reaction, $\text{CO}_2(\text{g}) + \text{H}_2(\text{g}) \longrightarrow \text{CO}(\text{g}) + \text{H}_2\text{O}(\text{g})$; $\Delta H = 2.8 \text{ kJ}$, ΔH represents
 (A) heat of reaction (B) heat of combustion (C) heat of formation (D) heat of solution
- C-2.** Given, $\text{H}_2(\text{g}) + \text{Br}_2(\text{g}) \longrightarrow 2\text{HBr}(\text{g})$, ΔH°_1 and standard enthalpy of condensation of bromine is ΔH°_2 , standard enthalpy of formation of HBr at 25°C is
 (A) $\Delta H^\circ_1 / 2$ (B) $\Delta H^\circ_1 / 2 + \Delta H^\circ_2$ (C) $\Delta H^\circ_1 / 2 - \Delta H^\circ_2$ (D) $(\Delta H^\circ_1 - \Delta H^\circ_2) / 2$
- C-3.** For the following reaction,
 $\text{C}(\text{diamond}) + \text{O}_2 \longrightarrow \text{CO}_2(\text{g})$; $\Delta H = -97.6 \text{ kcal/mol}$
 $\text{C}(\text{graphite}) + \text{O}_2 \longrightarrow \text{CO}_2(\text{g})$; $\Delta H = -94.3 \text{ kcal/mol}$
 The heat required to change 1 g of $\text{C}(\text{graphite}) \longrightarrow \text{C}(\text{diamond})$ is
 (A) 1.59 kcal (B) 0.1375 kcal (C) 0.55 kcal (D) 0.275 kcal
- C-4.** The standard heat of combustion of solid boron is equal to :
 (A) $\Delta H^\circ_f(\text{B}_2\text{O}_3)$ (B) $1/2 \Delta H^\circ_f(\text{B}_2\text{O}_3)$ (C) $2\Delta H^\circ_f(\text{B}_2\text{O}_3)$ (D) $4\Delta H^\circ_f(\text{B}_2\text{O}_3)$
- C-5.** The heat of combustion of sucrose ($\text{C}_{12}\text{H}_{22}\text{O}_{11}$) is 1350 kcal/mol . How much of heat will be liberated when 17.1 g of sucrose is burnt ?
 (A) 67.5 kcal (B) 13.5 kcal (C) 40.5 kcal (D) 25.5 kcal
- C-6.** If
 $\text{S} + \text{O}_2 \longrightarrow \text{SO}_2$, $\Delta H = -298.2 \text{ kJ mole}^{-1}$
 $\text{SO}_2 + 1/2 \text{O}_2 \longrightarrow \text{SO}_3$, $\Delta H = -98.7 \text{ kJ mole}^{-1}$
 $\text{SO}_3 + \text{H}_2\text{O} \longrightarrow \text{H}_2\text{SO}_4$, $\Delta H = -130.2 \text{ kJ mole}^{-1}$
 $\text{H}_2 + 1/2 \text{O}_2 \longrightarrow \text{H}_2\text{O}$, $\Delta H = -287.3 \text{ kJ mole}^{-1}$
 the enthalpy of formation of H_2SO_4 at 298 K will be :
 (A) $-814.4 \text{ kJ mol}^{-1}$ (B) $+814.4 \text{ kJ mole}^{-1}$ (C) $-650.3 \text{ kJ mole}^{-1}$ (D) $-433.7 \text{ kJ mole}^{-1}$
- C-7.** When a certain amount of ethylene was combusted, 5644 kJ heat was evolved. If heat of combustion of ethylene is 1411 kJ , the volume of O_2 (at NTP) that entered into the reaction is :
 (A) 268.8 ml (B) 268.8 L (C) $6226 \times 22.4 \text{ L}$ (D) 22.4 L
- C-8.** The values of heat of combustion of ethane (C_2H_6) and ethyne (C_2H_2) are -341 and -310 Kcal respectively. Then which of the following is better fuel on mass basis :
 (A) C_2H_2 (B) C_2H_6 (C) Both (A) & (B) (D) None of these





Section (D) : Bond enthalpy method & Resonance energy

- D-1.** If enthalpy of dissociation of CH_4 and C_2H_6 are 320 and 600 calories respectively then bond energy of C–C bond is :
 (A) 80 cal (B) 40 cal (C) 60 cal (D) 120 cal
- D-2.** The bond dissociation energy of gaseous H_2 , Cl_2 and HCl are 104, 58 and 103 kcal mol⁻¹ respectively. The enthalpy of formation for HCl gas will be
 (A) – 44.0 kcal (B) – 22.0 kcal (C) 22.0 kcal (D) 44.0 kcal
- D-3.** AB , A_2 and B_2 are diatomic molecules. If the bond enthalpies of A_2 , AB & B_2 are in the ratio 1 : 1 : 0.5 and enthalpy of formation of AB from A_2 and B_2 is – 100 kJ/mol⁻¹. What is the bond enthalpy of A_2 .
 (A) 400 kJ/mol (B) 200 kJ/mol (C) 100 kJ/mol (D) 300 kJ/mol

