SELECT THE CORRECT ALTERNATIVE (ONLY ONE CORRECT ANSWER)

1.  Which of the following equations represents a reaction that provides the heat of formation of ethane ($CH_3CH_3$)?

    (A) $2\ C(s) + 6\ H(g) \rightarrow CH_3CH_3(g)$                (B) $2\ C(s) + 3\ H_2(g) \rightarrow CH_3CH_3(g)$

    (C) $CH_2 = CH_2(g) + 2\ H_2(g) \rightarrow CH_3CH_3(g)$        (D) $CH^-CH(g) + 2\ H_2O(g) \rightarrow CH_3CH_3(g) + O_2(g)$

2.  Which of the following equations represents a reaction that provides the heat of formation of $CH_3Cl$?

    (A) $C(s) + HCl(g) + H_2(g) \rightarrow CH_3Cl(g)$

    (B) $C(s) + 3/2\ H_2(g) + 1/2\ Cl_2(g) \rightarrow CH_3Cl(g)$

    (C) $C(s) + 3\ H(g) + Cl(g) \rightarrow\ CH_3Cl(g)$

    (D) $CH_4(g) + Cl_2(g) \rightarrow CH_3Cl(g) + HCl(g)$

3.  Use the given standard enthalpies of formation to determine the heat of reaction of the following reaction:

    $TiCl_4(g) + 2\ H_2O(g) \rightarrow TiO_2(g) + 4\ HCl(g)$

    $\Delta H^\circ_f\ TiCl_4(g) = -763.2\ kJ/mole$

    $\Delta H^\circ_f\ TiO_2(g) = -944.7\ kJ/mole$

    $\Delta H^\circ_f\ H_2O(g) = -241.8\ kJ/mole$

    $\Delta H^\circ_f\ HCl(g) = -92.3\ kJ/mole$

    (A) – 278.1            (B) + 369.2            (C) + 67.1            (D) – 67.1

4.  The heats of formation of $CO_2(g)$ and $H_2O(l)$ are –394 kJ/mole and –285.8 kJ/mole respectively. Using the data for the following combustion reaction, calculate the heat of formation of $C_3H_8(g)$.

    $C_3H_8(g) + 5\ O_2(g) \rightarrow 3\ CO_2(g) + 4\ H_2O(l)$

    $\Delta H^\circ = -2221.6\ kJ$

    (A) 212.2            (B) – 143.3            (C) 185.4            (D) – 103.6

5.  The heats of formation of $CO_2(g)$ and $H_2O(l)$ are –394 kJ/mole and –285.8 kJ/mole respectively. Using the data for the following combustion reaction, calculate the heat of formation of $C_2H_2(g)$.

    $2\ C_2H_2(g) + 5\ O_2(g) \rightarrow 4\ CO_2(g) + 2\ H_2O(l)$

    $\Delta H^\circ = -\ 2601\ kJ$

    (A) – 238.6            (B) 253.2            (C) 238.7            (D) 226.7

6.  Using the following information calculate the heat of formation of NaOH.

    $2\ Na(s) + 2\ H_2O(l) \rightarrow 2\ NaOH(s) + H_2(g)$

    $\Delta H^\circ = -\ 281.9\ kJ$

    $\Delta H^\circ_f\ H_2O(l) = -285.8\ kJ/mole$

    (A) – 141.6            (B) – 712.6            (C) – 426.8            (D) – 650.4

7.  Using the following information calculate the heat of formation of $CH_4$.

    $CH_4(g) + 2\ O_2(g) \rightarrow\ CO_2(g) + 2\ H_2O(l)$

    $\Delta H^\circ = -\ 890.4\ kJ$

    $\Delta H^\circ_f\ CO_2(g) = -\ 393.5\ kJ/mole$

    $\Delta H^\circ_f\ H_2O(l) = -\ 285.9\ kJ/mole$

    (A) – 98.6            (B) – 65.5            (C) – 74.9            (D) – 43.5

8. The heat of formation of $CO_2(g)$ is –394 kJ/mole and that of $H_2O(l)$ is –286 kJ/mole. The heat of combustion of $C_2H_4$ is –1412 kJ/mole. What is the heat of formation of $C_2H_4$?

$C_2H_4(g) + 3\ O_2(g) \rightarrow 2\ CO_2(g) + 2\ H_2O(l)$

(A) +1360          (B) – 108          (C) + 52          (D) +108

9. What amount of heat energy (kJ) is released in the combustion of 12.0 g of $C_3H_4$?

(Atomic weights: C = 12.01, H = 1.008, O = 16.00).

$C_3H_4(g) + 4\ O_2(g) \rightarrow 3\ CO_2(g) + 2\ H_2O(l)$

$\Delta H° = -1939.1$ kJ

(A) 725          (B) 504          (C) 783          (D) 581

10. The standard heat of combustion of solid boron is equal to :-

(A) $\Delta H_f(B_2O_3)$          (B) $\dfrac{1}{2}\Delta H_f(B_2O_3)$          (C) $2\Delta H_f(B_2O_3)$          (D) $\dfrac{1}{2}\Delta H_f(B_2O_3)$

11. In the reaction, $CO_2(g) + H_2(g) \longrightarrow CO(g) + H_2O(g)$; $\Delta H = 2.8$ kJ $\Delta H$ represents :-

(A) heat of reaction      (B) heat of combustion    (C) heat of formation      (D) heat of solution

12. A gas mixture 3.67 L in volume contain $C_2H_4$ and $CH_4$ is proportion of 2 : 1 by moles and is at 25 C and 1 atm. If the $\Delta H_C$ $(C_2H_4)$ and $\Delta H_C$ $(CH_4)$ are –1400 and –900 kJ/mol find heat evolved on burning this mixture :-

(A) 20.91 kJ          (B) 50.88 kJ          (C) 185 kJ          (D) 160 kJ

13. 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

14. The average, S – F bond energy in $SF_6$ if the $\Delta H_f$ value are –1100, +275 and +80 kJ/mol respectively for $SF_6(g)$, S(g) and F(g) is :-

(A) 390.1 kJ/mol      (B) 103.9 kJ/mol      (C) 903.1 kJ/mol      (D) 309.1 kJ/mol

15. The average O–H bond energy in $H_2O$ with the help of following data :-

(1) $H_2O_{(\ell)} \longrightarrow H_2O_{(g)}$ ; $\Delta H = + 40.6$ kJ mol$^{-1}$

(2) $2H_{(g)} \longrightarrow H_{2(g)}$ ; $\Delta H = - 435.0$ kJ mol$^{-1}$

(3) $O_{2(g)} \longrightarrow 2O_{(g)}$ ; $\Delta H = + 489.6$ kJ mol$^{-1}$

(4) $2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O(\ell)$ ; $\Delta H = - 571.6$ kJ mol$^{-1}$

(A) 584. 9 kJ mol$^{-1}$      (B) 279.8 kJ mol$^{-1}$      (C) 462.5 kJ mol$^{-1}$      (D) 925 kJ mol$^{-1}$

16. The enthalpy change for the following reaction is 514 kJ. Calculate the average Cl – F bond energy.

$ClF_3(g) \rightarrow Cl(g) + 3\ F(g)$

(A) 1542          (B) 88          (C) 171          (D) 514

17. Given the following equations and $\Delta H°$ values, determine the heat of reaction (kJ) at 298 K for the reaction:

$4\ H_2O(g) + 3\ Fe(s) \rightarrow Fe_3O_4(s) + 4\ H_2(g)$

| | |
|---|---|
| $H_2(g) + 1/2\ O_2(g) \rightarrow H_2O(g)$ | $\Delta H°/kJ = -285.8$ |
| $3\ FeO(s) + 1/2\ O_2(g) \rightarrow Fe_3O_4(s)$ | $\Delta H°/kJ = -302.4$ |
| $FeO(s) + H_2(g) \rightarrow Fe(s) + H_2O(g)$ | $\Delta H°/kJ = -13.8$ |

(A) +391.7          (B) – 24.8          (C) – 602.0          (D) +24.8

18. For the following reaction :

$C_{Diamond} + O_2 \longrightarrow CO_2(g)$ ; $\Delta H = -94.3$ kcal

$C_{Graphite} + O_2 \longrightarrow CO_2(g)$; $\Delta H = -97.6$ kcal

The heat required to change 1 g of $C_{diamond} \longrightarrow C_{graphite}$ is :-

(A) 1.59 kcal      (B) 0.1375 kcal      (C) 0.55 kcal      (D) 0.275 kcal

19. The standard heat of combustion of Al is $-837.8$ kJ $mol^{-1}$ at 25 C which of the following releases 250 kcal of heat :-

(A) The reaction of 0.624 mol of Al      (B) The formation of 0.624 mol of $Al_2O_3$

(C) The reaction of 0.312 mol of Al      (D) The formation of 0.150 mol of $Al_2O_3$

20. If heat of dissociation of $CHCl_2COOH$ is 0.7 kcal/mole then $\Delta H$ for the reaction :-

$CHCl_2COOH + KOH \rightarrow CHCl_2COOK + H_2O$

(A) $-13$ kcal      (B) $+ 13$ kcal      (C) $-14.4$ kcal      (D) $-13.7$ kcal

21. A solution is 500 mL of 2 M KOH is added to 500 mL of 2 M HCl and the mixture is well shaken. The rise in temperature $T_1$ is noted. The experiment is then repeated using 250 mL of each solution and rise in temperature $T_2$ is again noted. Assume all heat is taken by the solution :-

(A) $T_1 = T_2$      (B) $T_1$ is 2 times as large as $T_2$

(C) $T_2$ is twice of $T_1$      (D) $T_1$ is 4 times as large as $T_2$

22. Anhydrous $AlCl_3$ is a covalent compound. From the data given below, predict whether it would remain covalent or become ionic in an aqueous solution .

