HINTS & SOLUTIONS

EXERCISE - 1
Single Choice

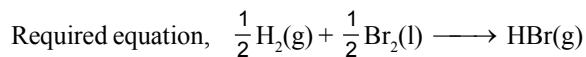**4.** $C(s) \longrightarrow C(g)$ can be obtained as,

$$\Delta H = \Delta H_1 - \Delta H_2 - \frac{1}{2}\Delta H_3 + \Delta H_4$$

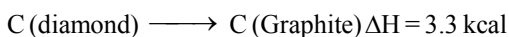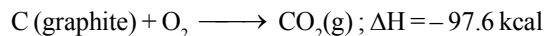**5.** $2C + O_2 \rightarrow 2CO$; $\Delta H = -220\,KJ$

This reaction does not represent complete combustion of carbon, hence heat of combustion of carbon will not be equal to 110 kJ . The negative sign of ΔH indicates that this reaction is exothermic. Also, despite being spontaneous reaction, it requires initiation.

6. $H_2(g) + Br_2(g) \longrightarrow 2HBr(g)$ $\Delta H = \Delta H^{\circ}_1$ ...(i)

$Br_2(g) \longrightarrow Br_2(\ell)$ $\Delta H = \Delta H^{\circ}_2$ ...(ii)

$[eq_1 - eq_2]$

$H_2(g) + Br_2(l) \longrightarrow 2HBr(g)$ $\Delta H = \Delta H^{\circ}_1 - \Delta H^{\circ}_2$

Required equation, $\frac{1}{2}H_2(g) + \frac{1}{2}Br_2(l) \longrightarrow HBr(g)$

$$\Delta H = \left[\frac{\Delta H_1^{0} - \Delta H_2^{0}}{2}\right]$$

7. $C(\text{diamond}) + O_2 \longrightarrow CO_2(g)$; $\Delta H = -94.3$ kcal

$C(\text{graphite}) + O_2 \longrightarrow CO_2(g)$; $\Delta H = -97.6$ kcal

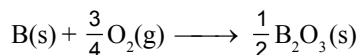$C(\text{diamond}) \longrightarrow C(\text{Graphite}) \Delta H = 3.3$ kcal

Heat required to convert 12 gram diamond to graphite = 3.3

$\therefore$ Heat required to convert 1 gm diamond to graphite

$$= \frac{3.3}{12} = 0.275$$

10. Combustion reaction of solid boron

$$B(s) + \frac{3}{4}O_2(g) \longrightarrow \frac{1}{2}B_2O_3(s)$$

$\Delta H^{\circ}_r = \Delta H^{\circ}_c = \frac{1}{2}\Delta H^{\circ}_f(B_2O_3, s) - \Delta H^{\circ}_f(B, s) - \frac{3}{4}\Delta H^{\circ}_f(O_2, g)$

ΔH_f° of element in stable state of aggregation is assumed to be zero.

$$\mathbf{\Delta H^{\circ}_c = \frac{1}{2}\Delta H^{\circ}_f(B_2O_3, s)}$$

12. $CS_2(\ell) + 3O_2(g) \longrightarrow CO_2(g) + 2SO_2(g)$

$$\Delta H = -256\,Kcal$$

Let $\Delta H_f(CO_2, g) = -4x$ and $\Delta H_f(SO_2, g) = -3x$

$\Delta H_{reaction} = \Delta H_f(CO_2, g) + 2\Delta H_f(SO_2, g) - \Delta H_f(CS_2, \ell)$

$-265 = -4x - 6x - 26$

$x = +23.9$

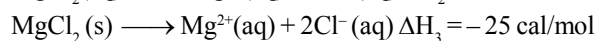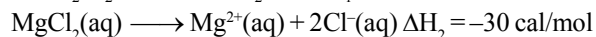$\therefore \Delta H_f(SO_2, g) = 3x = \mathbf{-71.7\,Kcal/mol.}$

13. $S + O_2 \longrightarrow SO_2$ $\Delta H = -298.2$ KJ/mole   ....**(1)**

$SO_2 + \frac{1}{2}O_2 \longrightarrow SO_3$ $\Delta H = -98.7$ KJ/mole   ....**(2)**

$SO_3 + H_2O \longrightarrow H_2SO_4$ $\Delta H = -130.2$ KJ/mole   ....**(3)**

$H_2 + \frac{1}{2}O_2 \longrightarrow H_2O$ $\Delta H = -287.3$ KJ/mole   ....**(4)**

Adding (1),(2),(3) and (4) we get desired equation.

15. $MgCl_2.H_2O \longrightarrow MgCl_2(aq)\,\Delta H_1 = ?$

$MgCl_2(aq) \longrightarrow Mg^{2+}(aq) + 2Cl^-(aq)\,\Delta H_2 = -30$ cal/mol

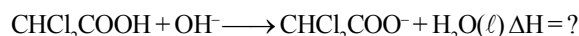$MgCl_2(s) \longrightarrow Mg^{2+}(aq) + 2Cl^-(aq)\,\Delta H_3 = -25$ cal/mol

$\Delta H_1 + \Delta H_2 = \Delta H_3$

$\Delta H_1 = \Delta H_3 - \Delta H_2 = -25 + 30 = +5$ cal/mol.

16. $H^+ + OH^- \longrightarrow H_2O(\ell)$ $\Delta H = -13.7$ kcal   ...**(i)**

$CHCl_2COOH \longrightarrow CHCl_2COO^- + H^+$

$$\Delta H = 0.7\,kcal...\textbf{(ii)}$$

$CHCl_2COOH + OH^- \longrightarrow CHCl_2COO^- + H_2O(\ell)\,\Delta H = ?$
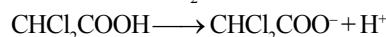
Adding equation **(i)** and **(ii)** $\Delta H = \mathbf{-13\,kcal.}$

17. $H_3PO_3 \longrightarrow 2H^+ + HPO_3^{2-}$; $\Delta_r H = ?$

$2H^+ + 2OH^- \longrightarrow 2H_2O;$
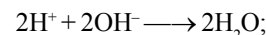
$\Delta_r H = -55.84 \times 2 = -111.68$

$-106.68 = \Delta_{ion}H - 55.84 \times 2$

$\Delta_{ion}H = 5$ kJ/mol.

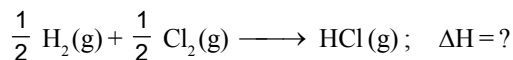**20.** $\frac{1}{2}A-A + \frac{1}{2}B-B \rightarrow AB\,\Delta H = -100$ KJ/mole

$\frac{1}{2}x + \frac{1}{2}(0.5x) - x = -100 \Rightarrow \frac{x}{2} + 0.25x - x = -100$

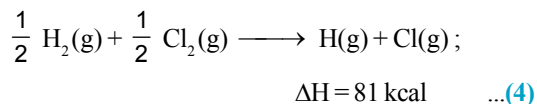$\Rightarrow -0.25x = -100$ $\Rightarrow x = 400$ KJ/mole

Bond enthalpy = **400 kJ/mol.**

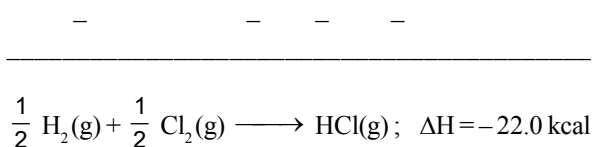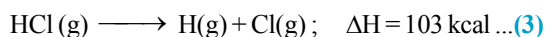**21.** Given $\quad H_2(g) \longrightarrow 2H(g);\qquad \Delta H = 104\ kcal$ ...**(1)**

$\quad Cl_2(g) \longrightarrow 2Cl(g);\qquad\qquad \Delta H = 58\ kcal$ ...**(2)**

$\quad HCl(g) \longrightarrow H(g) + Cl(g);\quad \Delta H = 103\ kcal$...**(31)**

Heat of formation for HCl

$$\frac{1}{2}\ H_2(g) + \frac{1}{2}\ Cl_2(g) \longrightarrow HCl(g);\quad \Delta H = ?$$

Divide equation (1) and (2) by 2, and then add

$$\frac{1}{2}\ H_2(g) + \frac{1}{2}\ Cl_2(g) \longrightarrow H(g) + Cl(g);$$

$$\Delta H = 81\ kcal \qquad ...\textbf{(4)}$$

Subtracting equation (3) from equation (4)

$$HCl(g) \longrightarrow H(g) + Cl(g);\quad \Delta H = 103\ kcal\ ...\textbf{(3)}$$