Section (E) : Enthalpy of Solution & Born Haber's cycle

- E-1.** One mole of anhydrous MgCl_2 dissolves in water and liberates 25 cal/mol of heat. $\Delta H_{\text{hydration}}$ of $\text{MgCl}_2 = -30$ cal/mol. Heat of dissolution of $\text{MgCl}_2 \cdot \text{H}_2\text{O}$ is
 (A) +5 cal/mol (B) –5 cal/mol (C) 55 cal/mol (D) –55 cal/mol
- E-2.** The enthalpy of solution of NaOH (s) in water is – 41.6 kJ/mole. When NaOH is dissolved in water then the temperature of water :
 (A) Increase (B) Decrease (C) Does not change (D) Fluctuates
- E-3.** The enthalpy change for the reaction of 5 liter of ethylene with 5 liter of H_2 gas at 1.5 atm pressure is $\Delta H = -0.5$ kJ. The value of ΔU will be : (1 atm Lt = 100 J)
 (A) – 1.25 kJ (B) + 1.25 kJ (C) 0.25 kJ (D) – 0.25 kJ
- E-4.** For which one of the following reaction does the molar enthalpy change of a reaction corresponds to Lattice energy of KBr ?
 (A) $\text{KBr(s)} \longrightarrow \text{K(s)} + \frac{1}{2}\text{Br}_2(\text{g})$ (B) $\text{KBr(g)} \longrightarrow \text{K(g)} + \text{Br(g)}$
 (C) $\text{KBr(s)} \longrightarrow \text{K}^+(\text{g}) + \text{Br}^-(\text{g})$ (D) $\text{KBr(g)} \longrightarrow \text{K}^+(\text{g}) + \text{Br}^-(\text{g})$
- E-5.** Calculate the lattice energy for the reaction
 $\text{Li}^+(\text{g}) + \text{Cl}^-(\text{g}) \longrightarrow \text{LiCl(s)}$
 Given that :
 $\Delta H_{\text{sub}}(\text{Li}) = 160$; $\Delta H_{\text{diss}}(\text{Cl}_2) = 244$; $\text{IP}(\text{Li}) = 520$;
 $\text{EA}(\text{Cl}) = 365$ and $\Delta H_f(\text{LiCl}) = -400$ (all in kJ mole⁻¹)
 (A) –837 (B) –959 (C) –1567 (D) –37

Section (F) : Enthalpy of neutralization

- F-1.** The enthalpy of neutralization of which of the following acid & base is nearly – 13.6 kcal.
 (A) HCN and NaOH (B) CH_3COOH and NH_4OH
 (C) HCl and KOH (D) HCl and NH_4OH
- F-2.** If heat of dissociation of CHCl_2COOH is 0.7 kcal/mole then ΔH for the reaction :
 $\text{CHCl}_2\text{COOH} + \text{KOH} \longrightarrow \text{CHCl}_2\text{COOK} + \text{H}_2\text{O}$
 (A) – 13 kcal (B) + 13 kcal (C) – 14.4 kcal (D) – 13.7 kcal

PART - III : MATCH THE COLUMN

1. Match the column :

| | Column-I | | Column-II |
|-----|----------------------------------------------------------------------------------------|-----|---------------------------------------|
| (A) | $\text{C (s, graphite)} + \text{O}_2(\text{g}) \longrightarrow \text{CO}_2(\text{g})$ | (p) | $\Delta H^\circ_{\text{combustion}}$ |
| (B) | $\text{C(s, graphite)} \longrightarrow \text{C(g)}$ | (q) | $\Delta H^\circ_{\text{formation}}$ |
| (C) | $\text{CO(g)} + \frac{1}{2}\text{O}_2(\text{g}) \longrightarrow \text{CO}_2(\text{g})$ | (r) | $\Delta H^\circ_{\text{atomization}}$ |
| (D) | $\text{CH}_4(\text{g}) \longrightarrow \text{C(g)} + 4\text{H(g)}$ | (s) | $\Delta H^\circ_{\text{sublimation}}$ |

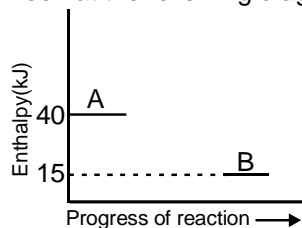




Exercise-2

PART - I : ONLY ONE OPTION CORRECT TYPE

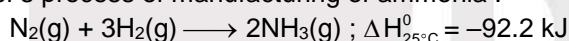
1. Look at the following diagram :



The enthalpy change for the reaction $A \rightarrow B$ will be

- (A) -25 kJ (B) -40 kJ (C) $+25$ kJ (D) -65 kJ

2. In Haber's process of manufacturing of ammonia :



| Molecule | $\text{N}_2(\text{g})$ | $\text{H}_2(\text{g})$ | $\text{NH}_3(\text{g})$ |
|----------------------------------------|------------------------|------------------------|-------------------------|
| $C_p \text{ JK}^{-1} \text{ mol}^{-1}$ | 29.1 | 28.8 | 35.1 |

If C_p is independent of temperature, then reaction at 100°C as compared to that of 25°C will be :