(Ionisation energy of Al = 5137 kJ $mol^{-1}$),

$\Delta H$ hydration for $Al^{3+}$ = $-4665$ kJ $mol^{-1}$.      $\Delta H$ hydration for $Cl^-$ = $-381$ kJ $mol^{-1}$

(A) Ionic      (B) Covalent      (C) Partially ionic      (D) Partially covalent

23. Given, $H_2(g) + Br_2(g) \longrightarrow 2HBr(g)$, $\Delta H_1$ and standard enthalpy of condensation of bromine is $\Delta H_2$, standard enthalpy of formation of HBr at 25 C is :-

(A) $\dfrac{\Delta H°_1}{2}$      (B) $\dfrac{\Delta H°_1}{2 + \Delta H°_2}$      (C) $\dfrac{\Delta H°_1}{2 - \Delta H°_2}$      (D) $\dfrac{(\Delta H°_1 - \Delta H°_2)}{2}$

24. From the following data of $\Delta H$, of the following reaction,

$C(s) + \dfrac{1}{2} O_2(g) \longrightarrow CO(g)$      $\Delta H = -110$ kJ

$C(s) + H_2O(g) \longrightarrow CO(g) + H_2(g)$      $\Delta H = 132$ kJ

What is the mole composition of the mixture of steam and oxygen on being passed over coke at 1273K, keeping temperature constant :-

(A) 0.5 : 1      (B) 0.6 : 1      (C) 0.8 : 1      (D) 1 : 1

| CHECK YOUR GRASP | | | | | | | ANSWER KEY | | | | | | EXERCISE -1 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Que. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Ans. | B | B | D | D | D | C | C | C | D | B | A | C | B | D | C |
| Que. | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | | | | | | |
| Ans. | C | D | D | B | A | A | A | D | B | | | | | | |

<u>SELECT THE CORRECT ALTERNATIVES (ONE OR MORE THEN ONE CORRECT ANSWERS)</u>

1. The standard enthalpy of formation of propene, $C_3H_6$, is +20.6 kJ/mole. Calculate the heat of combustion of one mole of $C_3H_6$. The heats of formation of $CO_2(g)$ and $H_2O(l)$ are −394 kJ/mole and −285.8 kJ/mole respectively.

   (A) 1721.2              (B) −1939.1              (C) 2060.0              (D) 2221.6

2. The fat, glyceryl trioleate, is metabolized via the following reaction. Given the enthalpies of formation, calculate the energy (kJ) liberated when 1.00 g of this fat reacts.

   (Atomic weights: C = 12.01, H = 1.008, O = 16.00).

   $$C_{57}H_{104}O_6(s) + 80\ O_2(g) \rightarrow 57\ CO_2(g) + 52\ H_2O(l)$$
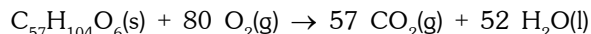
   $\Delta H°\ C_{57}H_{107}O_6 = -70870$ kJ/mole

   $\Delta H°\ H_2O(l) = -285.8$ kJ/mole

   $\Delta H°\ CO_2(g) = -393.5$ kJ/mole

   (A) 40.4              (B) 33.4              (C) 37.8              (D) 42.6

3. Using the enthalpies of formation, calculate the energy (kJ) released when 3.00 g of $NH_{3(g)}$ reacts according to the following equation.

   (Atomic weights: B = 10.81, O = 16.00, H = 1.008).

   $$4\ NH_3(g) + 5\ O_2(g) \rightarrow 4\ NO(g) + 6\ H_2O(g)$$
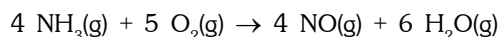
   $\Delta H°\ NH_3(g) = -46.1$ kJ/mole

   $\Delta H°\ NO(g) = +90.2$ kJ/mole

   $\Delta H°\ H_2O(g) = -241.8$ kJ/mole
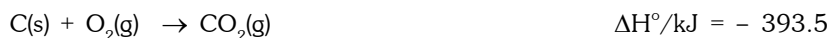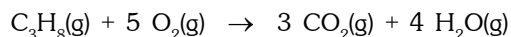
   (A) 34.3              (B) 30.8              (C) 39.9              (D) 42.6

4. A sheet of 15.0 g of gold at 25.0°C is placed on a 30.0 g sheet of copper at 45.0°C. What is the final temperature of the two metals assuming that no heat is lost to the surroundings. The specific heats of gold and copper are 0.129 J/g°C and 0.385 J/g°C respectively.

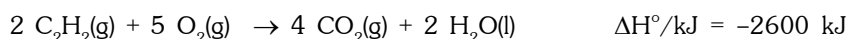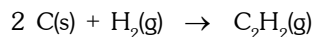   (A) 42.1                                (B) 40.1

   (C) 41.1                                (D) 43.4

5. Calculate the heat of combustion (kJ) of propane, $C_3H_8$ using the listed standard enthapy of reaction data:

   $$C_3H_8(g) + 5\ O_2(g) \rightarrow 3\ CO_2(g) + 4\ H_2O(g)$$

   | | |
   |---|---|
   | $3\ C(s) + 4\ H_2(g) \rightarrow C_3H_8(g)$ | $\Delta H°/kJ = -103.8$ |
   | $C(s) + O_2(g) \rightarrow CO_2(g)$ | $\Delta H°/kJ = -393.5$ |
   | $H_2(g) + 1/2\ O_2(g) \rightarrow H_2O(g)$ | $\Delta H°/kJ = -241.8$ |

   (A) − 2043.9              (B) − 1532.9              (C) − 1021.9              (D) −739.1

6. Calculate the value of $\Delta H°/kJ$ for the following reaction using the listed thermochemical equations:

   $$2\ C(s) + H_2(g) \rightarrow C_2H_2(g)$$

   | | |
   |---|---|
   | $2\ C_2H_2(g) + 5\ O_2(g) \rightarrow 4\ CO_2(g) + 2\ H_2O(l)$ | $\Delta H°/kJ = -2600$ kJ |
   | $C(s) + O_2(g) \rightarrow CO_2(g)$ | $\Delta H°/kJ = -390$ kJ |
   | $2\ H_2(g) + O_2(g) \rightarrow 2\ H_2O(l)$ | $\Delta H°/kJ = -572$ kJ |

   (A) +184              (B) +214              (C) +202              (D) +234

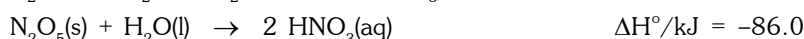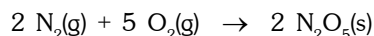7. Use the given standard enthalpies of formation to determine the heat of reaction of the following reaction:

$C_2H_5OH(l) + 3 O_2(g) \rightarrow 2 CO_2(g) + 3 H_2O(g)$
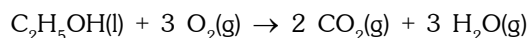
$\Delta H^\circ_f \ C_2H_5OH(l) = -277.7 \ kJ/mole$

$\Delta H^\circ_f \ CO_2(g) = -393.5 \ kJ/mole$

$\Delta H^\circ_f \ H_2O(g) = -241.8 \ kJ/mole$

(A) – 1456.3        (B) – 1234.7        (C) – 1034.0        (D) – 1119.4

8. Calculate $\Delta H^\circ$/kJ for the following reaction using the listed standard enthapy of reaction data:

$2 N_2(g) + 5 O_2(g) \rightarrow 2 N_2O_5(s)$

| | |
|---|---|
| $N_2(g) + 3 O_2(g) + H_2(g) \rightarrow 2 HNO_3(aq)$ | $\Delta H^\circ/kJ = -414.0$ |
| $N_2O_5(s) + H_2O(l) \rightarrow 2 HNO_3(aq)$ | $\Delta H^\circ/kJ = -86.0$ |
| $2 H_2(g) + O_2(g) \rightarrow 2 H_2O(l)$ | $\Delta H^\circ/kJ = -571.6$ |

(A) – 84.4        (B) – 243.6        (C) – 71.2        (D) – 121.8

9. Determine $\Delta H^\circ$/kJ for the following reaction using the listed enthalpies of reaction:

$4 CO(g) + 8 H_2(g) \rightarrow 3 CH_4(g) + CO_2(g) + 2 H_2O(l)$

| | |
|---|---|
| $C(graphite) + 1/2 O_2(g) \rightarrow CO(g)$ | $\Delta H^\circ/kJ = -110.5 \ kJ$ |
| $CO(g) + 1/2 O_2(g) \rightarrow CO_2(g)$ | $\Delta H^\circ/kJ = -282.9 \ kJ$ |
| $H_2(g) + 1/2 O_2(g) \rightarrow H_2O(l)$ | $\Delta H^\circ/kJ = -285.8 \ kJ$ |
| $C(graphite) + 2 H_2(g) \rightarrow CH_4(g)$ | $\Delta H^\circ/kJ = -74.8 \ kJ$ |
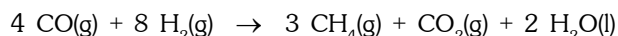
(A) – 622.4        (B) – 686.2        (C) – 747.5        (D) – 653.5

10. Use the given standard enthalpies of formation to determine the heat of reaction of the following reaction :

$2 LiOH(s) + CO_2(g) \rightarrow Li_2CO_3(s) + H_2O(l)$
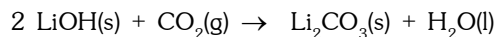
$\Delta H^\circ_f \ LiOH(s) = -487.23 \ kJ/mole$

$\Delta H^\circ_f \ Li_2CO_3(s) = -1215.6 \ kJ/mole$

$\Delta H^\circ_f \ H_2O(l) = -285.85 \ kJ/mole$

$\Delta H^\circ_f \ CO_2(g) = -393.5 \ kJ/mole$

(A) +303.4        (B) – 133.5        (C) – 198.6        (D) +198.6

11. $NH_3(g) + 3Cl_2(g) \rightleftharpoons NCl_3(g) + 3HCl (g) \ ; \ -\Delta H_1$

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \ ; \ \Delta H_2$

$H_2(g) + Cl_2 (g) \rightleftharpoons 2HCl (g) \ ; \ \Delta H_3$
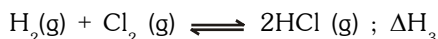
The heat of formation of $NCl_3$ (g) in the terms of $\Delta H_1$, $\Delta H_2$ and $\Delta H_3$ is ?