$\qquad -\qquad\qquad\qquad -\qquad\quad -\qquad\ -$
_____

$$\frac{1}{2}\ H_2(g) + \frac{1}{2}\ Cl_2(g) \longrightarrow HCl(g);\quad \Delta H = -22.0\ kcal$$

$\therefore$ Enthalpy of formation of HCl gas $= -\textbf{22.0 kcal}$

22. $\Delta H° = -92.2$
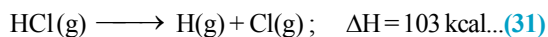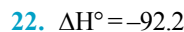
$\Delta C_P = 2C_P\,(NH_3,\ g) - C_P\,(N_2,\ g) - 3C_P\,(H_2)$

$\quad = 2 \times 35.1 - 29.1 - 3 \times 28.8$

$\quad = 70.2 - 29.1 - 86.4 = -45.3\ J/K$

$$\Delta H°_{100°C} = \Delta H°_{25°C} + \Delta C_P\,(\Delta T) = -92.2 - \frac{45.3 \times 75}{1000}$$
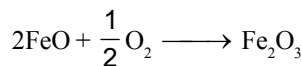
$\Delta H°_{100°C} = -92.2 - 1.3975 = -95.6\ kJ/mole$

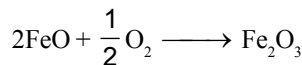Then, reaction at 100°C as compared to that at 25°C will be more exothermic.

23. Let mixture contain x mole of steam & y mole oxygen then,
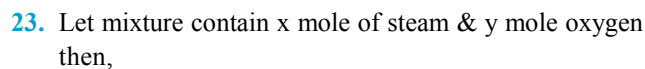
Here, temperature is constant. So, amount of heat released = amount of heat gain

$$x \times 132 = y(220) \quad\Rightarrow\quad \frac{x}{y} = \frac{220}{132} = \frac{1.66}{1}$$
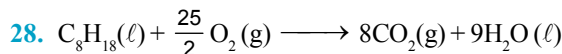
$\Rightarrow \textbf{y : x = 1 : 0.6}$

25. $FeO + Fe_2O_3$

$\quad 2x \qquad\ x$

$$Fe + \frac{1}{2}O_2 \longrightarrow FeO \qquad \Delta H_f^o = -65\ Kcal/mole$$

$$2Fe + \frac{3}{2}O_2 \longrightarrow Fe_2O_3 \qquad \Delta H_f^o = -197\ Kcal/mole$$

$$2FeO + \frac{1}{2}O_2 \longrightarrow Fe_2O_3$$

$\Delta H = -197 + 65 \times 2 \Rightarrow \Delta H = -67\ Kcal/mole$

$$2FeO + \frac{1}{2}O_2 \longrightarrow Fe_2O_3$$

$\quad \dfrac{2}{3} \qquad\qquad\qquad \dfrac{1}{3}$
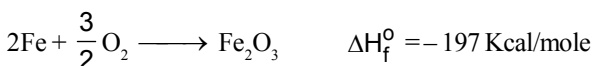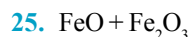
$\quad \dfrac{2}{3} - 2x \qquad\qquad\quad \dfrac{1}{3} + x$
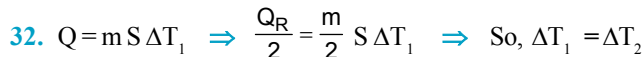
$$\frac{\frac{2}{3} - 2x}{\frac{1}{3} + x} = \frac{1}{2} \qquad \Rightarrow\quad x = \frac{1}{5}$$

So, energy released $= \dfrac{1}{5} \times 67 = \textbf{13.4 kcal/mole}$

28. $C_8H_{18}(\ell) + \dfrac{25}{2}O_2(g) \longrightarrow 8CO_2(g) + 9H_2O\,(\ell)$

$$\Delta n_g = 8 - \frac{25}{2} = \frac{16 - 25}{2} = -\frac{9}{2} = -4.5$$

$$\Delta H - \Delta E = \Delta n_g RT = -\frac{4.5 \times 8.314 \times 298}{1000} = \textbf{-11.15 kJ}$$
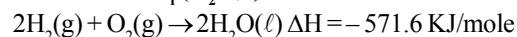
32. $Q = m\,S\,\Delta T_1 \quad\Rightarrow\quad \dfrac{Q_R}{2} = \dfrac{m}{2}\,S\,\Delta T_1 \quad\Rightarrow\quad$ So, $\Delta T_1 = \Delta T_2$

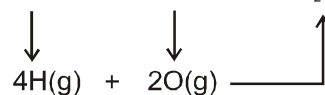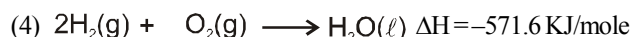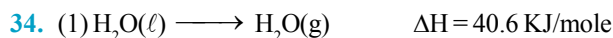**33.** Assuming density of solution is 1g/cc

and specipic heat is 4.2 J/gc

$\quad q = ms\Delta T = 100 \times 4.2 \times 3$

millimoles of acid nuetralized $= 5$

$$\Delta H = -100 \times 4.2 \times 3 \times \frac{1000}{5} = -2.52 \times 10^2\ kJ/mole.$$

34. (1) $H_2O(\ell) \longrightarrow H_2O(g) \qquad \Delta H = 40.6\ KJ/mole$

(2) $2H(g) \longrightarrow H_2(g) \qquad \Delta H = -435.0\ KJ/mole$

(3) $2O(g) \longrightarrow O_2(g) \qquad \Delta H = -489.6\ KJ/mole$

(4) $2H_2(g) + O_2(g) \longrightarrow H_2O(\ell)\ \ \Delta H = -571.6\ KJ/mole$

$\qquad\downarrow\qquad\qquad\downarrow\qquad\qquad\quad\uparrow$

$4H(g) + 2O(g) \longrightarrow$

(1) Calculation of $\Delta H°_f\,(H_2O, \ell)$

$\quad 2H_2(g) + O_2(g) \rightarrow 2H_2O(\ell)\ \Delta H = -571.6\ KJ/mole$

$\Delta H°_r = 2\Delta H°_F(H_2O,\ \ell) - 2\Delta H°_F\{H_2(g)\} - \Delta H°_F(O_2,\ g)$

$\qquad\qquad\qquad\qquad\downarrow\qquad\qquad\qquad\downarrow$

$\qquad\qquad\qquad\quad Zero\qquad\qquad Zero$

$-571.6 = 2\Delta H°_F(H_2O,\ \ell)$ so $\Delta H°_F(H_2O,\ \ell) = -285.8$

(2) Calculation of $\Delta H^\circ_F(H_2O, g)$
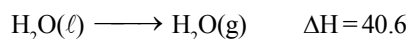
$$H_2O(\ell) \longrightarrow H_2O(g) \qquad \Delta H = 40.6$$

$$\Delta H_r = \Delta H^\circ_F(H_2O, g) - \Delta H^\circ(H_2O, \ell)$$
$$\Delta H^\circ_F(H_2O, g) = \Delta H^\circ_F(H_2O, \ell) + \Delta H_r$$
$$= -285.8 + 40 = -245.8$$

(3) $H_2(g) + \dfrac{1}{2}O_2(g) \longrightarrow H_2O(g) \qquad \Delta H = -245.8$

$$2H(g) + O(g) \longrightarrow$$
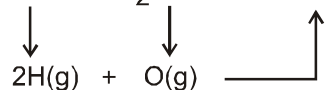
$$\Delta Hr = \in_{H-H} + \frac{1}{2}\in_{O-O} - 2\in_{O-H}$$
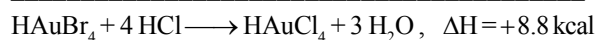
$$\Rightarrow -245.8 = +435 + \frac{1}{2}(489.6) - 2 \times \in_{O-H}$$

$$2\in_{O-H} = 435 + 244.8 + 245.8$$
$$\Rightarrow 2\in_{O-H} = 925.6$$
$\in O{-}H = 462.8$