- (A) More endothermic (B) Less endothermic (C) More exothermic (D) Less exothermic
3. In the reaction $\text{AB}_2(\ell) + 3\text{X}_2(\text{g}) \rightleftharpoons \text{AX}_2(\text{g}) + 2\text{BX}_2(\text{g})$ $\Delta H = -270$ kcal per mol. of $\text{AB}_2(\ell)$, the enthalpies of formation of $\text{AX}_2(\text{g})$ & $\text{BX}_2(\text{g})$ are in the ratio of 4 : 3 and have opposite sign. The value of $\Delta H_f^\circ(\text{AB}_2(\ell)) = +30$ kcal/mol. Then
- (A) $\Delta H_f^\circ(\text{AX}_2) = -96$ kcal/mol
 (B) $\Delta H_f^\circ(\text{BX}_2) = +480$ kcal/mol
 (C) $K_p = K_c$ & $\Delta H_f^\circ(\text{AX}_2) = +480$ kcal/mol
 (D) $K_p = K_c$ & $\Delta H_f^\circ(\text{AX}_2) + \Delta H_f^\circ(\text{BX}_2) = -240$ kcal/mol
4. The heat of formation of $\text{C}_2\text{H}_5\text{OH}(\ell)$ is -66 kcal/mole. The heat of combustion of $\text{CH}_3\text{OCH}_3(\text{g})$ is -348 kcal/mole. ΔH_f for H_2O and CO_2 are -68 kcal/mole and -94 kcal/mole respectively. Then, the ΔH for the isomerisation reaction $\text{C}_2\text{H}_5\text{OH}(\ell) \longrightarrow \text{CH}_3\text{OCH}_3(\text{g})$ and ΔE for the same are at $T = 25^\circ\text{C}$
- (A) $\Delta H = 18$ kcal/mole, $\Delta E = 17.301$ kcal/mole (B) $\Delta H = 22$ kcal/mole, $\Delta E = 21.408$ kcal/mole
 (C) $\Delta H = 26$ kcal/mole, $\Delta E = 25.709$ kcal/mole (D) $\Delta H = 30$ kcal/mole, $\Delta E = 28.522$ kcal/mole
5. Cesium chlorides is formed according to the following equation $\text{Cs}(\text{s}) + 0.5 \text{Cl}_2(\text{g}) \rightarrow \text{CsCl}(\text{s})$. The enthalpy of sublimation of Cs, enthalpy of dissociation of chlorine, ionization energy of Cs and electron affinity of chlorine are 81.2, 243.0, 375.7 and -348.3 kJ mol^{-1} . The energy change involved in the formation of CsCl is -388.6 kJ mol^{-1} . Calculate the lattice energy of CsCl.
- (A) 618.7 kJ mol^{-1} (B) 1237.4 kJ mol^{-1} (C) -1237.4 kJ mol^{-1} (D) -618.7 kJ mol^{-1}
6. The enthalpies of neutralization of a weak base AOH and a strong base BOH by HCl are -12250 cal/mol and -13000 cal/mol respectively. When one mole of HCl is added to a solution containing 1 mole of AOH and 1 mole of BOH, the enthalpy change was -12500 cal/mol. In what ratio the acid is distributed between AOH and BOH ?
- (A) 2 : 1 (B) 2 : 3 (C) 1 : 2 (D) None of these
7. The enthalpy of neutralization of 40.0 g of NaOH by 60.0 g of CH_3COOH will be :
- (A) 57.1 kJ equiv^{-1} (B) less than 57.1 kJ equiv^{-1}
 (C) more than 57.1 kJ equiv^{-1} (D) 13.7 kJ equiv^{-1}
8. Given $\Delta_{\text{ioniz}} H^\circ(\text{HCN}) = 45.2$ kJ mol^{-1} and $\Delta_{\text{ioniz}} H^\circ(\text{CH}_3\text{COOH}) = 2.1$ kJ mol^{-1} . Which one of the following facts is true ?
- (A) $pK_a(\text{HCN}) = pK_a(\text{CH}_3\text{COOH})$ (B) $pK_a(\text{HCN}) > pK_a(\text{CH}_3\text{COOH})$
 (C) $pK_a(\text{HCN}) < pK_a(\text{CH}_3\text{COOH})$ (D) $pK_a(\text{HCN}) = (45.17/2.07) pK_a(\text{CH}_3\text{COOH})$



9. The average O–H bond energy in H_2O with the help of following data.
 (1) $\text{H}_2\text{O}(\ell) \longrightarrow \text{H}_2\text{O}(\text{g})$; $\Delta H = + 40.6 \text{ KJ mol}^{-1}$
 (2) $2\text{H}(\text{g}) \longrightarrow \text{H}_2(\text{g})$; $\Delta H = - 435.0 \text{ KJ mol}^{-1}$
 (3) $\text{O}_2(\text{g}) \longrightarrow 2\text{O}(\text{g})$; $\Delta H = + 489.6 \text{ KJ mol}^{-1}$
 (4) $2\text{H}_2(\text{g}) + \text{O}_2(\text{g}) \longrightarrow 2\text{H}_2\text{O}(\ell)$; $\Delta H = - 571.6 \text{ KJ mol}^{-1}$
 (A) $584.9 \text{ KJ mol}^{-1}$ (B) $279.8 \text{ KJ mol}^{-1}$ (C) $462.5 \text{ KJ mol}^{-1}$ (D) 925 KJ mol^{-1}
10. Enthalpy of polymerisation of ethylene, as represented by the reaction, $n\text{CH}_2=\text{CH}_2 \longrightarrow (-\text{CH}_2-\text{CH}_2-)_n$ is -100 kJ per mole of ethylene. Given bond enthalpy of $\text{C}=\text{C}$ bond is 600 kJ mol^{-1} , enthalpy of $\text{C}-\text{C}$ bond (in kJ mol^{-1}) will be :
 (A) 116.7 (B) 350 (C) 700 (D) indeterminate
11. The average energy required to break a $\text{P}-\text{P}$ bond in $\text{P}_4(\text{s})$ into gaseous atoms is $53.2 \text{ kcal mol}^{-1}$. The bond dissociation energy of $\text{H}_2(\text{g})$ is $104.2 \text{ kcal mol}^{-1}$; ΔH_f° of $\text{PH}_3(\text{g})$ from $\text{P}_4(\text{s})$ is $5.5 \text{ kcal mol}^{-1}$. The $\text{P}-\text{H}$ bond energy in kcal mol^{-1} is [Neglect presence of Van der Waals forces in $\text{P}_4(\text{s})$]
 (A) 85.2 (B) 57.6 (C) 76.9 (D) 63.3