(A) $\Delta H_f = -\Delta H_1 + \dfrac{\Delta H_2}{2} - \dfrac{3}{2} \Delta H_3$        (B) $\Delta H_f = \Delta H_1 + \dfrac{\Delta H_2}{2} - \dfrac{3}{2} \Delta H_3$

(C) $\Delta H_f = \Delta H_1 - \dfrac{\Delta H_2}{2} - \dfrac{3}{2} \Delta H_3$        (D) None

12. Determine $\Delta H^\circ$ of the following reaction using the listed heats of formation :

$4 HNO_3(l) + P_4O_{10}(s) \rightarrow 2 N_2O_5(s) + 4 HPO_3(s)$
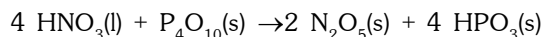
$\Delta H^\circ_f \ HNO_3(l) = -174.1 \ kJ/mole$

$\Delta H^\circ_f \ N_2O_5(s) = -43.1 \ kJ/mole$

$\Delta H^\circ_f \ P_4O_{10}(s) = -2984.0 \ kJ/mole$

$\Delta H^\circ_f \ HPO_3(s) = -948.5 \ kJ/mole$

(A) –176.3        (B) – 199.8        (C) +276.2        (D) – 242.4

13. If $x_1$, $x_2$ and $x_3$ are enthalpies of H–H, O=O and O–H bonds respectively, and $x_4$ is the enthalpy of vaporisation of water, estimate the standard enthalpy of combustion of hydrogen.
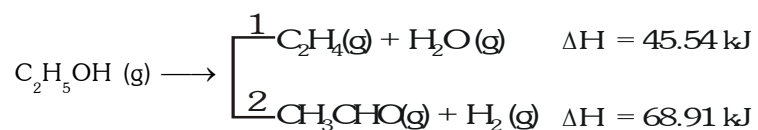
(A) $x_1 + \dfrac{x_2}{2} - 2x_3 + x_4$    (B) $x_1 + \dfrac{x_2}{2} - 2x_3 - x_4$    (C) $x_1 + \dfrac{x_2}{2} - x_3 + x_4$    (D) $2x_1 - x_1 - \dfrac{x_2}{2} - x_4$

**14.** Use the given bond enthalpy data to estimate the $\Delta H°$ (kJ) for the following reaction.

(C – H = 414 kJ, H – Cl = 431 kJ, Cl – Cl = 243 kJ, C – Cl = 331 kJ).

$$CH_4(g) + 4\ Cl_2(g) \rightarrow CCl_4(g) + 4\ HCl(g)$$

(A) 620     (B) 330     (C) 420     (D) 105

**15.** For which of the following change $\Delta H \neq \Delta E$ ?

(A) $H_2\ (g) + I_2\ (g) \longrightarrow 2HI\ (g)$     (B) $HCl\ (aq) + NaOH\ (aq) \longrightarrow NaCl(aq) + H_2O\ (l)$

(C) $C(s) + O_2\ (g) \longrightarrow CO_2\ (g)$     (D) $N_2\ (g) + 3H_2(g) \longrightarrow 2\ NH_3\ (g)$

**16.** $\Delta H_r$ of which of the following reactions is zero ?

(A) $H_2\ (g) \longrightarrow 2H^+\ (g) + 2e^-$     (B) $2H\ (g) + aq \longrightarrow 2H^+(aq) + 2e^-$

(C) $2H\ (g) \longrightarrow 2H^+\ (g) + 2e^-$     (D) $H_2\ (g) + aq \longrightarrow 2H^+\ (aq) + 2e^-$

**17.** $\Delta H_f^0$ of water is $-285.8$ kJ mol$^{-1}$. If enthalpy of neutralisation of monoacid strong base is $-57.3$ kJ mol$^{-1}$, $\Delta H_f^0$ of OH$^-$ ion will be ?

(A) $-228.5$ kJ mol$^{-1}$    (B) $228.5$ kJ mol$^{-1}$    (C) $114.25$ kJ mol$^{-1}$    (D) $-114.25$ kJ mol$^{-1}$

**18.** 4 grams of sodium hydroxide pellets were dissolved in 100 cm$^3$ of water. The temperature before adding the sodium hydroxide pellets was 25 degrees C, and after adding the pellets it was 35 degrees C. Calculate the enthalpy change in kJ/mole of the reaction (Specific heat capacity of water = 4.2 J/K/g)

(A) 42 kJ/mole    (B) 4.2 kJ/mole    (C) 4200 kJ/mole    (D) none

**19.** 50.0 mL of 0.10 M HCl is mixed with 50.0 mL of 0.10 M NaOH. The solution temperature rises by 3.0 C. Calculate the enthalpy of neutralization per mol of HCl.

(A) $-2.5 \times 10^2$ kJ    (B) $-1.3 \times 10^2$ kJ    (C) $-8.4 \times 10^1$ kJ    (D) $-6.3 \times 10^1$ kJ

**20.** Which of the following statements is (are) correct ?

(A) the reaction between the strong acid and strong base takes place with the evolution of heat

(B) $\Delta H_{neut.}$ of weak acid/strong base is less than the $\Delta H_{neut.}$ of strong acid/strong base

(C) $\Delta H_{neut.}$ of strong acid/strong base is equal to the $\Delta H$ of formation of $H_2O(l)$ from its ions in the aqueous medium

(D) $\Delta H_{neut.(weak\ acid/strong\ base)} - \Delta H_{neut.(strong\ acid/strong\ base)} = \Delta H_{ioni(weak\ acid)}$

**21.** The standard enthalpies of formation of $CO_{2(g)}$, and HCOOH(l) are $-393.7$ kJ/mol and $-409.2$ kJ/mol respectively :-

(A) $-393.7$ kJ/mol is the enthalpy change for the reaction $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$

(B) the enthalpy change for the reaction $CO_{2(g)} + H_{2(g)} \rightarrow HCOOH_{(l)}$ would be $-15.5$ kJ/mol

(C) the enthalpy change for the reaction

$$H_2O + CO \rightarrow HCOOH \text{ is } -409.2 \text{ kJ/mol}$$

(D) the enthalpy change for the reaction

$$H_{2(g)} + CO_{2(g)} \rightarrow H_2O_{(l)} + CO_{(g)} \text{ is } -409.2 \text{ kJ/mol}$$

**22.** Ethanol can undergoes decomposition to form two sets of products ?

$$C_2H_5OH\ (g) \longrightarrow \begin{cases} \overset{1}{\phantom{.}} C_2H_4(g) + H_2O\ (g) & \Delta H = 45.54\ kJ \\ \overset{2}{\phantom{.}} CH_3CHO(g) + H_2\ (g) & \Delta H = 68.91\ kJ \end{cases}$$

if the molar ratio of $C_2H_4$ to $CH_3CHO$ is 8 : 1 in a set of product gases, then the energy involved in the decomposition of 1 mole of ethanol is ?

(A) 65.98 kJ    (B) 48.137 kJ    (C) 48.46 kJ    (D) 57.22 kJ

23. Reactions involving gold have been of particular interest to a chemist. Consider the following reactions,

$Au(OH)_3 + 4\ HCl \longrightarrow HAuCl_4 + 3\ H_2O,$ $\quad\quad\quad \Delta H = -28\ kcal$

$Au(OH)_3 + 4\ HBr \longrightarrow HAuBr_4 + 3\ H_2O,$ $\quad\quad\quad \Delta H = -36.8\ kcal$

In an experiment there was an absorption of 0.44 kcal when one mole of $HAuBr_4$ was mixed with 4 moles of HCl. What is the percentage conversion of $HAuBr_4$ into $HAuCl_4$ ?

