Chapter 5 Energetics of Chemical Reactions

Multiple Choice Questions (M.C.Qs)

Choose the correct answer for each from the given options:

01 **This is an intensive property:**
(a) Density (b) Mass (c) Mole (d) Volume

02 **Hess's law may be used to calculate:**
(a) ΔH (b) Δs (c) ΔE (d) K

03 **The heat content of a system is called:**
(a) internal energy (b) enthalpy (c) entropy (d) potential energy

04 **In endothermic reaction, the temperature of the surrounding:**
(a) remains constant (b) decreases (c) increases (d) becomes zero

05 **For the reaction: $NaOH + HCl \rightarrow NaCl + H_2O$, the enthalpy change is called:**
(a) heat of reaction (b) heat of sublimation
(c) heat of neutralization (d) heat of combustion

06 **ΔH represents:**
(a) enthalpy (b) change in enthalpy
(c) quantity of heat absorbed (d) quantity of heat evolved

07 **The equation $q_p = \Delta H$ represents:**
(a) enthalpy (b) pressure change
(c) heat changes at constant pressure (d) none of them

08 **Hess's law deals with:**
(a) calculating heat of reaction (b) the rate of reaction
(c) the equilibrium constant (d) the effect of pressure on a gas

09 **First law of thermodynamics is mathematically represented as:**
(a) $\Delta E = E_2 - E_1$ (b) $\Delta E = P\Delta V$ (c) $\Delta E = q - T$ (d) none of these

10 **1 K. Cal is equal to:**
(a) 4.1868 KJ (b) 1.005 KJ (c) 3.6 KJ (d) 1.4868 KJ

11 **The relationship of 'H' (heat constant) is represented by:**
(a) $H = E + PV$ (b) $H = E - PV$ (c) $H = P + EV$ (d) none of them

12 $\Delta H = \Delta H_1 + \Delta H_2 + \Delta H_3$, ***represents:***

(a) the first law of thermodynamics *(b) Hess's law*

(c) law of conservation of energy *(d) partial pressure of gases*

13 ***Which of the following equation is correct?***

(a) $\Delta H = \Delta E + W$ *(b)* $\Delta E = -\Delta H - W$ *(c)* $\Delta E = W + \Delta H$ *(d)* $\Delta H = \Delta H - W$

14 ***Which of the following is exothermic reaction?***

(a) $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ *(b)* $H_2 + I_2 \rightarrow 2HI$

(c) $C + 2S \rightarrow CS_2$ *(d)* $Fe + S \rightarrow FeS$

15 $C + 2S \rightarrow CS_2$ $\Delta H = +117.5\ KJ/mol$ ***is an:***

(a) exothermic reaction *(b) endothermic reaction*

(c) decomposition reaction *(d) displacement reaction*

16 ***The properties of the system that depends upon the amount of material concerned are called:***

(a) intensive properties *(b) extensive properties*

(c) chemical properties *(d) physical properties*

17 ***Examples of intensive properties of a system are:***

(a) surface tension & viscosity *(b) pressure and density*

(c) melting & boiling point *(d) All of the above*

18 ***Which of the following is not extensive property?***

(a) Entropy *(b) Internal energy* *(c) Enthalpy* *(d) Temperature*

19 ***The factor*** $E + PV$ ***is known as:***

(a) heat constant *(b) change in enthalpy*

(c) change in entropy *(d) work done*

20 ***Pressure - volume work is represented as:***

(a) $P\Delta V$ *(b)* $V\Delta P$ *(c)* $P/\Delta V$ *(d)* $\Delta V/P$

21 ***Heat evolved or absorbed at constant volume is shown by:***

(a) $q_v = \Delta H$ *(b)* $q_v = P\Delta V$ *(c)* $q_v = \Delta E$ *(d)* $q_v = W$

22 ***The description of the system before it suffers any change is called:***

(a) the initial state *(b) the final state* *(c) equilibrium state* *(d) ground state*

23 ***When*** NH_4Cl ***is dissolved in water, the container becomes cold. This reaction is:***