PART - II : NUMERICAL VALUE PROBLEMS

1. If heat of reaction for the given acid-base reaction :
 $\text{HA} + \text{NaOH} \longrightarrow \text{NaA} + \text{H}_2\text{O}$; $\Delta H = - 4.7 \text{ kcal}$
 The heat of dissociation of HA is _____ .
2. The enthalpy of combustion at 25°C of $\text{H}_2(\text{g})$, cyclohexane and cyclohexene are $- 241$, $- 3920$ and $- 3717 \text{ kJ mol}^{-1}$ respectively. The heat of hydrogenation of cyclohexene is (Kcal/mole) approximate integer :
3. When 0.36 g of glucose was burned in a bomb calorimeter (Heat capacity 600 JK^{-1}) the temperature rise by 10 K . Calculate the magnitude of standard molar enthalpy of combustion (MJ/mole).
4. Calculate the magnitude of enthalpy change when infinitely dilute solution of CaCl_2 and Na_2CO_3 are mixed. ΔH_f° for $\text{Ca}^{+2}(\text{aq})$, $\text{CO}_3^{-2}(\text{aq})$ and $\text{CaCO}_3(\text{s})$ are -129.80 , -161.7 , $-288.50 \text{ kcal mol}^{-1}$ respectively.
5. How many of the following have standard heat of formation is zero.
 (i) $\text{Br}_{2(\ell)}$ (ii) $\text{CO}_{2(\text{g})}$ (iii) $\text{C}_{(\text{graphite})}$ (iv) $\text{Cl}_{2(\ell)}$ (v) $\text{Cl}_{2(\text{g})}$
 (vi) $\text{F}_{2(\text{g})}$ (vii) $\text{F}_{(\text{g})}$ (viii) $\text{I}_{2(\text{g})}$ (ix) $\text{S}_{(\text{monoclinic})}$ (x) $\text{N}_{2(\text{g})}$
 (xi) $\text{P}_{(\text{Black})}$ (xii) $\text{P}_{(\text{red})}$ (xiii) CH_4
6. Standard enthalpy of combustion of cyclopropane is $- 2091 \text{ kJ/mole}$ at 25°C then calculate the enthalpy of formation of cyclopropane. If $\Delta H_f^\circ(\text{CO}_2) = - 393.5 \text{ kJ/mole}$ and $\Delta H_f^\circ(\text{H}_2\text{O}) = - 285.8 \text{ kJ/mole}$.
7. Bond energies of $\text{N}\equiv\text{N}$; $\text{H}-\text{H}$ and $\text{N}-\text{H}$ bonds are 945 , 463 & 391 kJ mol^{-1} respectively, the enthalpy of the following reactions is :
 $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \longrightarrow 2\text{NH}_3(\text{g})$
8. The reaction of nitrogen with hydrogen to make ammonia has $\Delta H = - 92 \text{ kJ}$
 $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \longrightarrow 2\text{NH}_3(\text{g})$
 What is the value of ΔU (in kJ) if the reaction is carried out at a constant pressure of 40 bar and the volume change is $- 1.25 \text{ litre}$.
9. Calculate $|\Delta U|$ of reaction for the hydrogenation of acetylene at constant volume and at 77°C .
 Given that $\Delta H_f(\text{H}_2\text{O}) = -67.8 \text{ kcal mole}$; $\Delta H_{\text{comb}}(\text{C}_2\text{H}_2) = -310.1 \text{ kcal/mole}$, $\Delta H_{\text{comb}}(\text{C}_2\text{H}_4) = -337.2 \text{ kcal/Mole}$
10. Calculate the $\text{C}-\text{C}$ bond enthalpy from the following data :
 (a) $\text{C}(\text{s}) \longrightarrow \text{C}(\text{g})$; $\Delta H = 170 \text{ Kcal}$ (b) $\frac{1}{2} \text{H}_2(\text{g}) \longrightarrow \text{H}(\text{g})$; $\Delta H = 52 \text{ Kcal}$
 (c) Heat of formation of ethane = $- 20 \text{ Kcal}$ (d) $\text{C}-\text{H}$ bond enthalpy = 99 Kcal .