(A) 0.5 %            (B) 0.6 %            (C) 5 %            (D) 50%

24. Which of the following statement is (are) correct ?

(A) for an exothermic reactions, $\sum\Delta H_f^\circ$ (products) $< \sum\Delta H_f^\circ$ (reactants)

(B) $\sum\Delta H_f^\circ$ of $CO_2(g)$ is same as the $\Delta H_{comb.}$ of carbon graphite

(C) all exothermic reactions have a free energy change negative

(D) for a reaction $N_{2(g)} + O_{2(g)} \longrightarrow 2NO_{(g)}$, the heat at constant pressure and the heat at constant volume at a given temperature are same

---

| BRAIN TEASERS | | | | | | ANSWER KEY | | | | | | | EXERCISE -2 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Que. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Ans. | C | C | C | A | A | D | B | A | C | B | A | B | B | C | D |
| Que. | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | | | | | | |
| Ans. | D | A | A | A | A,B,C,D | A,B | B | C | A,B,D | | | | | | |

## TRUE / FALSE

1. The enthalpies of elements are always taken to be zero.

2. Heat of neutralisation of weak acid-strong base is not constant.

3. Resonance energy is always negative.

4. For reaction $2A(g) + B(g) \longrightarrow 3C(g)$ $\Delta H = -x$ kJ

   then for reaction $\dfrac{3}{2} C(g) \longrightarrow A(g) + \dfrac{B}{2}(g)$ $\Delta H = \dfrac{x}{2}$ kJ.

5. $\Delta H_f$ (C, diamond) $\neq 0$

6. For a particular reaction $\Delta E = \Delta H + P.\Delta V$

7. If BE (bond energy) of $N \equiv N$ bond is $x_1$ that of $H - H$ bond is $x_2$ and $N - H$ bond is $x_3$ then enthalpy change of the reaction is

   $N_2 + 3H_2 \longrightarrow 2NH_3$ $\qquad\qquad\qquad\qquad \Delta H_r = x_1 + 3x_2 - 2x_3$

8. Enthalpy change is dependent on temperature and on the path adopted.

9. Heat of hydrogenation of ethene is $x_1$ and that of benzene is $x_2$, hence resonance energy of benzene is $(x_1 - x_2)$.

## FILL IN THE BLANKS

1. The combustion of a substance is always ................... .

2. If heat content of X is smaller than that of Y then the process $X \to Y$ is ................... .

3. C (Diamond) $\longrightarrow$ C (Graphite) + x kJ. The heat change in this process is called ................... .

4. As per reaction, $N_2(g) + 2O_2(g) \longrightarrow 2NO_2(g)$ –66 kJ the value of $\Delta H_f$ of $NO_2$ is ................... .

5. Heats of combustion of methane, carbon and hydrogen are –212, –94, –68 kcal mol$^{-1}$. The heat of formation of $CH_4$ is ................... .

6. The heat of neutralisation of 1 mole of $HClO_4$ with 1 gm-equivalent of NaOH in aqueous solutions is ................... kJ mol$^{-1}$.

7. The heat of combustion of graphite and carbon monoxide respectively are –393.5 kJ mol$^{-1}$ and –283 kJ mol$^{-1}$. Thus heat of formation of carbon monoxide in kJ mol$^{-1}$ is ................... .

8. For the reaction,

   $C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(\ell)$

   at constant temperature, $\Delta H - \Delta U$ is ................... .

## MATCH THE COLUMN

1. Match the reaction (In Column I) with relation between $\Delta H$ and $\Delta E$ (in Column II) :

| Column-I | | Column-II | |
|---|---|---|---|
| (A) | $C(s) + O_2(g) \longrightarrow CO_2(g)$ | (p) | $\Delta H = \Delta E + RT$ |
| (B) | $N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$ | (q) | $\Delta H = \Delta E$ |
| (C) | $NH_4HS(s) \longrightarrow NH_3(g) + H_2S(g)$ | (r) | $\Delta H = \Delta E - 2RT$ |
| (D) | $PCl_5(g) \longrightarrow PCl_3(g) + Cl_2$ | (s) | $\Delta H = \Delta E + 2RT$ |
| (E) | $2SO_2(g) + O_2(g) \longrightarrow 2SO_3(g)$ | (t) | $\Delta H = \Delta E - RT$ |

2. List equation/law (in Column I) with statement (in Column II) :

| | Column-I | | | Column-II |
|---|---|---|---|---|
| (A) | Arrhenius equation | (p) | | Variation of enthalpy of a reaction with temperature |
| (B) | Kirchhoff equation | (q) | | Variation of rate constant with temperature |
| (C) | Second law of thermodynamics | (r) | | Entropy of an isolated system tends to increase and reach a maximum value |
| (D) | Hess's law of constant heat summation | (s) | | Enthalpy change in a reaction is always constant and independent of the manner in which the reaction occurs. |

3.

| | Column-I | | | Column-II |
|---|---|---|---|---|
| (A) | $S(g) + O_2(g) \longrightarrow SO_2(g)$ ; $\Delta H$ | (p) | | Heat of solution |
| (B) | $CH_4(g) + 2O_2(g) \longrightarrow CO_2(g)$ $+ 2H_2O(l)$ ; $\Delta H$ | (q) | | Heat of neutralisation |
| (C) | $NaOH(s) + aq \longrightarrow NaOH\ (aq)$ ; $\Delta H$ | (r) | | Heat of formation |
| (D) | $NaOH(aq) + HCl(aq) \longrightarrow NaCl\ (aq)$ $+ H_2O(l)$ ; $\Delta H$ | (s) | | Heat of combustion |

## ASSERTION & REASON

These questions contains, Statement I (assertion) and Statement II (reason).

(A) Statement-I is true, Statement-II is true ; Statement-II is correct explanation for Statement-I.

(B) Statement-I is true, Statement-II is true ; Statement-II is NOT a correct explanation for statement-I

(C) Statement-I is true, Statement-II is false

(D) Statement-I is false, Statement-II is true

1. **Statement-I :** Enthalpy of neutralization of $CH_3COOH$ by NaOH is less than that of HCl by NaOH.

   **Because**

   **Statement-II :** Enthalpy of neutralization of $CH_3COOH$ is less because of the absorption of heat in the ionization process.

2. **Statement-I :** Enthalpy changes are positive when $Na_2SO_4.10H_2O$, $CuSO_4.5H_2O$ and salts like NaCl, KCl, etc., which do not form hydrates are dissolved in water. But enthalpy changes are negative when anhydrous salts capable of forming hydrates are dissolved in water.

   **Because**

   **Statement-II :** The difference in the behaviour is due to large differences in the molecular weight of hydrated and anhydrous salts. The substances with larger molecular weights usually show positive enthalpy changes on dissolution.

3. **Statement-I :** Heat of neutralisation of HF (aq.), a weak acid, with NaOH (aq.) is more than 13.7 kcal, in an exothermic reaction.

   **Because**

   **Statement-II :** Some heat is lost in the ionisation of a weak acid.

**4.** **Statement-I :** Enthalpy of formation of HCl is equal to bond energy of HCl.

**Because**

**Statement-II :** Enthalpy of formation and bond energy both involve the formation of one mole of HCl from the elements.

**5.** **Statement-I :** Enthalpy of atomization is the heat of reaction $H_2O(l) \longrightarrow H_2O(g)$.

**Because**

**Statement-II :** Gaseous molecules are far apart of each other due to less attraction.

**6.** **Statement-I :** The enthalpy of formation of $H_2O(l)$ is greater than that of $H_2O(g)$.

**Because**

**Statement-II :** Enthalpy change is negative for the condensation reaction, $H_2O(g) \longrightarrow H_2O(l)$.

**7.** **Statement-I :** As temperature increases, heat of reaction also increases for exothermic as well as for endothermic reactions.

**Because**

**Statement-II :** $\Delta H$ varies with temperature as given by $\Delta H_2$ (at $T_2$) = $\Delta H_1$ (at $T_1$) + $\Delta C_P(T_2 - T_1)$

**8.** **Statement-I :** Heat of combustion is always negative.

**Because**

**Statement-II :** Heat of combustion is used to calculate of fuels.

## COMPREHENSION  BASED  QUESTIONS

## Comprehension  #  1

The industrial preparation of a polymer, PTFE, is based on the synthesis of the monomer $CF_2 = CF_2$, which is produced according to reaction (i) below :

$$2CHClF_2(g) \longrightarrow CF_2= CF_2(g) + 2HCl \qquad\qquad ........(i)$$
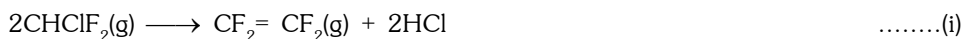
The monomer $CF_2= CF_2$ is also obtained by reaction (ii) below :

$$2CHF_3(g) \longrightarrow CF_2= CF_2(g) + 2HF(g) ; \Delta H = 198.1 kJ/mol \qquad\qquad .......(ii)$$

Consider the information below to answer the questions:

| Compound | $\Delta H_f$ | MoleculeX–X | $\Delta$(X–X) |
|---|---|---|---|
| HCl(g) | –92.3 | | |
| | | F–F | 154.7 |
| $CHClF_2$(g) | –485.2 | | |
| | | Cl–Cl | 246.7 |
| $CF_2= CF_2$(g) | –658.3 | | |
| $CF_4$ | –679.6 | | |
| $CCl_4$ | –106.6 | | |

**1.** The enthalpy change for reaction (i).

(A) 100.23 kJ/mol

(B) 127.5  kJ/mol

(C) –127.5  kJ/mol

(D) –100.23 kJ/mol

2.    (i) Use the expressions
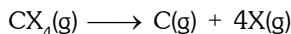
$CX_4(g) \longrightarrow C(s) + 2X_2(g)$

$\Delta H = -\Delta H_f$

$C(s) \longrightarrow C(g) \; ; \quad \Delta H = 718 \text{ kJ/mol}$

and

$2X_2(g) \longrightarrow 4X(g) \; ; \quad \Delta H = 2D(X - X)$
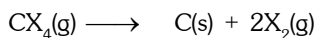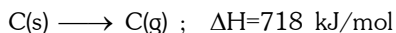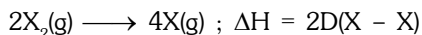
where X = F,Cl, to the enthalpy change for the two processes

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

What is the average C–X bond energies for the species $CX_4(g)$ (where X = F, Cl).