35. $Au(OH)_3 + 4HCl \longrightarrow HAuCl_4 + 3H_2O, \quad \Delta H = -28\,kcal$
$HAuBr_4 + 3H_2O \longrightarrow Au(OH)_3 + 4HBr, \quad \Delta H = +36.8\,kcal$
_____
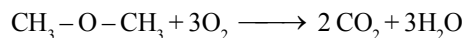$HAuBr_4 + 4HCl \longrightarrow HAuCl_4 + 3H_2O, \quad \Delta H = +8.8\,kcal$
When 100% conversion, heat absorbed = 8.8 Kcal

$$\% \text{ conversion} = \frac{0.44}{8.8} \times 100 = 5\%$$

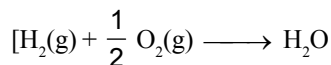**36.** $\Delta H_F^\circ\, C_2H_5OH(\ell) = -66\,Kcal/mole$

$$2C + 3H_2 + \frac{1}{2}O_2 \longrightarrow C_2H_5OH$$
$$\Delta H = -66\,kcal/mole \quad ....(1)$$

$$CH_3 - O - CH_3 + 3O_2 \longrightarrow 2CO_2 + 3H_2O$$
$$\Delta H = -348\,kcal/mole \quad ....(2)$$

$$[H_2(g) + \frac{1}{2}O_2(g) \longrightarrow H_2O$$
$$\Delta H_3 - 68\,kcal/mole \quad ....(3)$$
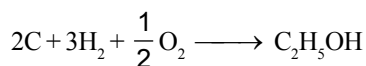
$[C + O_2 \longrightarrow CO_2 \qquad \Delta H_4 = -94\,kcal/mole \quad ....(4)$
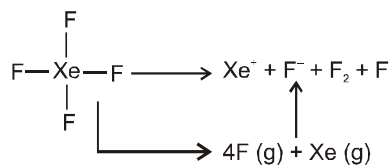Target equation = $-$ eq 1 $-$ eq 2 + 3eq 3 + 2 eq 2
$\Delta H = +66 + 348 - 3 \times 68 - 2 \times 94 = \qquad +66 + 348 - 204 - 188$
$\Rightarrow$ **$\Delta H = 22\,K\,cal/mole$**
$\Delta H = \Delta E + \Delta ngRT \qquad \Rightarrow \quad 22 = \Delta E + 1 \times 2 \times 298 \times 10^{-3}$
$\Rightarrow$ **$\Delta E = 21.4\,Kcal/mole$**

37.

$$\Delta H = 4E_{Xe-F} + \Delta H_{Ioni}[Xe \rightarrow Xe^+] - \Delta E_{F-F} - \Delta H_{eg}[F \rightarrow F^-]$$
$$= 4 \times 34 + 279 - 85 - 38 = 136 + 279 - 123 = 415 - 213$$
$= 292\,kcal/\,mole.$

39. $-12250x - 13000(1-x) = -12500$
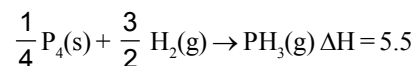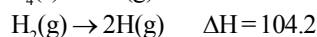$750\,x = 500 \qquad \Rightarrow \quad x = 2/3$

So, required ratio is $= \dfrac{2}{1}$

40. $1\,M\,H_2SO_4 = 2g$ eq. of H_2SO_4

hence, $y = 2x$ or $x = \dfrac{1}{2}\,y$.

42. $P_4(s) \rightarrow 4P(g) \qquad \Delta H = 53.2 \times 6$
$H_2(g) \rightarrow 2H(g) \qquad \Delta H = 104.2$

$$\frac{1}{4}P_4(s) + \frac{3}{2}H_2(g) \rightarrow PH_3(g)\ \Delta H = 5.5$$

$$\frac{1}{4} \times 6 \times 53.2 + \frac{3}{2} \times 104.2 - 3\in_{P-H} = 5.5$$

$$\Rightarrow \in_{P-H} = 76.866\ i.e.\ 76.9\,kcal\,mol^{-1}$$

EXERCISE - 2
Part # I : Multiple Choice

3. $\Delta H_r = \Big[2(\Delta H_f)_{N_2O_5} + 4(\Delta H_f)_{HPO_3} - 4(\Delta H_5)_{HNO_3} -$
$\qquad -(\Delta H_f)_{P_4O_{10}}\Big]$

$\Delta H_r = \Big[2(-43.1) + 4(-948.5) - 4(-174.1) - (-2984.0)\Big]$
$\qquad = -199.8$

5. $\Delta H_r^\circ = \Big[4\Delta H_{C-H} + 4\Delta H_{Cl-Cl} - 4\Delta H_{C-Cl} - 4\Delta H_{C-Cl}\Big]$
$\qquad = \Big[4 \times 414 + 4 \times 243 - 4 \times 331 - 4 \times 4313\Big]$
$\Delta H_r^\circ = 420$
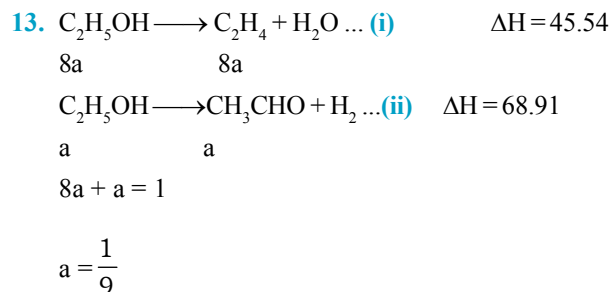
6. For $\Delta H_g = 0,\ \Delta H = \Delta E$
$\qquad \Delta H_g \neq 0,\ \Delta H \neq \Delta E$

9. Heat evolve $= mC_V\Delta t = 100 \times 4.2 \times 10 = 4.2\,kJ$
for 0.1 mole the enthalpy change = 4.2 kJ
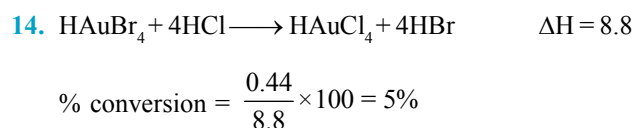for 1 mole the enthalpy change = 42 kJ

10. $HCl + NaOH \longrightarrow NaCl + H_2O$

enthalpy change $= mC_V dT = 100 \times 4.2 \times 3$

$\qquad\qquad\qquad = 1.26$ kJ

enthalpy change for 5 millimole $= 1.26$ kJ

enthalpy change for 1 mole $\Rightarrow \dfrac{1.26}{5 \times 10^{-3}}$

$\Rightarrow 2.52 \times 10^2$ kJ

13. $C_2H_5OH \longrightarrow C_2H_4 + H_2O$ ... **(i)** $\qquad \Delta H = 45.54$

$\quad$ 8a $\qquad\qquad$ 8a

$\quad C_2H_5OH \longrightarrow CH_3CHO + H_2$ ...**(ii)** $\quad \Delta H = 68.91$

$\quad$ a $\qquad\qquad$ a

$\quad 8a + a = 1$

$\quad a = \dfrac{1}{9}$

$\quad$ energy involve in **(i)** reaction $= 45.54 \times \dfrac{8}{9}$

$\quad$ energy involve in **(ii)** reaction $= 68.91 \times \dfrac{1}{9}$

$\quad$ total involve in **(i)** + **(ii)** are $\Rightarrow 48.137$ Kg

14. $HAuBr_4 + 4HCl \longrightarrow HAuCl_4 + 4HBr \qquad \Delta H = 8.8$

$\quad$ % conversion $= \dfrac{0.44}{8.8} \times 100 = 5\%$

Part # II : Assertion & Reason

1. Heat of neutralisation for strong acid and strong base combination is constant is equal to -13.7 Kcal or -57.1 KJ.

2. For reaction $C(s) + O_2(g) \rightarrow CO_2(g)$; $\Delta H = \Delta U$
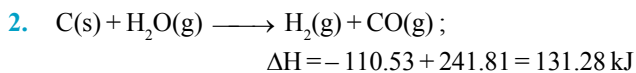
EXERCISE - 3
Part # I : Matrix Match Type

1. **(A)** This is combustion reaction as well as formation reaction of CO_2.

$\quad$ **(B)** This is sublimation, atomization as well as formation reaction of $C(g)$.

$\quad$ **(C)** This is combustion reaction of $CO(g)$.

$\quad$ **(D)** This is atomization of $CH_4(g)$.

Part # II : Comprehension

Comprehension # 1 :

2. $C(s) + H_2O(g) \longrightarrow H_2(g) + CO(g)$;

$\qquad\qquad \Delta H = -110.53 + 241.81 = 131.28$ kJ

For 100 moles of air heat liberated $= 21 \times 314$ kJ.

No. of moles of H_2O converted to product

$= \dfrac{21 \times 314}{131.28} = 50.23$

No. of moles of H_2O taken $= \dfrac{50.23}{0.75} = 66.97$.