(a) exothermic *(b) endothermic* *(c) thermless* *(d) low thermic*

24 ***Anything under observation in the laboratory is called:***

(a) system *(b) surrounding* *(c) state* *(d) experiment*

25 ***A heterogenous system consists of :***

(a) one phase *(b) two phases*

(c) three phases *(d) any number of phases*

26 ***If temperature remains constant during each stage of process is called:***

(a) isothermal *(b) equilibrium* *(c) physical* *(d) chemical*

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Energetics of Chemical Reactions

27 ***The apparatus generally used for measuring heat changes is called:***
(a) voltmeter (b) volta meter (c) calorimeter (d) viscometer

28 ***Chemical reactions which are accompanied by heat changes are called:***
(a) thermochemical (b) photochemical (c) pseudochemical (d) protochemical

29 ***Internal energy is equal to:***
(a) K.E (b) P.E (c) heat energy (d) KE + P.E

30 ***The enthalpy associated with the hydration process is called:***
(a) heat of neutralization (b) heat of solution
(c) heat of hydration (d) heat of combustion

31 ***The equation*** $N_2 + O_2 \rightarrow 2NO$ $\Delta H = 180\ KJ$ ***represents:***
(a) exothermic reaction (b) endothermic reaction
(c) irreversible reaction (d) reversible reaction

32 ***The bonds broken in a chemical reaction is more than formed, the*** ΔH ***will be:***
(a) positive (b) negative (c) zero (d) none

33 ***The properties of a system which are easily measurable in bulk are called:***
(a) microscopic (b) macroscopic (c) hydroscopic (d) telescopic

34 ***Volume of a gas is:***
(a) intensive property (b) extensive property (c) positive property (d) negative property

35 ***This is used to calculate heat of reaction:***
(a) Newton's law (b) Hess's law (c) Boyle's law (d) Dalton's law

36 ***Which one of the following is endothermic reaction?***
(a) Vaporization (b) Sublimation (c) Melting (d) All of them

37 ***Evaporation of water is:***
(a) an endothermic change (b) an exothermic change
(c) a chemical change (d) sublimation

38 ***Enthalpy is an expression for the:***
(a) energy state (b) reaction rate (c) heat content (d) activation energy

39 ***Which is true for an exothermic reaction?***
(a) $\Delta H > 0$ *(b)* $\Delta H = 0$ *(c)* $\Delta H \cong 0$ *(d)* $\Delta H < 0$

40 ***The heat of neutralization of strong acid and strong base is always:***
(a) positive (b) negative (c) constant (d) zero

Answer Key

1. (a)	7. (c)	13. (a)	19. (a)	25. (d)	31. (b)	37. (a)
2. (a)	8. (a)	14. (a)	20. (a)	26. (a)	32. (a)	38. (c)
3. (b)	9. (a)	15. (b)	21. (c)	27. (c)	33. (b)	39. (a)
4. (b)	10. (a)	16. (b)	22. (a)	28. (z)	34. (b)	40. (b)
5. (c)	11. (a)	17. (d)	23. (b)	29. (d)	35. (b)	
6. (b)	12. (b)	18. (d)	24. (a)	30. (c)	36. (d)	

Short / Detailed Answer Questions

Q.01 ***What is thermodynamics?***

Ans. *(Therm = heat, dynamics = movement).* It is the study of the transformations of energy from one form to another form i.e changes based on the principle of conservation of energy.

Q.02 ***What is thermochemistry?*** ***Karachi Board: 2015***

Ans. It is the branch of thermodynamics, which deals with thermal energy changes in chemical reactions. Thermochemistry deals with measurement and calculations of heat changes accompanying chemical reactions.

Q.03 ***Define thermochemical reaction.***

Ans. Those reactions which take place with the change of heat energy (i.e evolution or absorption of heat energy) along with material changes are known as "thermochemical reactions".

Q.04 ***What are the types of thermochemical reactions?***

Ans. Thermochemical reactions are of two types depending upon changes in heat content.