(A) 329.5 kJ/mol, 426.75 kJ/mol

(B) 426.75 kJ/mol, 329.5 kJ/mol

(C) –329.5 kJ/mol, –426.75 kJ/mol

(D) –426.75 kJ/mol, –329.5 kJ/mol

(ii) Given that the C–H bond energy is 416.1 kJ/mol, the order of relative chemical reactivities of C–H, C–F, and C–Cl bonds.
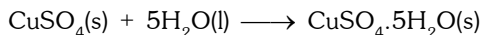
(A) C – H > C – Cl > C – F

(B) C – F > C – Cl > C – H

(C) C – Cl > C – H > C – F

(D) C – Cl > C – F > C – H

## Comprehension # 2

The hydration enthalpy of anhydrous copper (II) sulphate is defined as the heat absorbed or evolved when one mole of anhydrous solid is converted to one mole of crystalline hydrated solid.

$CuSO_4(s) + 5H_2O(l) \longrightarrow CuSO_4.5H_2O(s)$

It cannot be measured directly.

In an experiment to determine the hydration enthalpy indirectly, 4 g of the anhydrous solid were added to 50 g of water and the rise in temperature was 8 degrees. When 4 g of the hydrated solid was added to 50 g of water the fall in temperature was 1.3 degrees.

1.    What is the heat produced when 4 g of anhydrous solid is added to 50 g of water.

(A) 400 kJ          (B) 1672  kJ          (C) 200 kJ          (D) 836 kJ

2.    What is the enthalpy of solution of anhydrous copper (II) sulphate in kJ/mol.

(A) 69.9472 kJ/mol     (B) 4054.375  kJ/mol     (C) 139.8948  kJ/mol     (D) 8108.750 kJ/mol

3.    Given that the enthalpy of solution of the hydrated copper (II) sulphate is +11.3 kJ/mol, what is the enthalpy of hydration of the anhydrous solid.
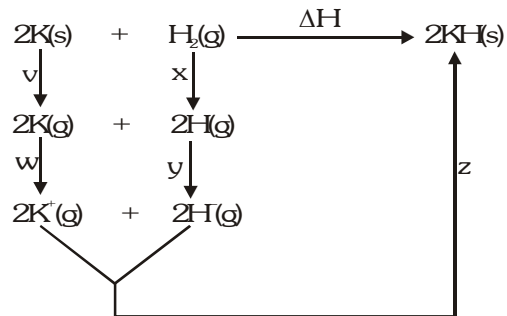
(A) 97.321 kJ/mol     (B) –97.321  kJ/mol     (C) –77.971  kJ/mol     (D) 77.971 kJ/mol

## Comprehension # 3

The Born Haber cycle below represents the energy changes occurring at 298K when KH is formed from its elements



$\Delta H_{atomisation}$ K = 90 kJ/mol

$\Delta H_{ionisation}$ K = 418 kJ/mol

$\Delta H_{dissociation}$ H = 436 kJ/mol

$\Delta H_{electron\ affinity}$ H = –78 kJ/mol

$\Delta H_{lattice}$ KH = –710 kJ/mol

1. In terms of the letters v to z write down expressions for

   (i) $\Delta H$ for the reaction

   $$2K(s) + H_2(g) \longrightarrow 2KH(s)$$

   (ii) $\Delta H_i$ of K

   (iii) $\Delta H_{electron\ affinity}$ of H

   (iv) $\Delta H_{lattice}$ of KH(s)

2. Which of v to y is

   (i) The most exothermic ...................... .

   (ii) The most endothermic ...................... .

3. Calculate the value of $\Delta H$ showing all your working.

4. Calculate the $\Delta H_f$ of KH(s).

5. Write a balanced equation for the reaction of KH with water.

6. On complete reaction with water, 0.1 g of KH gave a solution requiring 25 cm$^3$ of 0.1M HCl for neutralisation. Calculate the relative atomic mass of potassium from this information.

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| MISCELLANEOUS TYPE QUESTION | ANSWER KEY | EXERCISE -3 |
|---|---|---|

**● True / False**

1. F        2. T        3. T        4. T        5. T        6. F        7. F        8. F

9. F

**● Fill in the Blanks**

1. exothermic        2. endothermic        3. heat of transition        4. +33 kJ mol$^{-1}$

5. –18 kcal mol$^{-1}$        6. –57.2        7. –110.5        8. –3 RT

**● Match the Column**

1. (A) - q, (B) - r, (C) - s, (D) - p, (E) - t        2. (A) - q, (B) - p, (C) - r, (D) - s

3. (A) - r, (B) - s, (C) - p, (D) - q

**● Assertion - Reason Questions**

1. (A)        2. (C)        3. (C)        4. (A)        5. (D)        6. (A)        7. (D)        8. (B)

**● Comprehension Based Questions**

Comprehension # 1 : 1. (B)        2. (i) (B)        (ii) (C)

Comprehension #2 : 1. (B)        2. (A)        3. (C)

Comprehension #3 : 1. (i) $\Delta H = (v + w + x + y + z)$        (ii) w/2        (iii) y/2        (iv) z/2

2. (i) y        (ii) w

3. –124 kJ/mol        4. –62 kJ/mol        6. 39

# EXERCISE–04 [A]                    CONCEPTUAL SUBJECTIVE EXERCISE

1. When 2 moles of $C_2H_6$ are completely burnt 3120 kJ of heat is liberated. Calculate the heat of formation, $\Delta H_f$ for $C_2H_6$. Give $\Delta H_f$ for $CO_2(g)$ & $H_2O(l)$ are –395 & –286 kJ respectively.

2. The standard heats of formation of $CH_4(g)$, $CO_2(g)$ and $H_2O(l)$ are –76.2, –398.8, –241.6 kJ $mol^{-1}$. Calculate amount of heat evolved by burning $1m^3$ of methane measured under normal (STP) conditions.

3. Calculate the enthalpy change when infinitely dilute solution of $CaCl_2$ and $Na_2CO_3$ mixed $\Delta H_f$ for $Ca^{2+}(aq)$, $CO_3^{2-}$ (aq) and $CaCO_3(s)$ are –129.80, –161.65, –288.5 kcal $mol^{-1}$ respectively.

4. The enthalpies of neutralization of NaOH & $NH_4OH$ by HCl are –13680 calories and –12270 cal respectively. What would be the enthalpy change if one gram equivalent of NaOH is added to one gram equivalent of $NH_4Cl$ is solution ? Assume that $NH_4OH$ and NaCl are quantitatively obtained.

5. The heat of solution of anhydrous $CuSO_4$ is –15.9 kcal and that of $CuSO_4.5H_2O$ is 2.8 kcal. Calculate the heat of hydration of $CuSO_4$.

6. The heat of reaction $\dfrac{1}{2} H_2(g) + \dfrac{1}{2} Cl_2(g) \longrightarrow HCl(g)$ at 27 C is –22.1 kcal. Calculate the heat of reaction at 77 C. The molar heat capacities at constant pressure at 27 C for hydrogen, chlorine & HCl are 6.82, 7.70 & 6.80 cal $mol^{-1}$ respectively.

7. Calculate standard heats of formation of carbon-di-sulphide (l). Given the standard heat of combustion of carbon (s), sulphur (s) & carbon-di-sulphide (l) are : –393.3, –293.72 and–1108.76 kJ $mol^{-1}$ respectively.

8. The standard enthalpy of neutralization of KOH with (a) HCN (b) HCl in dilute solution is –2480 cal. $geq^{-1}$ and –13.68 kcal, $geq^{-1}$ respectively. Find the enthalpy of dissociation of HCN at the same temperature.

9. At 300K, the standard enthalpies of formation of $C_6H_5COOH(s)$, $CO_2(g)$ & $H_2O(l)$ are; –408, –393 & –286 kJ $mol^{-1}$ respectively. Calculate the heat of combustion of benzoic acid at :

   (i) constant pressure    &         (ii)    constant volume.

10. The heat liberated on complete combustion of 7.8 g of benzene is 327 kJ. This heat has been measured at constant volume & at 27 C. Calculate the heat of combustion of benzene at constant pressure.

11. If the enthalpy of formation of HCl (g) and $Cl^-$ (aq) are –92.3 kJ/mole and –167.44 kJ/mol, find the enthalpy of solution of hydrogen chloride gas.

12. 0.16 g of methane was subjected to combustion at 27 C in a bomb calorimeter. The temperature of calorimeter system (including water) was found to rise by 0.5 C. Calculate the heat of combustion of methane at

   (i) constant volume              (ii)    constant pressure.

   The thermal capacity of calorimeter system is 17.7 kJ $K^{-1}$. (R = 8.313 $mol^{-1}K^{-1}$)

13. When 1.0 g of fructose $C_6H_{12}O_6(s)$ is burned in oxygen in a bomb calorimeter, the temperature of the calorimeter water increases by 1.56 C. If the heat capacity of the calorimeter and its contents is 10.0 kJ/ C. Calculate the enthalpy of combustion of fructose at 298 K.