Gas	H_2	CO	N_2	H_2O	CO_2
No. of moles	50.23	50.23	79	16.74	21
% (v/v)	23.1	23.1	36.4	7.7	9.7

Comprehension # 2 :

1. $\Delta H_{ionisation} = \Delta H°_{neutralisation} - \Delta H° \, (H + OH^- \longrightarrow H_2O)$

$= -49.86 - (-55.84)$ kJ/mole

$= 5.98$ kJ/mole

3. For max. rise in temp.; max. neutralization of H^+ and OH^- required.

If we take equal volume, all H^+ (5 m-mole) will react with all OH^- (5 m-mole).

Comprehension # 4 :

1. $\Delta H_r = \left[(\Delta H_f)_{C_2F_4} + 2(\Delta H_f)_{HCl} - 2(\Delta H_f)_{CHClF_2} \right]$

$= [-658.3 + 2(-92.3) + 2(485.2)]$

$= 127.5$ kJ/mole

2. Add eq. **(i)**, **(ii)** and **(iii)**

$CX_4(g) \longrightarrow C(g) + 4X$

$\Delta H = -\Delta H_1 + 718 + 2D(X - X)$

$\qquad$ X=F

$\Delta H = +679.6 + 718 + 2 \times 154.7$

$\Delta H = 1707$

Average bond energy of C – F bond $= \dfrac{1707}{4} = 426.75$

$\qquad\qquad$ X = Cl

$\Delta H = 106.6 + 718 + 2(246.7) = 1318$

Average bond energy of C – Cl bond $= 329.5$ Kg

3. C – Cl bond energy $= 329.5$

$\quad$ C – H bond energy $= 416.1$

$\quad$ C – F bond energy $= 426.75$

$\quad$ Order of reactivity C – Cl > C – H > C – F

Comprehension # 5 :

1. **(i)** $\Delta H = (v + w + x + y + z)$

   (ii) $(\Delta H_f)_{K^+} = \dfrac{w}{2}$

   (iii) $(\Delta H)_{EA}$ for $H = \dfrac{y}{2}$

   (iv) $(\Delta H)_{lattice}$ for $KH = \dfrac{z}{2}$

2. **(i)** electron affinity is exothermic
   (ii) ionization is endothermic

3. $(\Delta H)_r = 2 \times 90 + 2 \times 418 + 436 - 2 \times 78 - 2 \times 710$
   $(\Delta H)_r = -124$ kJ/mole

4. $(\Delta H_f)_{KH} = -\dfrac{124}{2} \qquad \Rightarrow \quad -62$ kJ/mole

6. Meq. of KH = Meq. of HCl

   $\dfrac{0.1}{E_{KH}} \times 1000 = 25 \times 0.1$

   Valency factor of K is 1 hence
   $E_K = M_K \qquad\qquad M_K = 39$
   $E_{KH} = 40 \qquad\qquad E_{KH} = E_K = E_H$
   $40 = E_K + 1 \qquad\quad E_K \Rightarrow 39$

EXERCISE - 4
Subjective Type

3. $\Delta H_2 - 24 = -0.024 \times (523 - 473)$ cal/g.
∴ $\Delta H_2 = 22.8$ cal/g.

4. When the heat capacities of all substances participating in a chemical reaction are assumed to be constant over the range of temperatures involved kirchoff's law integrates to
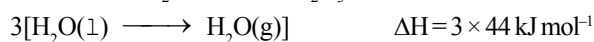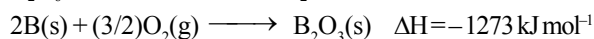 $\Delta H^\circ(T_2) = \Delta H^\circ(T_1) + \Delta C_P(T_2 - T_1)$

   $\Delta C_P = \displaystyle\sum_{Products} \upsilon C_{p,m}^0 - \sum_{Reactants} \upsilon C_{p,m}^0 -$

   $\Delta C_P = C_p(N_2O_4, g) - 2\, C_p(NO_2, g)$
   $= (77.28) - (2) \times (37.20\ \text{j K}^{-1}\,\text{mol}^{-1})$
   $= +2.88\ \text{JK}^{-1}\,\text{mol}^{-1}$
   $\Delta H^\circ(373\ \text{K}) = \Delta H^\circ(298\ \text{K}) + \Delta C_p \Delta T$
   $= (-57.20\ \text{kJ mol}^{-1}) + (2.88\ \text{J K}^{-1}) \times (75\ \text{K})$
   $= \{(-57.20) + (0.22)\}\ \text{kJ mol}^{-1}$
   $= -56.98\ \text{kJ mol}^{-1}$
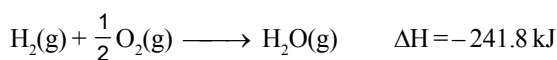
6. Given reaction can be obtained as follows :

   $B_2H_6(g) \longrightarrow 2B(s) + 3H_2(g) \qquad \Delta H = -36\ \text{kJ mol}^{-1}$
   $2B(s) + (3/2)O_2(g) \longrightarrow B_2O_3(s)\quad \Delta H = -1273\ \text{kJ mol}^{-1}$
   $3[H_2O(l) \longrightarrow H_2O(g)] \qquad\quad \Delta H = 3 \times 44\ \text{kJ mol}^{-1}$
   $3[H_g(s) + (1/2)O_2(g) \longrightarrow H_2O(l)$
   $\qquad\qquad\qquad\qquad\qquad \Delta H = -3 \times 286\ \text{kJ mol}^{-1}$

   Add ———————————————————————————————
   $B_2H_6(g) + 3O_2(g) \longrightarrow B_2O_3(s) + 3H_2O(g)$
   $\qquad\qquad\qquad\qquad \Delta H = -2035\ \text{kJ mol}^{-1}$
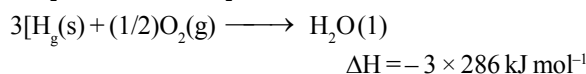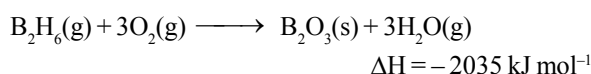
7. Equal volume of $H_2(g)$ & $CO(g)$
   Total volume = 112 L
   So, volume of CO = volume of H_2 = 56 L
   Mole of CO = Mole of H_2 = 2.5 mole

   $H_2(g) + \dfrac{1}{2}O_2(g) \longrightarrow H_2O(g) \qquad \Delta H = -241.8$ kJ

   For 1 mole $\qquad\qquad\qquad\qquad\qquad \Delta H = -241.8$ kJ
   For 2.5 mole $\qquad\qquad\qquad\qquad \Delta H = -241.8 \times 2.5$

   Similarly, $CO(g) + \dfrac{1}{2}O_2(g) \longrightarrow CO_2(g)$
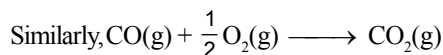
   $\qquad\qquad\qquad\qquad\qquad\qquad \Delta H = -283$ kJ
   $\qquad\qquad\qquad\qquad\qquad\qquad \Delta H = -283 \times 2.5$ kJ
   Total Heat evolved $= [-241.8 + (-283]\, 2.5 = -1312$ kJ

8. $K(s) + \dfrac{1}{2}O_2(g) + \dfrac{1}{2}H_2(g) \longrightarrow KOH \quad \Delta H = ?$

   $H_2 + \dfrac{1}{2}O_2 \longrightarrow H_2O \qquad\qquad \Delta H = -68$ kcal
   ...**(i)**

   $K + H_2O \longrightarrow KOH(aq.) + \dfrac{1}{2}H_2(g)$
   $\qquad\qquad\qquad\qquad \Delta H = -48$ kcal ...**(ii)**
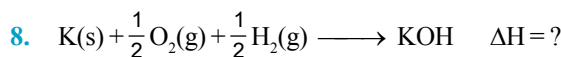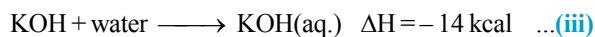
   $KOH + water \longrightarrow KOH(aq.)\quad \Delta H = -14$ kcal ...**(iii)**
   $\Delta H_{f,KOH} = $ **(i)** + **(ii)** − **(iii)**
   $\Delta H_{f,KOH} = -48 - 68 - (-14) = $ **−102 kcal.**

9. Heat generated $= C_T \Delta T = 1260 \times 0.667$ cal.

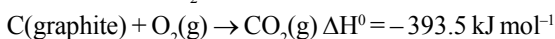   ∴ $n_{CH_4} = \dfrac{1260 \times 0.667}{210.8 \times 10^3}$

   $n_{total} = \dfrac{PV}{RT} = 3.98 \times 10^{-2}$

$$\therefore \quad mol\% = \frac{1260 \times 0.667}{210.8 \times 10^3 \times 3.98 \times 10^{-2}} \times 100\% = 10\% \, Ans.$$