(i) Exothermic reactions
(ii) Endothermic reactions

Q.05 ***Briefly describe about heat of reaction.***

Ans. As a result of chemical change heat is either evolved or absorbed. The breaking of bonds in the reactants need energy and formation of new bonds in the products results a release of energy. Different substances have different amounts of energy associated with them. Due to this reason, the total energy of the products is never equal to that of the reactants.

Definition: The energy in the form of heat evolved or absorbed during chemical reactions is called heat of reaction.

Q.06 ***Define endothermic reactions with example.*** ***Karachi Board: 2010***

Ans. ***Endothermic reaction:*** Endo means "inside", therm means "heat", the reactions during which heat is absorbed or heat travels from surrounding to system are called endothermic reactions.

Example 1:

During the formation of glucose from CO_2 and H_2O heat is absorbed. Hence it in endothermic reaction.

$$6CO_2 + 6H_2O + \text{Heat} \longrightarrow C_6H_{12}O_6 + 6O_2$$

Example 2:

The decomposition of water into O_2 and H_2 is an endothermic reaction.

$$2H_2O_{(l)} \longrightarrow 2H_{2(g)} + O_{2(g)} \qquad \Delta H = +571.16\ KJ/mol$$

Q.07 ***Define exothermic reaction with example.*** *Karachi Board: 2010, 2004*

Ans. ***Exothermic reaction:*** Exo means "outside", therm means "heat". The reaction during which heat is evolved, or heat travels from system to surrounding are called exothermic reactions.

Example 1: $C_{(s)} + O_{2(g)} \longrightarrow CO_2 \qquad \Delta H = -393.7\ KJ/mol$

The above reaction is exothermic and heat is evolved during the reaction.

Example 2: The formation of NH_3 in the Haber's process is also an exothermic reaction.

$$N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)} \qquad \Delta H = -92.0\ KJ/mol$$

Q.08 ***Write down the units of energy.*** *Karachi Board: 2008*

Ans. ***Units of energy:*** The energy units in which heat changes are usually expressed in S.I. system are joule (J) and kilo-joule (KJ)

1 joule = kgm^2s^{-2}

4.184 Joule = 1 cal.

Q.09 ***Describe about system and surroundings.***

Ans. ***System:*** In chemistry, a system is usually a substance or a mixture undergoing a physical or chemical change. OR A thing which is under-observation or under-examination is called a system.

Surroundings: Everything in the universe that is not a part of a system is called surroundings. OR The environment of a system is called its surroundings.

Example: The reaction between Zn and $CuSO_4$ can be called a system under-observation. The flask, the air etc. are surroundings of Zn and $CuSO_4$.

Q.10 ***Describe Macroscopic system.***

Ans. The properties of a system in bulk, rather than that of the part of the system, which are easily measurable are known as the macroscopic properties, such as pressure, temperature, volume, composition etc.

Q.11 ***Describe the properties of a system:*** *Karachi Board: 2005, 2013, 2014*

Ans. The properties of a system may be divided into two main groups.

(a) Intensive properties (b) Extensive properties

(a) Intensive properties:

These properties of a system which are independent of the quantity or amount of substance present in the system.

Example: Density, pressure, temperature, viscosity, surface tension, melting point, boiling point and refractive index.

(b) Extensive properties: *Karachi Board: 2011*

These are those properties of a system which depends upon the quantity or amount of the substance present in the system. The change in the extensive property is proportional to the change in the quantity of the material in the system. If the matter in a given system at a given condition is divided into two equal parts, the values of the extensive properties will become half of the original values.

Example: Mass, Volume, Enthalpy, Entropy, Internal energy, Gibb's free energy etc.

Q.12 ***Briefly describe state and state function.*** ***Karachi Board: 2004***

Ans. The macroscopic properties which we necessary to describe a system at particular moment are called as "state".

State Function: A state function is a macroscopic properties of a system which has some definite values for initial and final state and is independent of the path adopted to bring about that change.

Examples of state function:

We use capital letters as symbol for a state function. Pressure (P), temperature (T), volume (V), internal energy (E), enthalpy (H) are state functions.