14. The enthalpy of dissociation of $PH_3$ is 954 kJ/mol and that of $P_2H_4$ is 1.485 M J $mol^{-1}$. What is the bond enthlapy of the P–P bond ?

15. Using the bond enthalpy data given below, calculate the enthalpy change for the reaction,
       $C_2H_4(g) + H_2(g) \longrightarrow C_2H_6(g)$
   Data :

   | Bond | C – C | C = C | C – H | H – H |
   |------|-------|-------|-------|-------|
   | Bond Enthalpy | 336.81 kJ/mol | 606.68 kJ/mol | 410.87 kJ/mol | 431.79 kJ/mol |

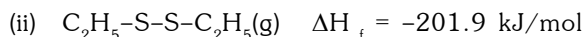16. The enthalpy change for the following process at 25 C and under constant pressure at 1 atm are as follows:

$CH_4(g) \longrightarrow C(g) + 4H(g)$ $\qquad$ $\Delta_r H = 396$ kcal/mole

$C_2H_6(g) \longrightarrow 2C(g) + 6H(g)$ $\qquad$ $\Delta_r H = 676$ kcal/mole

Calculate C–C bond energy in $C_2H_6$ & heat of formation of $C_2H_6(g)$

Given : $\Delta_{sub} C(s) = 171.8$ kcal/mole

$\qquad$ B.E. (H–H) = 104.1 kcal/mole

17. Find the enthalpy of S–S bond from the following data.

(i) $C_2H_5$–S–$C_2H_5(g)$ $\qquad$ $\Delta H_f = -147.2$ kJ/mol

(ii) $C_2H_5$–S–S–$C_2H_5(g)$ $\qquad$ $\Delta H_f = -201.9$ kJ/mol

(iii) S(g) $\qquad$ $\Delta H_f = -222.8$ kJ/mol

18. Calculate the electron affinity of fluorine atom using the following data. Make Born–Haber's cycle. All the values are in kJ $mol^{-1}$ at 25 C, $\Delta H_{diss}(F_2) = 160$, $\Delta H_f^\circ$ (NaF(s)) = –571.I.E. [Na(g)] = 494, $\Delta H_{vap}$ [Na(s)] = 101. Lattice energy of NaF(s) = –894.

19. Cesium chloride is formed according to the following equation :

$\qquad$ $Cs(s) + 0.5Cl_2(g) \longrightarrow CsCl(s).$
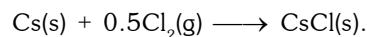
The enthalpy of sublimation of Cs, enthalpy of dissociation of chlorine, ionization energy of Cs & electron affinity of chlorine are 81.2, 243.0, 375.7 and –348.3 kJ $mol^{-1}$. The energy change involved in the formation of CsCl is –388.6 kJ $mol^{-1}$. Calculate the lattice energy of CsCl.

20. The enthalpy of formation of ethane, ethylene and benzene from the gaseous atom are –2839.2, –2275.2 and –5506 kJ $mol^{-1}$ respectively. Calculate the resonance energy of benzene. The bond enthalpy of C–H bond is given as equal to +410.87 kJ/mol.

21. Two mole of ideal diatomic gas ($C_{V,m} = 5/2$ R) at 300 K and 5 atm expanded irreversly & adiabatically to a final pressure of 2 atm against a constant pressure of 1 atm. Calculate q, w, $\Delta H$ & $\Delta U$.

22. A bomb containing 5.4g of Al and 15.97g of $Fe_2O_3$ is placed in an ice calorimeter containing initially 8 kg of ice and 8 kg of water. The reaction $2Al(s) + Fe_2O_3(s) \rightarrow Al_2O_3(s) + 2Fe(s)$ is set off by remote control and it is then observed that the calorimeter contains 7.746 kg of ice and 8.254 kg of water. Find the $\Delta H$ for the above reaction.

$\qquad$ $\Delta H_{fusion}$ (ice) = 1.436 kcal/mole

23. A sample of the sugar D–ribose ($C_5H_{10}O_5$) of mass 0.727g was placed in a calorimeter and then ignited in the presence of excess oxygen. The temperature raise by 0.910 K. In a separate experiment in the same calorimeter, the combustion of 0.825g of benzoic acid, for which the internal energy of combustion is –3251kJ $mol^{-1}$, gave a temperature rise of 1.940K. Calculate the internal energy of combustion of D–ribose and its enthalpy of formation.

24. The heat of combustion of formaldehyde$_{(g)}$ is –134 kcal $mole^{-1}$ and the heat of combustion of paraformaldehyde$_{(s)}$ is –122 kcal per (1/n) $(CH_2O)_n$. Calculate the heat of polymerization of formaldehyde to paraformaldehyde.

**25.** The disaccharide $\alpha$ – maltose can be hydrolysed to glucose according to the equation

$$C_{12}H_{22}O_{11}(aq) + H_2O(l) \longrightarrow 2C_6H_{12}O_6(aq)$$
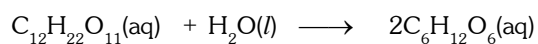
Using the following values, calculate the standard enthalpy change in this reaction:

$$\Delta_f H \; (H_2O, \; l) \qquad = \qquad -285.85 \text{ kJ mol}^{-1}$$

$$\Delta_f H \; (C_6H_{12}O_6, \; aq) \qquad = \qquad -1263.1 \text{kJ mol}^{-1}$$

$$\Delta_f H \; (C_{12}H_{22}O_{11}, \; aq) \qquad = \qquad -2238.3 \text{ kJ mol}^{-1}$$

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| CONCEPTUAL SUBJECTIVE EXERCISE | ANSWER KEY | EXERCISE-4(A) |
|---|---|---|

| | | | | |
|---|---|---|---|---|
| 1.   −88 kJ/mol | 2.   35.973 MJ | 3.   2.95 kcal | 4.   −1410 cal | 5.   −18.7 kcal |
| 6.   −22.123 kcal | 7.   128.02 kJ | 8.   11.2 kcal | 9.   (i) −3201 kJ/mol (ii) −3199.75 kJ/mol | |
| 10. −3273.77 kJ/mol | 11. −75.14 kJ/mol | 12. (i) −885 kJ/mol   (ii) −889.980 kJ/mol | | |
| 13. −2808 kJ/mol | 14. 213 kJ/mol | 15.   −120.08 J/mol | | |
| 16. B.E. (C–C) = 82 kcal/mol, $\Delta_f H$ [$C_2H_6(g)$] = −20.1 kcal/mol | | 17. 277.5 kJ/mol | | |
| 18. E.A = −352 kJ mol$^{-1}$ | | 19. −618.7 kJ mol$^{-1}$ | | |
| 20. −23.68 kJ/mol | | 21. q = 0, $\Delta U$ = w = −1247.1 J, $\Delta H$ = − 1745.94 J | | |
| 22. $\Delta H$ = −202.5 kcal | | 23.   −2.13MJ mol$^{-1}$, 1.267MJ mol$^{-1}$ | | |
| 24. −12 kcal | | 25.   −2.05 kJmol$^{-1}$ | | |

1. For the reaction cis-2-butene $\to$ trans-2-butene and cis-2-butene $\to$ 1-butene, $\Delta H$ = – 950 and + 1771 cal/mol respectively. The heat of combustion of 1-butene is –649.8 kcal/mol. Determine the heat of combustion of trans-2-butene. Also calculate the bond energy of C=C bond in trans-2-butene. Given B.E of C = O = 196, O—H = 110, O = O = 118, C—C = 80 and C—H = 98 kcal/mol respectively. $\Delta H_v(H_2O)$ = 11 kcal/mol.

2. Using the data (all values are in kJ/mol at 25 C) given below :
   (i) Enthalpy of polymerization of ethylene = – 72.
   (ii) Enthalpy of formation of benzene ($\ell$) = 49
   (iii) Enthalpy of vaporization of benzene ($\ell$) = 30
   (iv) Resonance energy of benzene ($\ell$) = – 152
   (v) Heat of formation of gaseous atoms from the elements in their standard states H = 218, C = 715.
   Average bond energy of C—H = 415. Calculate the B.E. of C—C and C= C. [A : 331 and 590 kJ/mol]

3. Determine resonance energy of benzene $[C_6H_6 (\ell)]$ from the following information :
   $$\Delta H_f \text{ of } C_6H_6 (\ell) = + 49 \text{ kJ} ;$$
   $\Delta H_f$ of $C_2H_2$ (g) = +75 kJ $\Delta H_v$ of $C_6H_6$ ($\ell$) = + 45 kJ
   B.E.   C $\equiv$ C = 930 kJ/mol ; C = C = 615 kJ/mol ; C — C = 348 kJ/mol

4. Consider the following thermodynamic data :
   Enthalpy of formation of $CaC_2$ (s) = – 60 kJ/mol ;
   Enthalpy of sublimation of Ca (s) = 179 kJ/mol ;
   Enthalpy of sublimation of C (s) = 718 kJ/mol ;
   First ionization energy of Ca (g) = 590 kJ/mol ;
   Second ionization energy of Ca (g) = 1143 kJ/mol ;
   Bond energy of $C_2$ (g) = 614 kJ/mol ;
   First electron affinity of $C_2$ (g) = –315 kJ/mol ;
   Second electron affinity of $C_2$ (g) = +410   kJ/mol ;
   Draw a clear Born-Haber cycle and determine lattice energy of $CaC_2$ (s).