12. We have

$$\text{Amount of carbon} = \frac{12.0g}{12.0 \, g \, mol^{-1}} = 1 \, mol$$

The equations to be considered are

$C(graphite) + \frac{1}{2}O_2(g) \rightarrow CO(g) \; \Delta H^0 = -110.5 \, kJ \, mol^{-1}$

$C(graphite) + O_2(g) \rightarrow CO_2(g) \; \Delta H^0 = -393.5 \, kJ \, mol^{-1}$

Let the amount x of carbon be converted into CO and the remaining (i.e. 1.0 mol – x) into CO_2. we will have

$[x(-110.5) + (1.0 \, mol - x)(-393.5)] \, kJ \, mol^{-1} = -313.8 \, kJ$

Which gives $x = \dfrac{313.8 + 393.5}{393.5 - 110.5} \, mol = 0.282 \, mol$

$$\text{Amount of oxygen needed} = \left[\frac{0.282}{2} + (1.0 - 0.282)\right]$$

$mol = 0.859 \, mol$

Mass of oxygen needed $= (0.859 \, mol)(32 \, g \, mol^{-1}) = 27.48 \, g$

15. Equation **(vi)** can be generated by the following manipulations.

Eq. **(i)** – Eq. **(ii)** – Eq. **(iii)** – Eq. **(iv)** – ½ Eq. **(v)**

Carrying out the corresponding manipulations on ΔH^0_L, we get

$\Delta H^0_L = (-563 - 419 - 88 + 322 - 79) \, kJ \, mol^{-1}$

$\quad = -829 \, kJ \, mol^{-1}$

16. (i) $CHCl_2COOH + NaOH \longrightarrow CHCl_2COONa + H_2O$
$\Delta H = -12830 \, Cal$

(ii) $HCl + NaOH \longrightarrow H_2O + NaCl$
$\Delta H = -13680 \, Cal$

(iii) $NH_4OH + HCl \longrightarrow NH_4Cl + H_2O$
$\Delta H = -12270 \, Cal$

(iv) $CHCl_2COOH + NH_4OH \longrightarrow CHCl_2COONH_4 + H_2O$
$\Delta H = ?$
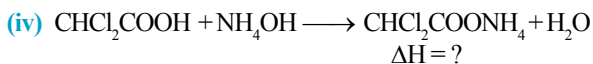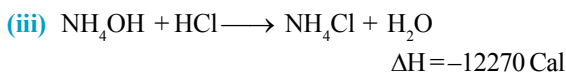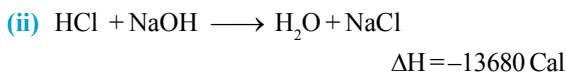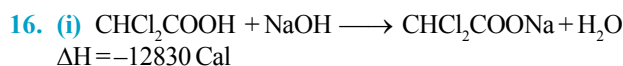
(iv) = (i) + (iii) – (ii) $= -12830 - 12270 + 13680 = -11420$ Cal

Heats of ionization of $CHCl_2COOH = -13680 + 12830$
$= -850 \, cal$

Heats of ionization of $NH_4OH = -13680 + 12270 = -1410 \, cal$

17. Given total solution = 200 + 400 = 600 mL.

200 mL of 1 MHCl neutralize 400 mL of 0.5 M NaOH

$\therefore$ Meq. $= N \times V$

$\therefore$ mM or Meq. of acid and base = 200 (For mono valent

nature)

i.e., 200 Meq. of HCl react with 200 Meq. of NaOH to produce heat = ΔH

1000 Meq. of HCl + 1000 Meq. of NaOH will give heat $= 5 \times \Delta H$.

i.e, heat of neutralization. Now,

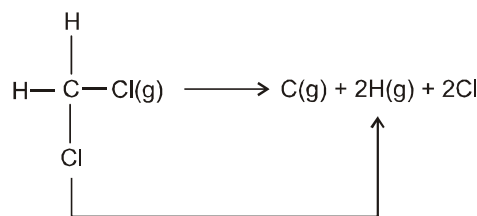ΔH, i.e., Heat produced during neutralization of 200 Meq. of acid and base

$\quad$ = Heat taken up by calorimeter + solution = $m_1 s_1 \Delta T + m_2 s_2 \Delta T$

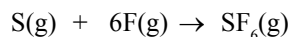$\quad = 12 \times 4.4 + 600 \times 1 \times 4.4 = 2692.8 \, cal$

$\therefore$ Heat of neutralization $= -5 \times 2692.8 \, cal = -13.464 \, kcal$

18.

$\Delta Hr = 2 \in_{C-H} + 2 \in_{C-Cl} = 2 \times 414 + 2 \times 330 = 828 + 660$
$= 1488 \, kJ/mol.$

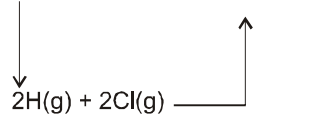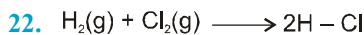**20.** To calculate the average S–F bond enthalpy, we determine the enthalpy change for the following reaction.

$S(g) + 6F(g) \rightarrow SF_6(g)$

$\Delta H^0_f \quad 275 \, kJ \, mol^{-1} \quad 80 \, kJ \, mol^{-1} \quad 1100 \, kJ \, mol^{-1}$

$\Delta H^0_f = \Delta H^0_f(F_6, g) - [\Delta H^0_f(S, g) + 6\Delta H^0_f(F, g)]$

$= [-1100 - (275 + 6 \times 80)] \, kJ \, mol^{-1}$

Hence $\varepsilon(S-F) = \dfrac{-\Delta H^0_f(SF_6, g)}{6} = \dfrac{1855 \, kJ \, mol^{-1}}{6}$

$= 309.2 \, kJ \, mol^{-1}$

22.

$\Delta H_r = \in_{H-H} + \in_{Cl-Cl} - 2 \in_{H-Cl} = 435 + 240 - 2 \times 430$

$\Delta H_r = -185 \, kJ$

$\Delta S = 2S^\circ_m HCl - S^\circ_m H_2(g) - S^\circ_m Cl_2(g) = 2 \times 187 - 131 - 223$

$\Delta S = 20 \, J/mole \, K$

$$\Delta G = \Delta H - T\Delta S = -185 - \frac{300 \times 20}{1000} = -186 - 6 = -191\, KJ.$$

23. Target equation : $N_2H_4(\ell) + O_2(g) \rightarrow N_2(g) + 2H_2O\,(\ell)$

which can be obtained by the given manipulation.

$$\frac{1}{4} \times \text{(i)} - \frac{3}{4}\,\text{(ii)} + \frac{9}{4}\,\text{(iv)} - \frac{1}{8}\,\text{(iii)}$$

Hence, ΔH for targeted equation is

$$\frac{1}{4}(-1011) - \frac{3}{4}(-317) + \frac{9}{4}(-286) - \frac{1}{8}(-286)$$

$$= \frac{1}{4}\,[-1011 + 3 \times 317 - 9 \times 286 + 0.5 \times 286]$$

$$= -622.75\, kJ/mole\, hydrazine$$

Now, $\quad -622.75 = 2 \times (-286) - \Delta H_f(N_2H_4)$

$\Rightarrow \quad \Delta H_f(N_2H_4) = +50.75\, kJ/mol$

Yes it is an endothermic compound.