Let us suppose V_1 is the initial volume of a gas and its final value become V_2. The change in volume (ΔV) of the gas is given by the following equation:

$$\Delta V = V_2 - V_1$$

Now this change in volume of the gas can be brought about either by changing temperature or pressure of the gas. Since V is a state function so ΔV will be independent of the way the volume of the gas has been changed. It will only depend upon the initial and final volume of the gas.

Q.13 ***State and describe the first law of thermodynamics. Derive the expression:*** $\Delta H = \Delta E + P\Delta V$ ***Karachi Board: 2006, 2007, 2009, 2012, 2014, 2016, 2018***

Ans. ***Statement:*** "Energy can neither be created nor destroyed but can change from one form to another."

It is also called the law of conservation of energy

Mathematical Derivation:

Let us consider a system whose energy in the initial state is 'E'. If 'q' amount of energy is supplied to the system from outside then with the absorption of this energy the total energy of the system will now be $E_1 + q$ and the work done by the system on the surrounding will be 'W'. As a result initial energy of the system changes to 'E_2'. Due to this heat and work operations, the changes in the internal energy is given as under:

$$E_2 = E_1 + q - W$$

or $$E_2 - E_1 = q - W$$

or $$\Delta E = q - W$$

This is called equation for the first law of thermodynamics where ΔE depends upon initial and final states of the system.

To prove $\Delta H = \Delta E + P\Delta V$ (or process at constant pressure):

Since most of the chemical reactions in the laboratory are carried out in open vessels, so chemists are more interested in the process that take place at constant pressure.

According to the first law of thermodynamics:

$$\Delta E = q - W$$

At constant pressure it can be written as:

$$\Delta E = q_p - P\Delta V \qquad (\text{as } W = P\Delta V)$$

or $$q_p = \Delta E + P\Delta V \qquad \text{_____ (i)}$$

We know that $\Delta E = E_2 - E_1$ and $\Delta V = V_2 - V_1$

Therefore equation (i) will be

$$q_p = (E_2 - E_1) + P(V_2 - V_1)$$

$$q_p = E_2 - E_1 + PV_2 - PV_1$$

Re-arranging the above equation, we get:

$$q_p = (E_2 + PV_2) - (E_1 + PV_1) \quad \text{_____ (ii)}$$

As (E+PV) is called 'enthalpy' and is shown by 'H':

$$H = E + PV$$

For initial and final states it is written as:

$$H_1 = E_1 + PV_1, \qquad H_2 = E_2 + PV_2$$

The equation (ii) becomes:

$$q_p = H_2 - H_1 = \Delta H \qquad \text{or} \qquad (\Delta H = \Delta E + P\Delta V)$$

$$q_p = \Delta H$$

The heat evolved or absorbed at constant pressure is equal to change in enthalpy. Now by substituting the values in equation (i) i.e.

$$q_p = \Delta E + P\Delta V \qquad \text{we get:}$$

$$\Delta H = q_p = \Delta E + P\Delta V$$

or $$\Delta H = \Delta E + P\Delta V$$

Q.14 ***Briefly describe internal energy.*** ***Karachi Board: 2004, 2012***

Ans. ***Definition:*** Sum of kinetic energy (translation, vibrational, rotational energies), potential energy and all kinds of possible energies are called internal energy. The kinetic and potential energies of nuclei and electrons within the molecules also contribute to the energy of the system. The total of all the possible kinds of energies of the system is called its internal energy (E).

Q.15 ***Describe enthalpy of a system:*** ***Karachi Board: 2006, 2011, 2012***

Ans. ***Enthalpy of a system:*** The total heat content of a system is called enthalpy.