5. A swimmer breaths 20 times in one minute when swimming and inhale 200 mL of air in one breath. Inhalded air contain 20% $O_2$ by volume and exhaled air contain 10% $O_2$ by volume. If all oxygen are consumed in combustion of glucose in the body and 25% of energy obtained from combustion is available for muscular work. Determine the maximum distance this swimmer can swim in one hour if 100 kJ energy is required for 1.0 km swimming. Standard molar enthalpy of combustion of glucose is –2880 kJ/mol and body temperature is 37 C.

6. Given the following standard molar enthalpies :
   $\Delta H_f$ of $CH_3CN$ (g) = 88 kJ/mol, $\Delta H_f$ of $C_2H_6$ = – 84 kJ/mol, $\Delta H_{Sublimation}$ of C(gr) = 717 kJ/mol, bond dissociation energy of $N_2$ (g) and $H_2$ (g) are 946 and 436 kJ/mole respectively, B.E. (C—H) = 410 kJ/mol. Determine C—C and C $\equiv$ N bond energies.

7. By using the following data draw an appropriate energy cycle & calculate the enthalpy change of hydration of (i) the chloride ion ;    (ii) the iodide ion.
   Comment on the difference in their values.
   *   enthalpy change of solution of NaCl(s) = – 2 kJ/mol.
   *   enthalpy change of solution of NaI(s) = + 2 kJ/mol.
   *   enthalpy change of hydration of $Na^+$ (g) = – 390 kJ/mol.
   *   lattice energy of NaCl = – 772 kJ/mol.
   *   lattice energy of NaI = – 699 kJ/mol.

8. Use the following enthalpies of combustion in the calculations that follow.

| Element/Compound | Enthalpy of Combustion |
|---|---|
| $C(s)$ | – 394 |
| $H_2(g)$ | – 286 |
| $CH_3CO_2H(l)$ | – 876 |
| $C_4H_6(g)$ | – 2542 |
| $C_2H_6(g)$ | – 1561 |
| $C_2H_4(g)$ | – 1393 |

(i) Calculate the enthalpy change for the reaction :

$$2C(s) + 2H_2(g) + O_2(g) \longrightarrow CH_3CO_2H(l)$$
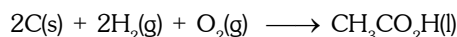
(ii) Calculate the enthalpy of formation of buta–1, 3– diene $C_4H_6$.

(iii) Calculate the enthalpy of formation of ethene $C_2H_4$.

(iv) Calculate the enthalpy change for the conversion of ethene $C_2H_4$ to ethane $C_2H_6$.

9. Becker and Roth measured the heat evolved in the following processes at 20 C: (1) 1 mole of solid $(COONH_4)_2H_2O$ is burned in oxygen, (2) 1 mole of solid $(COOH)_2(H_2O)_2$ is burned in oxygen, (3) 1 mole of solid $(COONH_4)_2H_2O$ is dissolved in a large excess of water, (4) 1 mole of solid $(COOH)_2(H_2O)_2$ is dissolved in a large excess of water, (5) 1 mole of oxalic acid in dilute solution is neutralized with gaseous ammonia. They found (1) 189.86 kcal, (2) 53.10 kcal, (3) –11.47 kcal, (4) –8.62 kcal, (5) 43.13 kcal; (1) and (2) were measured at constant volume, the others at constant pressure. The end products of (1) and (2) were nitrogen, carbon dioxide, and water. The heat of formation for 1 mole of water from the elements had previously been determined as 68.35 kcal at constant pressure and 20 C. Find the change in enthalpy when 1 mole of $NH_3$ is formed from the elements at 20 C.

10. Set up a thermodynamic cycle for determining the enthalpy of hydration of $Ca^{2+}$ ions using the following data :
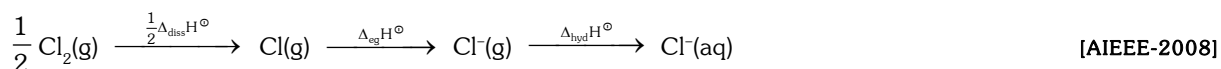
Enthalpy of sublimation of $Ca(s)$, +178.2kJ $mol^{-1}$; first and second ionization enthalpies of $Ca(g)$, 589.7 kJ $mol^{-1}$ and 1145 kJ $mol^{-1}$; enthalpy of vaporization of bromine, + 30.91kJmol$^{-1}$; dissociation enthalpy of $Br_2(g)$, +192.9 kJmol$^{-1}$; electron gain enthalpy of $Br(g)$, –331.0kJmol$^{-1}$; enthalpy of solution of $CaBr_2(s)$, –103.1 kJ $mol^{-1}$; enthalpy of hydration of $Br^-(g)$, –337 kJmol$^{-1}$.

| BRAIN STORMING SUBJECTIVE EXERCISE | ANSWER KEY | EXERCISE-4(B) |
|---|---|---|

1. $\Delta H$ = –647.079 kcal, B.E. (C = C) = 159.921 kcal

2. C – C = 343.67 kJ, C = C = 615.33

3. R.E. = –132 kJ/mol

4. L.E. = –2889 kJ

5. 1.1328 km

6. 366 kJ/mol, 1095 kJ/mol

7. for Cl$^-$ – 384 kJ mol$^{-1}$, for I$^-$ – 307 kJ mol$^{-1}$

8. (i) $\Delta H$ = –484 kJ/mol     (ii) $\Delta H$ = 108 kJ/mol      (iii) $\Delta H$ = 33       (iv) $\Delta H$ = –118 kJ/mol

9. –11.01 kcal

10. –1587kJmol$^{-1}$

**1.** If at 298 K the bond energies of C–H, C–C, C=C and H–H bonds are respectively 414, 347, 615 and 435 kJ mol$^{-1}$, the value of enthalpy change for the reaction :                    **[AIEEE-2003]**

$H_2C=CH_2(g) + H_2(g) \longrightarrow H_3C–CH_3(g)$ at 298 K will be :-

(1) +125 kJ                                      (2) –125 kJ

(3) +250 kJ                                      (4) –250 kJ

**2.** The enthalpies of combustion of carbon and carbon monoxide are –393.5 and –283 kJ mol$^{-1}$ respectively. The enthalpy of formation of carbon monoxide per mole :-                    **[AIEEE-2004]**

(1) 110.5 kJ                                      (2) 676.5 kJ

(3) –676.5 kJ                                     (4) –110.5 kJ

**3.** Consider the reaction : $N_2 + 3H_2 \longrightarrow 2NH_3$ carried out at constant temperature and pressure, if $\Delta H$ and $\Delta U$ are the enthalpy and internal energy changes for the reaction, which of the following expressions is true?                    **[AIEEE-2005]**

(1) $\Delta H = \Delta U$                        (2) $\Delta H = 0$

(3) $\Delta H > \Delta U$                        (4) $\Delta H < \Delta U$

**4.** If the bond dissociation energies of XY, $X_2$ and $Y_2$ (all diatomic molecules) are in the ratio of 1 : 1 : 0.5 and $\Delta_f H$ for the formation of XY is –200 kJ mol$^{-1}$. The bond dissociation energy of $X_2$ will be :-

(1) 200 kJ mol$^{-1}$                            (2) 100 kJ mol$^{-1}$                    **[AIEEE-2005]**

(3) 800 kJ mol$^{-1}$                            (4) 300 kJ mol$^{-1}$

**5.** The standard enthlapy of formation ($\Delta_f H$) at 298K for methane, $CH_4(g)$, is –74.8 kJ mol$^{-1}$. The additional information required to determine the average energy for C–H bond formation would be:-

(1) Latent heat of vapourization of methane                    **[AIEEE-2006]**

(2) The first four ionization energies of carbon and electron gain enthalpy of hydrogen

(3) The dissociation energy of hydrogen molecule $H_2$

(4) The dissociation energy of $H_2$ and enthalpy of sublimation of carbon

**6.** The enthalpy changes for the following processes are listed below :                    **[AIEEE-2006]**

$Cl_2(g) = 2Cl(g)$,            242.3 kJ mol$^{-1}$

$I_2(g) = 2I(g)$,              151.0 kJ mol$^{-1}$

$ICl(g) = I(g) + Cl(g)$,      211.3 kJ mol$^{-1}$

$I_2(s) = I_2(g)$,            62.76 kJ mol$^{-1}$

Given that the standard states for iodine and chlorine are $I_2(s)$ and $Cl_2(g)$, the standard enthalpy of formation for $ICl(g)$ is :-

(1) –16.8 kJ mol$^{-1}$                          (2) +16.8 kJ mol$^{-1}$

(3) +244.8 kJ mol$^{-1}$                         (4) –14.6 kJ mol$^{-1}$

**7.** $(\Delta H - \Delta U)$ for the formation of carbon monoxide (CO) from its elements at 298 K is

$(R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1})$ **[AIEEE-2006]**

(1) 1238.78 J mol$^{-1}$          (2) –2477.57 J mol$^{-1}$

(3) 2477.57 J mol$^{-1}$          (4) –1238.78 J mol$^{-1}$

**8.** Assuming that water vapour is an ideal gas, the internal energy change ($\Delta U$) when 1 mol of water is vapourised at 1 bar pressure and 100 C, (Given : Molar enthalpy of vapourisation of water at 1 bar and 373 K = 41 kJ mol$^{-1}$ and R = 8.3 J mol$^{-1}$ K$^{-1}$ will be) :- **[AIEEE-2007]**