PART - III : ONE OR MORE THAN ONE OPTIONS CORRECT TYPE

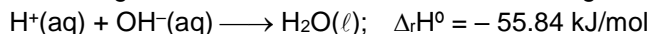
- Which of the following is(are) endothermic reaction :
 (A) Combustion of methane (B) Decomposition of water
 (C) Dehydrogenation of ethane to ethylene (D) Conversion of graphite to diamond
- Heat of reaction depend upon :
 (A) Physical state of reactants and products
 (B) Whether the reaction is carried out at constant pressure or at constant volume
 (C) Method by which the final products are obtained from the reactants
 (D) Temperature of the reaction
- Which of the following reaction cannot be used to define the heat of formation of CO_2 (g).
 (A) $\text{CO (g)} + \frac{1}{2} \text{O}_2 \longrightarrow \text{CO}_2 \text{ (g)}$ (B) $\text{C}_6\text{H}_6 \text{ (l)} + \frac{7}{2} \text{O}_2 \text{ (g)} \longrightarrow 6\text{CO}_2 \text{ (g)} + 3\text{H}_2\text{O (l)}$
 (C) $\text{C (diamond)} + \text{O}_2 \text{ (g)} \longrightarrow \text{CO}_2 \text{ (g)}$ (D) $\text{C (graphite)} + \text{O}_2 \text{ (g)} \longrightarrow \text{CO}_2 \text{ (g)}$
- Heat of formation of CH_4 are :
 If given :
 $\text{C (s)} + \text{O}_2 \text{ (g)} \longrightarrow \text{CO}_2 \text{ (g)} \quad \Delta H = -394 \text{ kJ}$
 $\text{H}_2 \text{ (g)} + \frac{1}{2} \text{O}_2 \text{ (g)} \longrightarrow \text{H}_2\text{O (l)} \quad \Delta H = -284 \text{ kJ}$
 $\text{CH}_4 \text{ (g)} + 2\text{O}_2 \text{ (g)} \longrightarrow \text{CO}_2 \text{ (g)} + 2\text{H}_2\text{O (l)} \quad \Delta H = -892 \text{ kJ}$
 (A) -70 kJ (B) -16.7 kcal (C) -244 kJ (D) -50 kcal
- Heat of neutralization of the acid-base reaction is 57.32 kJ for :
 (A) $\text{HCOOH} + \text{KOH}$ (B) $\text{CH}_3\text{COOH} + \text{NaOH}$
 (C) $\text{HNO}_3 + \text{LiOH}$ (D) $\text{HCl} + \text{NaOH}$
- For which of the following reaction $\Delta H^\circ_{\text{reaction}}$ is not equal to ΔH°_f of product.
 (A) $2\text{CO(g)} + \text{O}_2\text{(g)} \longrightarrow 2\text{CO}_2\text{(g)}$ (B) $\text{N}_2\text{(g)} + \text{O}_3\text{(g)} \longrightarrow \text{N}_2\text{O}_3\text{(g)}$
 (C) $\text{CH}_4\text{(g)} + 2\text{Cl}_2\text{(g)} \longrightarrow \text{CH}_2\text{Cl}_2\text{(l)} + 2\text{HCl(g)}$ (D) $\text{Xe(g)} + 2\text{F}_2\text{(g)} \longrightarrow \text{XeF}_4\text{(g)}$
- The following is (are) endothermic reaction(s) :
 (A) Combustion of methane. (B) Decomposition of water
 (C) Dehydrogenation of ethane to ethylene. (D) Conversion of graphite to diamond.
- Which of the reaction defines molar ΔH_f° ?
 (A) $\text{CaO(s)} + \text{CO}_2\text{(g)} \longrightarrow \text{CaCO}_3 \text{ (s)}$ (B) $\frac{1}{2} \text{Br}_2\text{(l)} + \frac{1}{2} \text{H}_2\text{(g)} \longrightarrow \text{HBr(g)}$
 (C) $\text{N}_2\text{(g)} + 2\text{H}_2\text{(g)} + \frac{3}{2} \text{O}_2\text{(g)} \longrightarrow \text{NH}_4 \text{NO}_3\text{(s)}$ (D) $\frac{1}{2} \text{I}_2\text{(s)} + \frac{1}{2} \text{H}_2\text{(g)} \longrightarrow \text{HI(g)}$

PART - IV : COMPREHENSION

Comprehension # 1

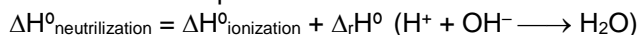
Enthalpy of neutralization is defined as the enthalpy change when 1 mole of acid/base is completely neutralized by base/acid in dilute solution.

For strong acid and strong base neutralization net chemical change is



$\Delta H^\circ_{\text{ionization}}$ of aqueous solution of strong acid and strong base is zero.

When a dilute solution of a weak acid or base is neutralized, the enthalpy of neutralization is some what less because of the absorption of heat in the ionization of the weak acid or base, for weak acid/base



- If enthalpy of neutralization of CH_3COOH by NaOH is -49.86 kJ/mol then enthalpy of ionization of CH_3COOH is:
 (A) 5.98 kJ/mol (B) -5.98 kJ/mol (C) 105.7 kJ/mol (D) None of these



2. What is ΔH° for complete neutralization of strong diacidic base $A(OH)_2$ by HNO_3 ?
 (A) -55.84 kJ (B) -111.68 kJ (C) 55.84 kJ/mol (D) None of these
3. Under the same condition how many mL of 0.1 M NaOH and 0.05 M H_2A (strong diprotic acid) solution should be mixed for a total volume of 100 mL produce the highest rise in temperature :
 (A) $25 : 75$ (B) $50 : 50$ (C) $75 : 25$ (D) $66.66 : 33.33$

Comprehension # 2

Answer Q.4, Q.5 and Q.6 by appropriately matching the information given in the three columns of the following table.

All the given reaction are carried out at constant pressure and temperature conditions. Assuming ideal behavior of all the gases involved.

| Column-1 | | Column-2 | | Column-3 | |
|----------|---------------------------------------------|----------|---------------------|----------|-------------------------------------------------------------------|
| (I) | $2Ag_2O(s) \longrightarrow 4Ag(s) + O_2(g)$ | (i) | $w_{rxn} > 0$ | (P) | Reaction is spontaneous at high temperature. |
| (II) | $2CO(g) + O_2(g) \longrightarrow 2CO_2(g)$ | (ii) | $w_{rxn} < 0$ | (Q) | Reaction is spontaneous at all temperatures. |
| (III) | $2C(s) + O_2(g) \longrightarrow 2CO(g)$ | (iii) | $\Delta_{rxn}H > 0$ | (R) | Reactant mixture is diamagnetic. |
| (IV) | $N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$ | (iv) | $\Delta_{rxn}S > 0$ | (S) | One of the reactant is used to reduce metallic oxide in to metal. |

4. The only incorrect combination is –
 (A) (I) (ii) (P) (B) (II) (iii) (P) (C) (IV) (i) (R) (D) (III) (ii) (Q)
5. The only correct combination is –
 (A) (I) (iv) (P) (B) (II) (ii) (S) (C) (II) (iii) (R) (D) (IV) (ii) (S)
6. The only correct combination is –
 (A) (III) (iv) (S) (B) (IV) (i) (Q) (C) (II) (iii) (S) (D) (I) (i) (P)

Exercise-3

* Marked Questions may have more than one correct option.