Mathematical form:

When the process is carried out at constant pressure, the system gas also expands in doing pressure-volume work. Therefore, the total heat content of the system at constant pressure is equivalent to the internal energy 'E' plus the PV energy. This is called enthalpy of the system and is denoted by the symbol 'H'.

$$H = E + PV$$

Q.16 ***Prove experimentally that W = PΔV. OR Derivation of pressure-volume work.*** ***Karachi Board: 2004, 2012***

Ans. ***Pressure - Volume work:***

Consider a cylinder of a gas having an area of cross section 'A' fitted with a frictionless and weightless piston. If the pressure on the piston is P, then the total force 'F' acting on the piston would be 'PA' since pressure is the force per unit area (P = F/A). If the piston goes up through a small distance 'dl' then the work-done 'δ W' is given as:

$$\delta W = F \times dl = PAdl = PdV$$

where $Adl = dV$

Thus, $W = P\Delta V$

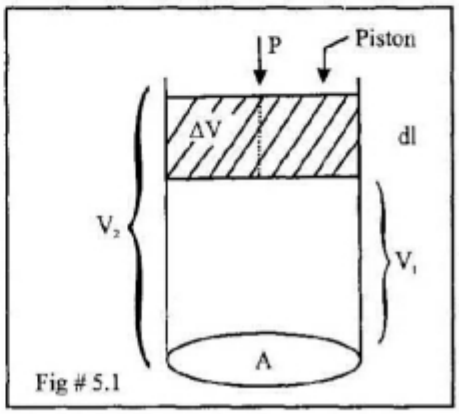


Fig # 5.1

Q.17 ***Explain the first law of thermodynamics at constant volume.*** ***Karachi Board: 2012, 2018***

Ans. From the first law of thermodynamics:

$$\Delta E = q - W$$

In an isolated system the initial and final volume are same:

i.e $\Delta V = V_2 - V_1$

$\Delta V = 0$

as $W = P \Delta V$

Since change in volume ΔV = zero

$\therefore$ $W = 0$ or $P\Delta V = 0$

$\Delta E = q - P\Delta V$

$\Delta E = q_v - 0$

q_v = heat absorbed at constant volume

$\Delta E = q_v$

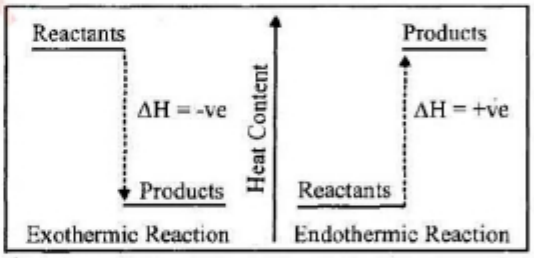
Thus the amount of heat evolved or absorbed at constant volume is equal to the energy change.

Q.18 ***Briefly describe the enthalpy of a reaction (sign of ΔH).*** ***Karachi Board: 2018***

Ans. ΔH is the change in enthalpy. ΔH is the characteristic property of a system and depends on the initial and final states of a system and not on the means by which the changes are bought. For all exothermic processes, ΔH would be negative and for all endothermic process, ΔH is positive. ***e.g.,***

$C + O_2 \longrightarrow CO_2 \quad \Delta H = -394\ KJ\ mol^{-1}$

$C + 2S \longrightarrow CS_2 \quad \Delta H = +117.6\ KJ\ mol^{-1}$



Q.19 ***State and explain Hess's law of constant heat summation with example and give its application.*** ***Karachi Board: 2008-2011-2013-2015-2017-2019***

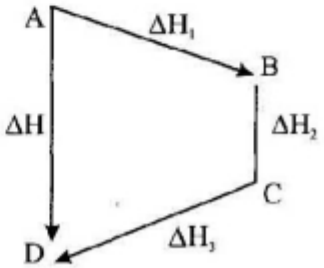
Ans. This law was discovered experimentally in 1840 by German Scientist Herry Hess.

Statement: According to this law "Heat evolved or absorbed in a given reaction (physical or chemical), carried out at constant pressure, is the same whether the reaction takes place in single step or several steps".

Explanation: The change in the enthalpy of any reaction depends only on the nature of reactants and products and is independent of number of steps in between reactants and the products (i.e path followed by the system).

Mathematical form of Hess's law:

Consider a chemical reaction in which reactant 'A' changes to the product 'D' in a single step with ΔH as the heat change (enthalpy change). It may proceed through different steps i.e. 'A' first changes to 'B' with heat change as ΔH_1, 'B' then changes to 'C' with heat changes as ΔH_2.