25. (i) $C(s) + O_2(g) \longrightarrow CO_2(g)$; $\Delta H_f^\circ = -393.33\, KJ/mol$;

$$\Delta H_f^\circ = \frac{590}{18} \times 12$$

(ii) $H_2(g) + \frac{1}{2}O_2(g) \longrightarrow H_2O(\ell)$; $\Delta H_f^\circ = -286\, KJ/mol$;

$$\Delta H_f^\circ = \frac{15889}{55.5}$$

(iii) $C_6H_6(\ell) + \frac{15}{2}O_2(g) \longrightarrow 6CO_2(g) + 3H_2O(\ell)$

∴ $\Delta H^\circ = [6(-393.33) + 3(-286)] - 50 = -3268\, KJ/mol$

Mass of benzene is $= 0.87 \times 100 = 87\,g$

∴ Heat evolved from 87 gm benzene $= 3645\, KJ$ **Ans.**

27. $C_6H_{12}O_6(s) + 6O_2(g) \longrightarrow 6CO_2 + 6H_2O(\ell)$

No. of Mole of $C_6H_{12}O_6 = \dfrac{0.36}{180} = 2 \times 10^{-3}\, mole$

$$C = \frac{q}{\Delta T} \quad \therefore \quad q = C \times \Delta T = 640 \times 10\,J = 6.4\, kJ$$

Heat released per mole $= \dfrac{6.4}{2 \times 10^{-3}} = 3.2 \times 10^3\, kJ = \mathbf{3.2\, MJ}$

$\Delta U = -3.2\, MJ$

$\Delta H = \Delta U + \Delta n_g RT$ here $\quad \Delta n_g = 0$

$\Delta H = \Delta U = \mathbf{-3.2\, MJ\, mole^{-1}}$

28. By the equations $C_p = f(T)$, we find

$$\Delta C_p = (C_p)_{CO} - (C_p)_c - \frac{1}{2}(C_P)_{O_2}$$

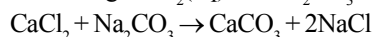$$= 2.37 - 4.973 \times 10^{-3}\,T + 1.585 \times 10^{-6}T^2$$

The condition where ΔH° does not depend on the temperature is the equation $\Delta C_p = 0$,

i.e. $2.37 \times 4.973 \times 10^{-3}T + 1.585 \times 10^{-6}T^2 = 0$,
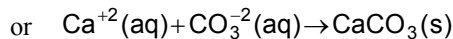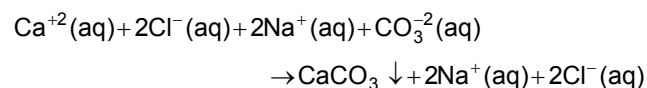
where $T \approx 586$.

Since the terms of the equation $\Delta C_p = f(T)$ containing T are negative, then at $T > 586$ we have $\Delta C_p < 0$. i.e. at this temperature ΔH° passes through a minimum.

30. On mixing $CaCl_2(aq)$ and Na_2CO_3

$CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaCl$

Solutions are very dilute and thus. 100% dissociation occurs.

$$Ca^{+2}(aq) + 2Cl^-(aq) + 2Na^+(aq) + CO_3^{-2}(aq)$$

$$\rightarrow CaCO_3 \downarrow + 2Na^+(aq) + 2Cl^-(aq)$$

or $\quad Ca^{+2}(aq) + CO_3^{-2}(aq) \rightarrow CaCO_3(s)$

∴ $\quad \Delta H = \Sigma H^0_{Products} - \Sigma H^0_{reactants}$

or $\quad \Delta H = \Delta H^0_{f\,CaCO_3} - [\Delta H^0_{f\,Ca^{+2}}\quad \Delta H^0_{f\,CO_3^{-2}}]$

∴ ΔH^0 of a compound $= \Delta H^0_{formation}$

$= -288.5 - (-129.80 - 161.65) = 2.95\, kcal$

31. $\quad$ trans - 2 - butene $\longrightarrow$ cis - 2 - butene
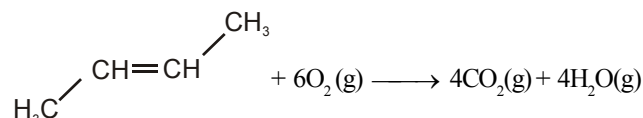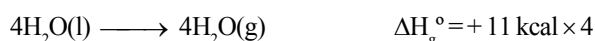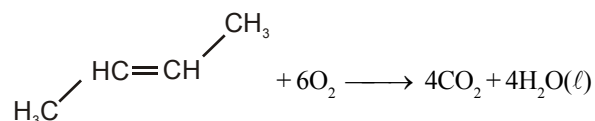
$$\Delta H = +0.95\, kcal$$

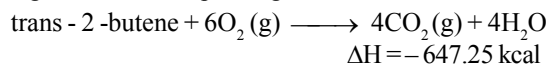cis - 2 - butene $\longrightarrow$ 1 - butene

$$\Delta H = +1.8\, kcal$$

1 - butene $+ 6O_2 \longrightarrow 4CO_2 + 4H_2O$
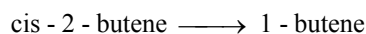
$$\Delta H = -650\, kcal$$

Adding above three eqution gives :

trans - 2 -butene $+ 6O_2(g) \longrightarrow 4CO_2(g) + 4H_2O$

$$\Delta H = -647.25\, kcal$$

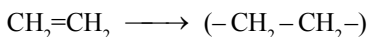$4H_2O(l) \longrightarrow 4H_2O(g) \qquad \Delta H_g^\circ = +11\, kcal \times 4$

_____

$\Delta H = -603.25$ kcal

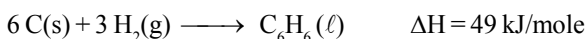$-603.25 = 8 \times 98 + 2 \times 80 + \text{B.E.} (C=C) + 6 \times 118 - 8 \times 196 - 8 \times 110$

B.E. $(C=C) = 192.75$ kcal.

32. In polymerisation of ethylene, double bond of ethylene is broken and two single bonds are formed.

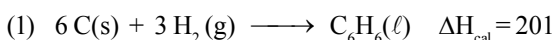$CH_2=CH_2 \longrightarrow (-CH_2-CH_2-)$

$\Delta H_{poly} = E_{C=C} - 2\,E_{C-C} = -72$

$\Rightarrow E_{C=C} - 2\,E_{C-C} = -72$ ....(1)

$6\,C(s) + 3\,H_2(g) \longrightarrow C_6H_6(\ell)$ $\Delta H = 49$ kJ/mole

$\Delta H_{resonance} = \Delta H_{exp} - \Delta H_{cal}$

$\Delta H_{cal} = 49 - (-\Delta H_{resonance}) = 49 - (-152) = 201$

(1) $6\,C(s) + 3\,H_2(g) \longrightarrow C_6H_6(\ell)$ $\Delta H_{cal} = 201$

(2) $C_6H_6(\ell) \longrightarrow C_6H_6(g)$ $\Delta H = 144$

Adding 1 & 2

$6\,C(s) + 3\,H_2(g) \longrightarrow C_6H_6(g)$ $\Delta H = 345$

$\downarrow \qquad \downarrow$

$6\,C(g) + 6\,H(g) \nearrow$
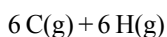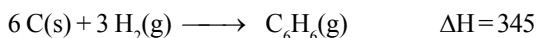
$\Delta H = 6 \times 715 + 3 \times 436 - 6E_{C-H} - 3E_{C=C} - 3E_{C-C}$

$345 = 4290 + 1308 - 6 \times 415 - 3\,E_{C=C} - E_{C-C}$

$3E_{C=C} + 3\,E_{C-C} = 2763$ So $E_{C=C} + E_{C-C} = 921$

$E_{C=C} + E_{C-C} = 921$ ...... **(i)**

$E_{C=C} - 2E_{C-C} = -72$ ...... **(ii)**

On solving **(i)** and **(ii)** equation, $3\,E_{c-c} = 993$

$E_{C-C} = 331$ kJ/mole, So, **$E_{C=C} = 590$ kJ/mole**

---

1. $C(s) + O_2(g) \rightarrow CO_2(g);\ \Delta H = -393.5$ kJ mol^{-1}

.... (1)

$CO(g) + \dfrac{1}{2}O_2(g) \rightarrow CO_2(g);\ \Delta H = -283$ kJ mol^{-1}

.... (2)
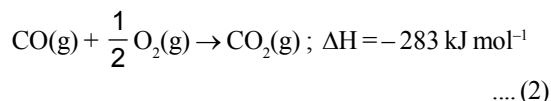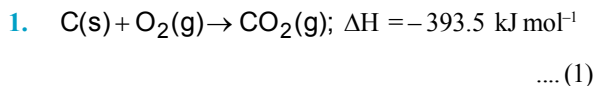
On subraction equation (2) from equation (1), we get

$C(s) + O_2(g) \rightarrow CO(g);\ \Delta H = -110.5$ kJ mol^{-1}.
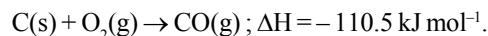
The enthalpy of formation of carbon monoxide per mole $= -110.5$ kJ mol^{-1}.

2. Let the bond dissociation energy of XY, X_2 and Y_2 be x, x and x, $\dfrac{x}{2}$ KJ/mol respectively,
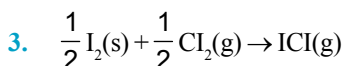
$\dfrac{1}{2}X_2 + \dfrac{1}{2}Y_2 \rightarrow XY;\ \Delta Hf = -200$ KJ mol^{-1}.