PART - I : JEE (ADVANCED) / IIT-JEE PROBLEMS (PREVIOUS YEARS)

1. The species which by definition has **ZERO** standard molar enthalpy of formation at 298 K is :
 [JEE 2010, 3/163]
 (A) $Br_2(g)$ (B) $Cl_2(g)$ (C) $H_2O(g)$ (D) $CH_4(g)$
2. The bond energy (in $kcal\ mol^{-1}$) of a C–C single bond is approximately : [JEE 2010, 3/163]
 (A) 1 (B) 10 (C) 100 (D) 1000
3. Match the transformation in **column-I** with appropriate options in **column-II**. [JEE 2011, 8/180]

| Column-I | Column-II |
|-----------------------------------------------------------|----------------------------|
| (A) $CO_2(s) \longrightarrow CO_2(g)$ | (p) phase transition |
| (B) $CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$ | (q) allotropic change |
| (C) $2H \longrightarrow H_2(g)$ | (r) ΔH is positive |
| (D) $P_{(white, solid)} \longrightarrow P_{(red, solid)}$ | (s) ΔS is positive |
| | (t) ΔS is negative |

4. Using the data provided, calculate the multiple bond energy ($kJ\ mol^{-1}$) of a $C\equiv C$ bond C_2H_2 . That energy is (take the bond energy of a C–H bond as 350 $kJ\ mol^{-1}$) [JEE 2012, 3/136]
- $2C(s) + H_2(g) \longrightarrow C_2H_2(g)$ $\Delta H = 225$ $kJ\ mol^{-1}$
 $2C(s) \longrightarrow 2C(g)$ $\Delta H = 1410$ $kJ\ mol^{-1}$
 $H_2(g) \longrightarrow 2H(g)$ $\Delta H = 330$ $kJ\ mol^{-1}$
- (A) 1165 (B) 837 (C) 865 (D) 815



5. The standard enthalpies of formation of $\text{CO}_2(\text{g})$, $\text{H}_2\text{O}(\text{l})$ and glucose(s) at 25°C are -400 kJ/mol , -300 kJ/mol and -1300 kJ/mol , respectively. The standard enthalpy of combustion per gram of glucose at 25°C is
[JEE (Advance)2013, 2/120]
 (A) $+2900 \text{ kJ}$ (B) -2900 kJ (C) -16.11 kJ (D) $+16.11 \text{ kJ}$
6. The standard state Gibbs free energies of formation of C(graphite) and C(diamond) at $T = 298 \text{ K}$ are
 $\Delta_f G^\circ[\text{C}(\text{graphite})] = 0 \text{ kJ mol}^{-1}$
 $\Delta_f G^\circ[\text{C}(\text{diamond})] = 2.9 \text{ kJ mol}^{-1}$
 The standard state means that the pressure should be 1 bar, and substance should be pure at a given temperature. The conversion of graphite [C(graphite)] to diamond [C(diamond)] reduces its volume by $2 \times 10^{-6} \text{ m}^3 \text{ mol}^{-1}$. If C(graphite) is converted to C(diamond) isothermally at $T = 298 \text{ K}$, the pressure at which C(graphite) is in equilibrium with C(diamond), is :
[JEE(Advanced) 2017, 3/122]
 [Useful information: $1 \text{ J} = 1 \text{ kg m}^2 \text{ s}^{-2}$, $1 \text{ Pa} = 1 \text{ kg m}^{-1} \text{ s}^{-2}$; $1 \text{ bar} = 10^5 \text{ Pa}$]
 (A) 58001 bar (B) 1450 bar (C) 14501 bar (D) 29001 bar

PART - II : JEE (MAIN) / AIEEE PROBLEMS (PREVIOUS YEARS)

JEE-MAIN OFFLINE PROBLEMS

1. $(\Delta H - \Delta U)$ for the formation of carbon monoxide (CO) from its elements at 298 K is **[AIEEE 2006]**
 $(R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1})$
 (1) $1238.78 \text{ J mol}^{-1}$ (2) $-2477.57 \text{ J mol}^{-1}$ (3) $2477.57 \text{ J mol}^{-1}$ (4) $-1238.78 \text{ J mol}^{-1}$
2. The standard enthalpy of formation ($\Delta_f H^\circ$) at 398 K for methane, $\text{CH}_4(\text{g})$ is 74.8 kJ mol^{-1} . The additional information required to determine the average energy for C–H bond formation would be : **[AIEEE 2006, 3/120]**
 (1) the dissociation energy of H_2 and enthalpy of sublimation of carbon
 (2) latent heat of vapourisation of methane
 (3) the first four ionization energies of carbon and electron gain enthalpy of hydrogen
 (4) the dissociation energy of hydrogen molecule, H_2
3. On the basis of the following thermochemical data : ($\Delta_f G^\circ \text{H}^+(\text{aq}) = 0$) **[AIEEE 2009, 8/144]**
 $\text{H}_2\text{O}(\ell) \longrightarrow \text{H}^+(\text{aq}) + \text{OH}^-(\text{aq}) ; \Delta H = 57.32 \text{ kJ}$
 $\text{H}_2(\text{g}) + \frac{1}{2} \text{O}_2(\text{g}) \longrightarrow \text{H}_2\text{O}(\ell) ; \Delta H = -286.20 \text{ kJ}$
 The value of enthalpy of formation of OH^- ion at 25°C is :
 (1) -228.88 kJ (2) $+228.88 \text{ kJ}$ (3) -343.52 kJ (4) -22.88 kJ
4. In a fuel cell methanol is used as fuel and oxygen gas is used as an oxidizer. The reaction is

$$\text{CH}_3\text{OH}(\ell) + \frac{3}{2} \text{O}_2(\text{g}) \longrightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\ell)$$