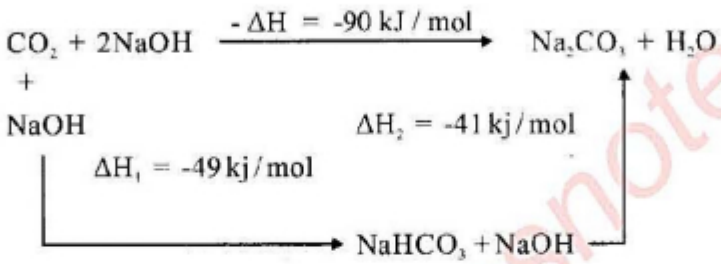
and finally 'C' changes to 'D' with heat change as ΔH_3.

According to Hess's law, $\Delta H = \Delta H_1 + \Delta H_2 + \Delta H_3$

Example of Hess's law:

CO_2 gas reacts with excess of NaOH solution to give Na_2CO_3 with heat change about -90KJ/mol. This reaction may easily be carried out via $NaHCO_3$ formation in two steps. In the first step the enthalpy change is -49 KJ/mol and in the second step, the enthalpy change is -41 KJ/mol.

It is given as follows:



Hence according to Hess's law

$\Delta H = \Delta H_1 + \Delta H_2$ i.e., $\Delta H = -49 - 41 = -90$ KJ/mol.

Application of Hess's law:

According to Hess's law themodynamical equation can be added, substracted, multiplied and divided like ordinary algebric method, therefore Hess's law enables us to calculate the heat of formation, heat of reaction, etc in such cases where direct measurement are not possible.

Q.20 ***Describe heat of formation or enthalpy of a reaction.*** *Karachi Board: 2006-2011-2019*

Ans. It is defined as "Enthalpy change for a reaction in which one mole of compound is formed from its element."

It is denoted by ΔH_f

Example: $C + O_2 \longrightarrow CO_2$ $\Delta H_f = -394$ KJ/mol

Q.21 ***Define standard heat of formation ($\Delta H_F°$)*** *Karachi Board: 2010*

Ans. It is defined as "The enthalpy change for the reaction in which one mole of compound is formed from its element at their standard states (i.e when pressure is one atmosphere and temperature is 25°C.

It is denoted by $\Delta H_F°$

Example: $C + 2H_2 \longrightarrow CH_4$ $\Delta H_F° = -75$ KJ/mol

Differences

Q.01 ***What is the difference between the following:***

(i) Intensive Properties and Extensive Properties

(ii) Endothermic reaction and Endothermic reaction

Karachi Board: 2005, 2013, 2014

S. No.	*Intensive Properties*	*Extensive property*
1.	These properties are independent of quantity of matter.	These properties depend on quantity of matter.
2.	These are non-additive properties.	These are additive properties.
3.	The intensive property does not change if we divide the system. e.g., The boiling point of water will unchange i.e. 100°C at 1 atm.	The extensive properties becomes half when we divide the system into two equal parts. For example: If we divide 4 kg rice into two equal parts we get two packets of 2 kg rice.
4.	***Example:*** Density, pressure, viscosity surface tension, refractive index, melting point, boiling point etc.	***Example:*** Mass, volume, mole, enthalpy, entropy, internal energy, Gibbs free energy etc.

Karachi Board: 2010

S. No.	*Endothermic Reaction*	*Endothermic Reaction*
1.	Reactions during which heat in absorbed.	Reactions during which heat is evolved.
2.	The heat energy absorbed is represented by positive sign.	The heat energy evolved is represented by negative sign.
3.	During this reaction, temperature of the system rises to room temperature and heat is absorbed from surrounding.	During this reaction, temperature of the system falls to room temperature and heat is evolved to surroundings.
4.	The decomposition of water into oxygen and hydrogen is an endothermic reaction. $2H_2O \longrightarrow 2H_{2(g)} + O_2 \quad \Delta H = +ve$	The formation of water from O_2 and H_2 is an exothermic reaction. $H_{2(g)} + \frac{1}{2} O_{2(g)} \longrightarrow H_2O_{(g)} \quad \Delta H = -ve$