ΔH reaction = [(sum of bond dissociation energy of all reactants) − (sum of bond dissociation energy of all product)]

$= \left[\dfrac{1}{2}\Delta H_{X2} + \dfrac{1}{2}\Delta H_{Y2} - \Delta H_{XY}\right]$

$= \dfrac{x}{2} + \dfrac{0.5x}{2} - x = -200$

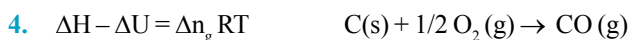$\therefore\ x = \dfrac{200}{0.25} = 800$ KJ mol^{-1}.

3. $\dfrac{1}{2}I_2(s) + \dfrac{1}{2}Cl_2(g) \rightarrow ICl(g)$

$\Delta H_{f,\,ICl}(g) = \left[\dfrac{1}{2}\Delta H_{I_2(s)\rightarrow I_2(g)} + \dfrac{1}{2}\Delta H_{I-I} + \dfrac{1}{2}\Delta H_{Cl-Cl}\right] - \left[\Delta H_{I-Cl}\right]$

$= \left[\dfrac{1}{2} \times 62.76 + \dfrac{1}{2}151.0 + \dfrac{1}{2} \times 242.3\right] - [211.3]$

$= 16.73$ kJ/mol.

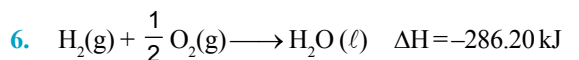**4.** $\Delta H - \Delta U = \Delta n_g\,RT$ $C(s) + 1/2\,O_2(g) \rightarrow CO(g)$

$\Delta n_g = 1 - \dfrac{1}{2} = +\dfrac{1}{2}$ $\Delta H - \Delta U = \dfrac{1}{2} \times 8.314 \times 298$
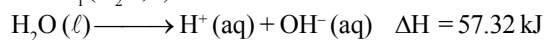
$= 1238.78$ J mol^{-1}

5. $C + 2H_2 \rightarrow CH_4$; $\Delta H° = -74.8$ kJ mol^{-1}

In order to calculate average energy for C – H bond formation we should know the followng data.

$C(graphite) \rightarrow C(g)$; $\Delta H_f^° =$ enthalpy of sublimation of carbon

$H_2(g) \rightarrow 2H(g)$; $\Delta H°$ bond dissociation energy of H_2.

6. $H_2(g) + \frac{1}{2} O_2(g) \longrightarrow H_2O(\ell)$ $\Delta H = -286.20$ kJ

$\Delta H_r = \Delta H_f(H_2O,\ell) - \Delta H_f(H_2, g) - \frac{1}{2}\Delta H_f(O_2, g)$

$-286.20 = \Delta H_f(H_2O(\ell))$
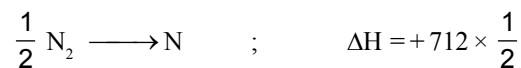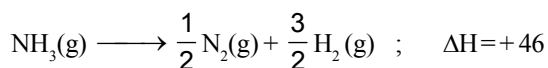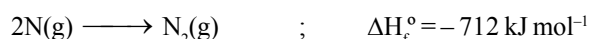So $\Delta H_f(H_2O, \ell) = -286.20$ KJ/mole
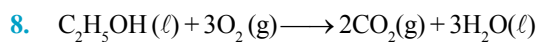$H_2O(\ell) \longrightarrow H^+(aq) + OH^-(aq)$ $\Delta H = 57.32$ kJ
$\Delta H_r = \Delta H°_f(H^+, aq) + \Delta H°_f(OH^-, aq) - \Delta H°_f(H_2O, \ell)$
$57.32 = 0 + \Delta H°_f(OH^-, aq) - (-286.20)$
$\Delta H°_f(OH^-, aq) = 57.32 - 286.20 = -228.88$ kJ.

7. $N_2(g) + \frac{3}{2} H_2(g) \longrightarrow NH_3(g)$; $\Delta H_f° = -46.0$ kJ mol^{-1}

$2H(g) \longrightarrow H_2(g)$; $\Delta H_f° = -436$ kJ mol^{-1}

$2N(g) \longrightarrow N_2(g)$; $\Delta H_f° = -712$ kJ mol^{-1}

$NH_3(g) \longrightarrow \frac{1}{2} N_2(g) + \frac{3}{2} H_2(g)$; $\Delta H = +46$

$\frac{3}{2} H_2 \longrightarrow 3H$; $\Delta H = +436 \times \frac{3}{2}$

$\frac{1}{2} N_2 \longrightarrow N$; $\Delta H = +712 \times \frac{1}{2}$
_____

$NH_3(g) \longrightarrow N(g) + 3H(g)$; $\Delta H = +1056$ kJ mol^{-1}
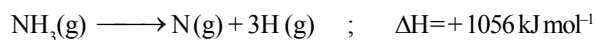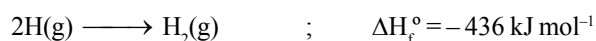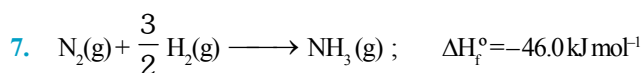
Average bond enthalpy of N–H bond $= \frac{1056}{3}$
$= +352$ kJ mol^{-1}

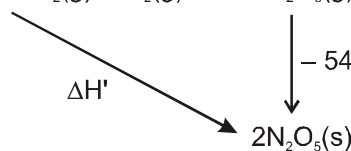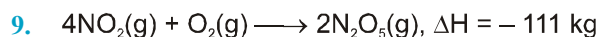**8.** $C_2H_5OH(\ell) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(\ell)$

$\Delta n_g = 2 - 3 = -1$

$\Delta U = \Delta H - \Delta n_g RT$

$= -1366.5 - (-1) \times \frac{8.314}{10^3} \times 300$

$= -1366.5 + 0.8314 \times 3 = -1364$ KJ

9. $4NO_2(g) + O_2(g) \longrightarrow 2N_2O_5(g)$, $\Delta H = -111$ kg

$-111 - 54 = \Delta H'$
$\Delta H' = -165$ KJ
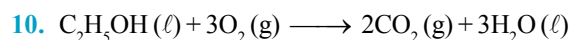
10. $C_2H_5OH(\ell) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(\ell)$
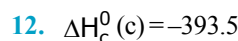$\Delta E = -1364.47$ kJ/mole
$\Delta H = ?$
$\Delta n_g = -1$
$\therefore \Delta H = -1366.95$ kJ/mole

11. $-\dfrac{R \times 298 \, \ell n\, 1.6 \times 10^{12}}{2}$

$= \Delta G°_r = 2\Delta G^0_{NO_2} - 2\Delta G^0_{NO}$

$\Delta G^0_{NO_2} = 86.6 \times 10^3 - \dfrac{298K\, \ell n\, 1.6 \times 10^{12}}{2}$

12. $\Delta H^0_c(c) = -393.5$

$\Delta H^0_c(w,g) = -283.5$

$C_{grophitro} + \frac{1}{2} O_2(q) \longrightarrow CO(q)$
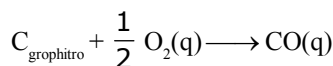
$\Delta H^0_F(w,g) = \Delta H^0_O(c) - \Delta H^0_c(co, g)$
$= -393.5 + 283.5$
$= -110.0$ Kg.

Part # II : IIT-JEE ADVANCED

1. $n = \dfrac{3.5}{28}$

$\Delta T = T_2 - T_1 = 298.45 - 298 = 0.45$
$C_V = 2.5$ kJ k^{-1} = 2500 JK^{-1}
$C_P = C_V + R = 2500 + 8.314 = 2508.314$ JK^{-1}
$Q_P = C_P\Delta T = 1128.74$ J

$\Delta H = \dfrac{Q_p}{n} = \dfrac{1128.74}{3.5/28} = 9030$ J mol^{-1} = 9.030 KJ mol^{-1} = 9 KJ mol^{-1}.

2. $\Delta H_f^\circ (Cl_2, g) = 0$,   As ΔH_f° of elements in their standard state is taken to be zero.

3. $E_{C-C} \cong 100$ KCal/mole.

4.

$$2C(s) + H_2(g) \longrightarrow C_2H_2(g) \quad \Delta H = 225 \text{ KJ/mol}$$

1410   330 $-(2\varepsilon_{C-H} + \varepsilon_{C\equiv C})$

$$2C(g) + 2H(g)$$
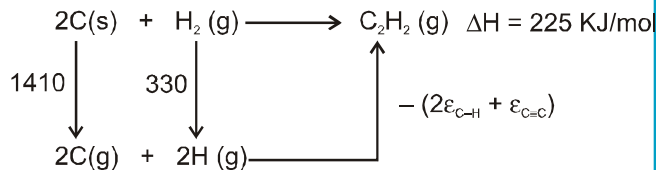
∴ $\Delta H = +1410 + 330 - (350 \times 2) - \varepsilon_{C\equiv C} = +225$

∴ $\varepsilon_{C\equiv C} = 1740 - 700 - 225 = +815$ KJ/mol.