 At 298 K , standard Gibb's energies of formation for $\text{CH}_3\text{OH}(\ell)$, $\text{H}_2\text{O}(\ell)$ and $\text{CO}_2(\text{g})$ are -166.2 , -237.2 and $-394.4 \text{ kJ mol}^{-1}$ respectively. If standard enthalpy of combustion of methanol is -726 kJ mol^{-1} , efficiency of the fuel cell will be : **[AIEEE 2009, 8/144]**
 (1) 87% (2) 90% (3) 97% (4) 80%
5. The standard enthalpy of formation of NH_3 is $-46.0 \text{ kJ mol}^{-1}$. If the enthalpy of formation of H_2 from its atoms is -436 kJ mol^{-1} and that of N_2 is -712 kJ mol^{-1} , the average bond enthalpy of N–H bond in NH_3 is **[AIEEE 2010, 4/144]**
 (1) -964 kJ mol^{-1} (2) $+352 \text{ kJ mol}^{-1}$ (3) $+1056 \text{ kJ mol}^{-1}$ (4) $-1102 \text{ kJ mol}^{-1}$
6. The value of enthalpy change (ΔH) for the reaction, $\text{C}_2\text{H}_5\text{OH}(\text{l}) + 3\text{O}_2(\text{g}) \longrightarrow 2\text{CO}_2(\text{g}) + 3\text{H}_2\text{O}(\text{l})$ at 27°C is $-1366.5 \text{ kJ mol}^{-1}$. The value of internal energy change for the above reaction at this temperature will be: **[AIEEE 2011, 4/120]**
 (1) -1369.0 kJ (2) -1364.0 kJ (3) -1361.5 kJ (4) -1371.5 kJ
7. Consider the reaction : $4\text{NO}_2(\text{g}) + \text{O}_2(\text{g}) \longrightarrow 2\text{N}_2\text{O}_5(\text{g})$, $\Delta_r H = -111 \text{ kJ}$.
 If $\text{N}_2\text{O}_5(\text{s})$ is formed instead of $\text{N}_2\text{O}_5(\text{g})$ in the above reaction, the $\Delta_r H$ value will be: **[AIEEE 2011, 4/120]**
 (given, ΔH of sublimation for N_2O_5 is 54 kJ mol^{-1})
 (1) $+54 \text{ kJ}$ (2) $+219 \text{ kJ}$ (3) -219 kJ (4) -165 kJ



8. For complete combustion of ethanol, $C_2H_5OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(l)$, the amount of heat produced as measured in bomb calorimeter, is $1364.47 \text{ kJ mol}^{-1}$ at 25°C . Assuming ideality the Enthalpy of combustion, $\Delta_c H$, for the reaction will be : ($R = 8.314 \text{ J mol}^{-1}$) [JEE(Main) 2014, 4/120]
 (1) $-1366.95 \text{ kJ mol}^{-1}$ (2) $-1361.95 \text{ kJ mol}^{-1}$ (3) $-1460.50 \text{ kJ mol}^{-1}$ (4) $-1350.50 \text{ kJ mol}^{-1}$
9. The heats of combustion of carbon and carbon monoxide are -393.5 and $-283.5 \text{ kJ mol}^{-1}$, respectively. The heat of formation (in kJ) of carbon monoxide per mole is : [JEE(Main) 2016, 4/120]
 (1) 676.5 (2) -676.5 (3) -110.5 (4) 110.5
10. Given : $C_{(\text{graphite})} + O_2(g) \longrightarrow CO_2(g)$; $\Delta_r H^\circ = -393.5 \text{ kJ mol}^{-1}$;
 $H_2(g) + \frac{1}{2} O_2(g) \longrightarrow H_2O(l)$; $\Delta_r H^\circ = -285.8 \text{ kJ mol}^{-1}$;
 $CO_2(g) + 2H_2O(l) \longrightarrow CH_4(g) + 2O_2(g)$; $\Delta_r H^\circ = +890.3 \text{ kJ mol}^{-1}$
 Based on the above thermochemical equations, the value of $\Delta_r H^\circ$ at 298 K for the reaction :
 $C_{(\text{graphite})} + 2H_2(g) \longrightarrow CH_4(g)$ will be : [JEE(Main) 2017, 4/120]
 (1) $+144.0 \text{ kJ mol}^{-1}$ (2) $-74.8 \text{ kJ mol}^{-1}$ (3) $-144.0 \text{ kJ mol}^{-1}$ (4) $+74.8 \text{ kJ mol}^{-1}$