Solved problems of Textbook

Heat of Formation

Q.01 ***The heat of formation of CH_4 ($C + 2H_2$) is -74.9 KJ / mol. It can be calculated from the following data:***

(i)	$C_{(s)} + 2H_{2(g)}$	⟶	$CH_{4(g)}$	$\Delta H_{25°C}$ = ?
(ii)	$C_{(s)} + O_{2(g)}$	⟶	$CO_{2(g)}$	$\Delta H_{25°C}$ = -394 KJ / mol
(iii)	$H_{2(g)} + ½O_{2(g)}$	⟶	$H_2O_{(l)}$	$\Delta H_{25°C}$ = -286 KJ / mol
(iv)	$CH_{4(g)} + 2O_{2(g)}$	⟶	$CO_{2(g)} + 2H_2O_{(l)}$	$\Delta H_{25°C}$ = -890.34 KJ / mol

Solution:

In order to obtain the heat of formation of methane, multiply (iii) equation by 2 and add in equation (ii):

	$C_{(s)} + O_{2(g)}$	⟶	$CO_{2(g)}$	$\Delta H_{25°C}$ = - 394 KJ / mol
	$2H_{2(g)} + O_{2(g)}$	⟶	$2H_2O$	$\Delta H_{25°C}$ = - 572 KJ / mol
(+)	$C_{(s)} + 2H_{2(g)} + 2O_{2(g)}$	⟶	$CO_{2(g)} + 2H_2O_{(l)}$	$\Delta H_{25°C}$ = -966 KJ / mol ____ (v)

Finally subtracting equation (iv) from equation (v), we obtain:

	$C + 2H_2 + 2O_2$	⟶	$CO_2 + 2H_2O$	$\Delta H_{25°C}$ = -966 KJ / mol
	$-CH_4 + 2O_2$	⟶	$CO_2 + 2H_2O$	$\Delta H_{25°C}$ = -890 KJ / mol
(-)	$C + 2H_2$	⟶	CH_4	$\Delta H_{25°C}$ = -75.66 KJ / mol

This is the heat of formation of CH_4 which we can not measure directly.

Solved Problems From Past Papers

(Calculation of the heat of formation)

Problem 1: ***Calculate the heat of formation from the following data:*** *Karachi Board: 2013*

(i)	$2Na_{(s)} + ½\ O_{2(g)}$	⟶	$Na_2O_{(s)}$	ΔH = ?
(ii)	$Na_{(s)} + H_2O_{(l)}$	⟶	$NaOH_{(aq)} + ½\ H_{2(g)}$	ΔH = - 43.2 K cal / mol
(iii)	$Na_2O_{(s)} + H_2O_{(l)}$	⟶	$2NaOH_{(aq)}$	ΔH = - 63.2 K cal / mol
(iv)	$H_{2(g)} + ½\ O_{2(g)}$	⟶	H_2O	ΔH = - 68.0 K cal / mol

Solution :

Multiply equation (ii) by '2' then add in equation (iv)

$2Na + 2H_2O \longrightarrow 2NaOH + H_2$ $\quad \Delta H = -86.4$ Kcal/mol

$H_2 + \frac{1}{2} O_2 \longrightarrow H_2O$ $\quad \Delta H = -68.0$ Kcal/mol

(+) $2Na + H_2O + \frac{1}{2} O_2 \longrightarrow 2NaOH$ $\quad \Delta H = -154.4$ Kcal/mol ____ (v)

Now subtracting eq (iii) from equation (v):

$2Na + H_2O + \frac{1}{2} O_2 \longrightarrow 2NaOH$ $\quad \Delta H = -154.4$ Kcal/mol

$Na_2O + H_2O \longrightarrow 2NaOH$ $\quad \Delta H = -63.2$ Kcal/mol

(-) $2Na + \frac{1}{2} O_2 \longrightarrow Na_2O$ $\quad \Delta H = -91.2$ Kcal/mol