(1) 4.100 kJ mol$^{-1}$          (2) 3.7904 kJ mol$^{-1}$

(3) 37.904 kJ mol$^{-1}$          (4) 41.00 kJ mol$^{-1}$

**9.** Oxidising power of chlorine in aqueous solution can be determined by the parameters indicated below:

$$\frac{1}{2} Cl_2(g) \xrightarrow{\frac{1}{2}\Delta_{diss}H^\ominus} Cl(g) \xrightarrow{\Delta_{eg}H^\ominus} Cl^-(g) \xrightarrow{\Delta_{hyd}H^\ominus} Cl^-(aq)$$ **[AIEEE-2008]**

The energy involved in the conversion of $\frac{1}{2} Cl_2(g)$ to Cl$^-$(aq)

(using the data $\Delta_{diss} H^\ominus_{Cl_2} = 240$ kJ mol$^{-1}$, $\Delta_{eg} H^\ominus_{Cl} = -349$ kJ mol$^{-1}$, $\Delta_{hyd} H^\ominus_{Cl^-} = -381$ kJ mol$^{-1}$) will be:-

(1) –610 kJ mol$^{-1}$          (2) –850 kJ mol$^{-1}$

(3) +120 kJ mol$^{-1}$          (4) +152 kJ mol$^{-1}$

**10.** On the basis of the following thermochemical data : $\left(\Delta G^0_f H^+_{(aq)} = 0\right)$

$H_2O(\ell) \rightarrow H^+(aq) + OH^-(aq)$ ; $\Delta H = 57.32$ kJ

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

The value of enthalpy of formation of OH$^-$ ion at 25 C is :- **[AIEEE-2009]**

(1) +228.88 kJ          (2) –343.52 kJ

(3) –22.88 kJ          (4) –228.88 kJ

**11.** The standard enthalphy of formation of NH$_3$ is –46.0 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]**

(1) –1102 kJ mol$^{-1}$          (2) –964 kJ mol$^{-1}$

(3) + 352 kJ mol$^{-1}$          (4) +1056 kJ mol$^{-1}$

**12.** The value of enthalpy change ($\Delta H$) for the reaction

$C_2H_5OH_{(\ell)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(\ell)}$

at 27 C is –1366.5 kJ mol$^{-1}$. The value of internal energy change for the above reaction at this temperature will be :- **[AIEEE-2011]**

(1) –1371.5 kJ          (2) –1369.0 kJ

(3) –1364.0 kJ          (4) –1361.5 kJ

13. Consider the reaction :

$4NO_{2(g)} + O_{2(g)} \rightarrow 2N_2O_{5(g)}$, $\Delta_rH = -111kJ$.

If $N_2O_{5(s)}$ is formed instead of $N_2O_{5(g)}$ in the above reaction, the $\Delta_rH$ value will be :-

(given, $\Delta H$ of sublimation for $N_2O_5$ is 54 kJ mol$^{-1}$)                                    [AIEEE-2011]

(1) −165 kJ                                              (2) +54 kJ

(3) +219 kJ                                              (4) −219 kJ

14. The enthalpy of neutralisation of $NH_4OH$ with HCl is −51.46 kJ mol$^{-1}$ and the enthalpy of neutralisation of NaOH with HCl is −55.90 kJ mol$^{-1}$. The enthalpy of ionisation of $NH_4OH$ is :- [AIEEE-2012 (Online)]

(1) +107.36 kJ mol$^{-1}$                                (2) −4.44 kJ mol$^{-1}$

(3) −107.36 kJ mol$^{-1}$                                (4) +4.44 kJ mol$^{-1}$

15. The difference between the reaction enthalpy change ($\Delta_rH$) and reaction internal energy change ($\Delta_rU$) for the reaction :

$2C_6H_6(\ell) + 15O_2(g) \rightarrow 12CO_2(g) + 6H_2O(\ell)$ at 300K is (R = 8.314 J mol$^{-1}$ K$^{-1}$) [AIEEE-2012 (Online)]

(1) 0 J mol$^{-1}$                                        (2) 2490 J mol$^{-1}$

(3) −2490 J mol$^{-1}$                                    (4) −7482 J mol$^{-1}$

| PREVIOUS YEAR QUESTIONS   ANSWER KEY | | | | | | | | | | | | | EXERCISE-5(A) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Que. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Ans | 2 | 4 | 4 | 3 | 4 | 2 | 1 | 3 | 1 | 4 | 3 | 3 | 4 | 4 | 4 |

1.　　Which of the following reaction defines $\Delta H_f$ ?　　　　　　　　　　　　　**[IIT-JEE-2003]**

(A) $C_{(diamond)} + O_2(g) \longrightarrow CO_2(g)$　　　　　　　　(B) $\frac{1}{2} H_2(g) + \frac{1}{2} F_2(g) \longrightarrow HF(g)$

(C) $N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$　　　　　　　　(D) $CO(g) + \frac{1}{2} O_2(g) \longrightarrow CO_2(g)$

2.　　$\Delta H_f$ for $CO_2(g)$, $CO(g)$ and $H_2O(g)$ are –393.5, –110.5 and –241.8 kJ mol$^{-1}$ respectively. The standard enthalpy change (in kJ) for the relation :　　　　　　　　　　　**[IIT-JEE-2000]**

　　$CO_2(g) + H_2(g) \longrightarrow CO(g) + H_2O(g)$ is :-

(A) 524.1　　　　　　　(B) 41.2　　　　　　　(C) –262.5　　　　　　　(D) –41.2

3.　　Which of the following is not an endothermic reaction :-　　　　　　　　**[IIT-JEE-1999]**

(A) Combustion of methane　　　　　　　　(B) Decomposition of water

(C) Dehydrogenation of ethene to ethylene　　　　(D) Conversion of graphite to diamond

4.　　Standard molar enthalpy of formation of $CO_2$ is equal to :-　　　　　　　**[IIT-JEE-1997]**

(A) Zero

(B) Standard molar enthalpy of combustion of carbon (graphite)

(C) Standard molar enthalpy of combustion of gaseous carbon

(D) Sum of molar enthalpies of formation of CO and $O_2$

5.　　Diborane is a potential rocket fuel which undergoes combustion according to the reaction,　　**[IIT-JEE-2000]**

　　$B_2H_6(g) + 3O_2(g) \longrightarrow B_2O_3(s) + 3H_2O(g)$

From the following data, calculate the enthalpy change for the combustion of diborane :

　　$2B(s) + \frac{3}{2} O_2(g) \longrightarrow B_2O_3(s)$ ;　　　　　　$\Delta H = -1273$ kJ

　　$H_2(g) + \frac{1}{2} O_2(g) \longrightarrow H_2O(l)$ ;　　　　　　$\Delta H = -286$ kJ

　　$H_2O(l) \longrightarrow H_2O(g)$ ;　　　　　　$\Delta H = 44$ kJ

　　$2B(s) + 3H_2(g) \longrightarrow B_2H_6(g)$ ;　　　　　　$\Delta H = 36$ kJ

6.　　Estimate the average S–F bond energy in $SF_6$. The $\Delta H_f$ values of $SF_6(g)$, $S(g)$ and $F(g)$ are –1100, 275 and 80 kJ/mol respectively.　　　　　　　　　　　　**[IIT-JEE-1999, 2005]**

7.　　From the following data, calculate the enthalpy change for the combustion of cyclopropane at 298 K. The enthalpy of formation of $CO_2(g)$, $H_2O(l)$ and propene (g) are –393.5, –285.8 & 20.42 kJ/mol respectively. The enthalpy of isomerisation of cyclopropane to propene is –33.0 kJ/mol.　　**[IIT-JEE-1998, 2005]**

8. Using the data provided, calculate the multiple bond energy (kJ mol$^{-1}$) of a C ≡ C bond in $C_2H_2$. That energy is (take the bond energy of a C–H bond as 350 kJ mol$^{-1}$.) **[JEE 2012]**

$$2\ C(s) + H_2(g) \longrightarrow C_2H_2(g) \qquad \Delta H = 225\ kJ\ mol^{-1}$$

$$2\ C(s) \longrightarrow 2C(g) \qquad \Delta H = 1410\ kJ\ mol^{-1}$$

$$H_2(g) \longrightarrow 2H(g) \qquad \Delta H = 330\ kJ\ mol^{-1}$$

(A) 1165      (B) 837      (C) 865      (D) 815

9. In a constant volume calorimeter, 3.5 g of a gas with molecular weight 28 was burnt in excess oxygen at 298.0 K. The temperature of the calorimeter was found to increase from 298.0 K to 298.45 K due to the combustion process. Given that the heat capacity of the calorimeter is 2.5 kJ K$^{-1}$, the numerical value for the enthalpy of combustion of the gas in kJ mol$^{-1}$ is **[JEE 2009]**

| PREVIOUS YEARS QUESTIONS | ANSWER KEY | EXERCISE -5(B) |
|---|---|---|

| 1. | (B) | 2. | (B) | 3. | (A) | 4. | (B) |
|---|---|---|---|---|---|---|---|
| 5. | −2035 kJ mol$^{-1}$ | 6. | 309.16 kJ/ mol | 7. | −2091.32 kJ mol$^{-1}$ | | |
| 8. | D | 9. | 9 | | | | |