JEE-MAIN ONLINE PROBLEMS

1. The standard enthalpy of formation of NH_3 is -46.0 kJ/mol . If the enthalpy of formation of H_2 from its atoms is -436 kJ/mol and that of N_2 is -712 kJ/mol , the average bond thalpy of N–H bond in NH_3 is : [JEE(Main) 2014 Online (09-04-14), 4/120]
 (1) -1102 kJ/mol (2) -964 kJ/mol (3) $+352 \text{ kJ/mol}$ (4) $+1056 \text{ kJ/mol}$
2. The standard enthalpy of formation ($\Delta_f H^\circ_{298}$) for methane, CH_4 is $-74.9 \text{ kJ mol}^{-1}$. In order to calculate the average energy given out in the formation of a C–H bond from this it is necessary to know which one of the following ? [JEE(Main) 2014 Online (12-04-14), 4/120]
 (1) the dissociation energy of the hydrogen molecule, H_2 .
 (2) the first four ionisation energies of carbon.
 (3) the dissociation energy of H_2 and enthalpy of sublimation of carbon (graphite).
 (4) the first four ionisation energies of carbon and electron affinity of hydrogen.
3. The heat of atomixation of methane and ethane are 360 kJ/mol and 620 kJ/mol , respectively. The longest wavelength of light capable of breaking the C–C bond is : [JEE(Main) 2015 Online (10-04-15), 4/120]
 (A vogadro number = 6.02×10^{23} , $h = 6.62 \times 10^{-34} \text{ J s}$):
 (1) $2.48 \times 10^3 \text{ nm}$ (2) $1.49 \times 10^3 \text{ nm}$ (3) $2.49 \times 10^4 \text{ nm}$ (4) $2.48 \times 10^4 \text{ nm}$
4. For a reaction, $A(g) \rightarrow A(l)$; $\Delta H = -3RT$. The correct statement for the reaction is : [JEE(Main) 2017 Online (08-04-17), 4/120]
 (1) $\Delta H = \Delta U \neq 0$ (2) $|\Delta H| > |\Delta U|$ (3) $|\Delta H| < |\Delta U|$ (4) $\Delta H = |\Delta U| = 0$
5. For which of the following reactions, ΔH is equal to ΔU ? [JEE(Main) 2018 Online (15-04-18), 4/120]
 (1) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ (2) $2HI(g) \rightarrow H_2(g) + I_2(g)$
 (3) $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$ (4) $2NO_2(g) \rightarrow N_2O_4(g)$
6. Given : (i) $C(\text{graphite}) + O_2(g) \rightarrow CO_2(g)$; $\Delta_r H^\circ = x \text{ kJ mol}^{-1}$
 (ii) $C(\text{graphite}) + \frac{1}{2} O_2(g) \rightarrow CO(g)$; $\Delta_r H^\circ = y \text{ kJ mol}^{-1}$
 (iii) $CO(g) + \frac{1}{2} O_2(g) \rightarrow CO_2(g)$; $\Delta_r H^\circ = z \text{ kJ mol}^{-1}$
 Based on the above thermochemical equations, find out which one of the following algebraic relationship is correct? [JEE(Main) 2019 Online (12-01-19), 4/120]
 (1) $x = y - z$ (2) $y = 2z - x$ (3) $x = y + z$ (4) $z = x + y$



Answers

EXERCISE – 1

PART – I

| | | | | | |
|------|------------------------------|------|-----------------------------|------|-----------------------------|
| A-1. | $-1368 \text{ kJ mol}^{-1}$ | A-2. | -4.955 kJ | B-1. | $-2035 \text{ kJ mol}^{-1}$ |
| B-2. | $-56.98 \text{ kJ mol}^{-1}$ | C-1. | (-94.1 kcal) | C-2. | -102 kcal |
| C-3. | -383 kJ mol^{-1} | C-4. | 24 g | D-1. | $243.7 \text{ kJ mol}^{-1}$ |
| D-2. | 1488 kJ mol^{-1} | D-3. | -2573 kJ/mole | D-4. | -185 kJ |
| D-5. | 309 kJ mol^{-1} | E-1. | $+65.3 \text{ kJ mol}^{-1}$ | E-2. | -28 kJ/mole |
| E-3. | 3890 kJmole^{-1} | F-1. | $2a = b$ | F-2. | -228 kJ/mole. |
| F-3. | 11.2 Kcal | | | | |

PART – II

| | | | | | | | | | |
|------|-----|------|-----|------|-----|------|-----|------|-----|
| A-1. | (C) | A-2. | (A) | A-3. | (D) | A-4. | (D) | A-5. | (A) |
| B-1. | (D) | B-2. | (A) | B-3. | (B) | B-4. | (D) | C-1. | (A) |
| C-2. | (D) | C-3. | (D) | C-4. | (B) | C-5. | (A) | C-6. | (A) |
| C-7. | (B) | C-8. | (A) | D-1. | (D) | D-2. | (B) | D-3. | (A) |
| E-1. | (A) | E-2. | (A) | E-3. | (C) | E-4. | (C) | E-5. | (A) |
| F-1. | (C) | F-2. | (A) | | | | | | |

PART – III

1. (A) \rightarrow (p, q) ; (B) \rightarrow (q, r, s) ; (C) \rightarrow (p) ; (D) \rightarrow (r)

EXERCISE – 2

PART – I

| | | | | | | | | | |
|-----|-----|----|-----|----|-----|----|-----|-----|-----|
| 1. | (A) | 2. | (C) | 3. | (C) | 4. | (B) | 5. | (D) |
| 6. | (A) | 7. | (B) | 8. | (B) | 9. | (C) | 10. | (B) |
| 11. | (C) | | | | | | | | |

PART – II

| | | | | | | | | | |
|----|----|----|------------------|----|-------|----|----|-----|---------|
| 1. | 9 | 2. | 9 Kcal/mole | 3. | 3 | 4. | 3 | 5. | 5 |
| 6. | 53 | 7. | -12 kJ | 8. | -87 | 9. | 40 | 10. | 78 Kcal |

PART – III

| | | | | | | | | | |
|----|-------|----|--------|----|-------|----|------|----|------|
| 1. | (BCD) | 2. | (ABCD) | 3. | (ABC) | 4. | (AB) | 5. | (CD) |
| 6. | (ABC) | 7. | (BCD) | 8. | (BCD) | | | | |

**PART – IV**

1. (A) 2. (B) 3. (B) 4. (B) 5. (AD)
6. (A)

EXERCISE – 3**PART – I**

1. (B) 2. (C) 3. (A – p, r, s) ; (B – r, s) ; (C – t) ; (D – p, q, t)
4. (D) 5. (C) 6. (C)

PART – II**JEE-MAIN OFFLINE PROBLEMS**

1. (1) 2. (1) 3. (1) 4. (3) 5. (2)
6. (2) 7. (3) 8. (1) 9. (3) 10. (2)

JEE-MAIN ONLINE PROBLEMS

1. (3) 2. (3) 3. (2) 4. (2) 5. (2)
6. (3)