5. $C_6H_{12}O_6(s) + 6O_2(g) \longrightarrow 6CO_2(g) + 6H_2O(\ell)$

$\Delta_c H = 6 \times \Delta_f H \, (CO_2) + 6 \, \Delta_f H \, (H_2O) - \Delta_f H \, (C_6H_{12}O_6) - 6\Delta_f (O_2, g)$

$= 6 \times (-400 - 300) - (-1300) - 0$

$= -4200 + 1300$

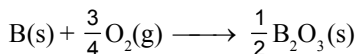$= -2900$ KJ/ mol

For one gram of glucose, enthalpy of combustion

$= -\dfrac{2900}{180} = -16.11$ KJ/g.

<div align="center">

◄ **MOCK TEST** ►

</div>

3. $C(s) \longrightarrow C(g)$ can   be   obtained   as,

$\Delta H = \Delta H_1 - \Delta H_2 - \dfrac{1}{2} \Delta H_3 + \Delta H_4$
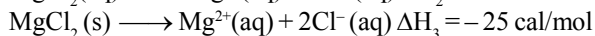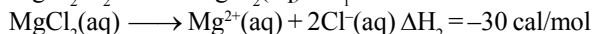
4. Combustion reaction of solid boron

$B(s) + \dfrac{3}{4} O_2(g) \longrightarrow \dfrac{1}{2} B_2O_3(s)$

$\Delta H^\circ_r = \Delta H^\circ_c = \dfrac{1}{2} \Delta H^\circ_f (B_2O_3, s) - \Delta H^\circ_f (B, s) - \dfrac{3}{4} \Delta H^\circ_f (O_2, g)$

ΔH_f° of element in stable state of aggregation is assumed to be zero.

$\boldsymbol{\Delta H^\circ C = \dfrac{1}{2} \Delta H^\circ f (B_2O_3, s)}$

6. $MgCl_2 . H_2O \longrightarrow MgCl_2(aq) \, \Delta H_1 = ?$
$MgCl_2(aq) \longrightarrow Mg^{2+}(aq) + 2Cl^-(aq) \, \Delta H_2 = -30$ cal/mol
$MgCl_2(s) \longrightarrow Mg^{2+}(aq) + 2Cl^-(aq) \, \Delta H_3 = -25$ cal/mol
$\Delta H_1 + \Delta H_2 = \Delta H_3$
$\Delta H_1 = \Delta H_3 - \Delta H_2 = -25 + 30 = +5$ cal/mol.
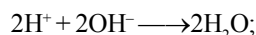
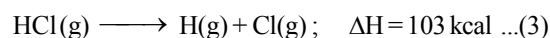**7.** $H_3PO_3 \longrightarrow 2H^+ + HPO_3^{2-} \, ; \Delta_r H = ?$
$2H^+ + 2OH^- \longrightarrow 2H_2O;$
$\Delta_r H = -55.84 \times 2 = -111.68$
$-106.68 = \Delta_{ion} H - 55.84 \times 2$
$\Delta_{ion} H = 5$ kJ/mol.

8. Given $H_2(g) \longrightarrow 2H(g);$ $\Delta H = 104$ kcal ...(1)
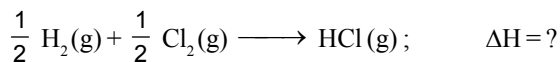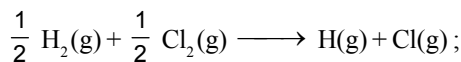
$Cl_2(g) \longrightarrow 2Cl(g);$ $\Delta H = 58$ kcal   ...(2)

$HCl(g) \longrightarrow H(g) + Cl(g);$ $\Delta H = 103$ kcal ...(3)

Heat of formation for HCl

$\dfrac{1}{2} H_2(g) + \dfrac{1}{2} Cl_2(g) \longrightarrow HCl(g);$ $\Delta H = ?$

Divide equation (1) and (2) by 2, and then add

$\dfrac{1}{2} H_2(g) + \dfrac{1}{2} Cl_2(g) \longrightarrow H(g) + Cl(g);$

$\Delta H = 81$ kcal   ...(4)

Subtracting equation (3) from equation (4)

$HCl(g) \longrightarrow H(g) + Cl(g);$ $\Delta H = 103$ kcal ...(3)

$-$ $-$ $-$ $-$

$\dfrac{1}{2} H_2(g) + \dfrac{1}{2} Cl_2(g) \longrightarrow HCl(g);$
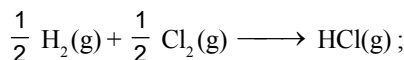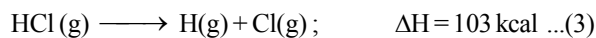
$\Delta H = -22.0$ kcal

∴   Enthalpy of formation of HCl gas $= \boldsymbol{-22.0}$ **kcal**

10. $\dfrac{1}{2} A - A + \dfrac{1}{2} B - B \rightarrow AB \, \Delta H = -100$ KJ/mole

$\dfrac{1}{2} x + \dfrac{1}{2} (0.5x) - x = -100 \Rightarrow \dfrac{x}{2} + 0.25x - x = -100$

$\Rightarrow -0.25x = -100$ $\Rightarrow x = 400$ KJ/mole

Bond enthalpy = **400 kJ/mol.**

13. Heat of neutralisation for strong acid and strong base combination is constant is equal to -13.7 Kcal or -57.1 KJ.

14. For reaction $C(s) + O_2(g) \rightarrow CO_2(g) \, ; \, \Delta H = \Delta U$

15. $\Delta H_{ionisation} = \Delta H^\circ_{neutralisation} - \Delta H^\circ (H + OH^- \longrightarrow H_2O)$
$= -49.86 - (-55.84)$ kJ/mole
$= 5.98$ kJ/mole

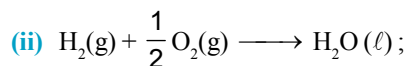**17.** For max. rise in temp.; max. neutralization of H^+ and OH^- required.
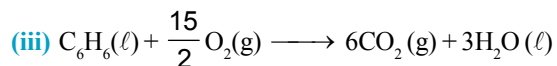If we take equal volume, all H^+ (5 m-mole) will react with all OH^-(5 m-mole).

18. **(A)** This is combustion reaction as well as formation reaction of CO_2.

(B) This is sublimation, atomization as well as formation reaction of C (g).

(C) This is combustion reaction of CO (g).

(D) This is atomization of CH_4 (g).

19. **(i)** $C(s) + O_2(g) \longrightarrow CO_2(g)$; $\Delta H_f^\circ = -393.33$ KJ/mol ;

$$\Delta H_f^\circ = \frac{590}{18} \times 12$$

(ii) $H_2(g) + \dfrac{1}{2} O_2(g) \longrightarrow H_2O\,(\ell)$;

$$\Delta H_f^\circ = -286 \text{ KJ/mol} ; \quad \Delta H_f^\circ = \frac{15889}{55.5}$$

(iii) $C_6H_6(\ell) + \dfrac{15}{2} O_2(g) \longrightarrow 6CO_2\,(g) + 3H_2O\,(\ell)$

∴ $\Delta H^\circ = [6(-393.33) + 3\,(-286)] - 50 = -3268$ KJ/ mol

Mass of benzene is $= 0.87 \times 100 = 87$ g

∴ Heat evolved from 87 gm benzene $= 3645$ KJ **Ans.**

21. $C_6H_{12}O_6(s) + 6O_2(g) \longrightarrow 6CO_2 + 6H_2O(\ell)$

No. of Mole of $C_6H_{12}O_6 = \dfrac{0.36}{180} = 2 \times 10^{-3}$ mole

$C = \dfrac{q}{\Delta T}$ ∴ $q = C \times \Delta T = 640 \times 10$ J $= 6.4$ kJ

Heat released per mole $= \dfrac{6.4}{2 \times 10^{-3}} = 3.2 \times 10^3$ kJ $= $ **3.2 MJ**

$\Delta U = -3.2$ MJ

$\Delta H = \Delta U + \Delta n_g RT$ here $\Delta n_g = 0$

$\Delta H = \Delta U = $ **−3.2 MJ mole⁻¹**