Ans. Heat of formation of Na_2O is $\quad \Delta H = -91.2$ Kcal/mol

Problem 2: ***Calculate ΔH for the reaction:*** ***Karachi Board: 2012***

$3Mg + N_2 \longrightarrow Mg_3N_2 \qquad H = ?$

Given: ***(i)*** $3Mg + 2NH_3 \longrightarrow Mg_3N_2 + 3H_2 \qquad \Delta H = -371$ KJ/mol

(ii) $\frac{1}{2} N_2 + 3/2\, H_2 \longrightarrow NH_3 \qquad \Delta H = -46$ KJ/mol

Solution:

Multiply equation (2) by 2 and then add in equation (1):

$2\left(\frac{1}{2} N_2 + \frac{3}{2} H_2 \longrightarrow NH_3\right)$ $\quad \Delta H = -46$ KJ)

$N_2 + 3H_2 \longrightarrow 2NH_3$ $\quad \Delta H = -92$ KJ

$N_2 + 3H_2 \longrightarrow 2NH_3$ $\quad \Delta H = -92$ KJ

$3Mg + 2NH_3 \longrightarrow Mg_3N_2 + 3H_2$ $\quad \Delta H = -371$ KJ

$3Mg + N_2 \longrightarrow Mg_3N_2$

$\therefore \Delta H = -463$ KJ **Ans.**

Problem 3: ***Calculate the standard heat of formation of the methyl alcohol from its elements from the following data:*** ***Karachi Board: 2010***

(i) $C_{(s)} + 2H_{2(g)} + \frac{1}{2} O_{2(g)} \longrightarrow CH_3OH_{(l)} \qquad \Delta H_f = ?$

(ii) $C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)} \qquad \Delta H_1 = -394$ KJ/mol

(iii) $H_{2(g)} + \frac{1}{2} O_{2(g)} \longrightarrow H_2O_{(l)} \qquad \Delta H_2 = -286$ KJ/mol

(iv) $CH_3OH_{(l)} + \frac{3}{2} O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(l)} \qquad \Delta H_3 = -726$ KJ/mol

Solution:

Multiply equation (iii) by 2 and invert equation (4):

$2H_2 + O_2 \longrightarrow 2H_2O$ $\quad \Delta H_4 = -572$ KJ/mol ..... (v)

$CO_2 + 2H_2O \longrightarrow CH_3OH + \frac{3}{2} O_2$ $\quad \Delta H_5 = -726$ KJ/mol ..... (vi)

Now add eq (ii), eq. (v) and eq (vi):

$C + O_2 \longrightarrow CO_2$ $\quad \Delta H = -394$ KJ/mol

$2H_2 + O_2 \longrightarrow 2H_2O$ $\quad \Delta H = -572$ KJ/mol

$CO_2 + 2H_2O \longrightarrow CH_3OH + \frac{3}{2} O_2$ $\quad \Delta H = +726$ KJ/mol

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$C + 2H_2 + 2O_2 \longrightarrow CH_3OH + \frac{3}{2} O_2$ $\quad \Delta H = +240$ KJ/mol

$C + 2H_2 + \frac{1}{2} O_2 \longrightarrow CH_3OH$ $\quad \Delta H_f = -240$ KJ/mol

Problem 4: ***Calculate the heat of formation of propane (C_3H_8) from the given reaction:***

$3C_{(s)} + 4H_{2(g)} \longrightarrow C_3H_{8(g)}$ $\quad \Delta H_f = ?$

(i) $C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$ $\quad \Delta H = -394$ KJ / mol

(ii) $H_{2(g)} + \frac{1}{2} O_{2(g)} \longrightarrow H_2O_{(l)}$ $\quad \Delta H = -286$ KJ / mol

(iii) $C_3H_{8(g)} + 5O_2 \longrightarrow 3CO_2 + 4H_2O$ $\quad \Delta H = -2200$ KJ / mol

Solution:

Multiply eq. (i) by 3, eq. (ii) by 4 and reverse eq. (iii) and then add all the three equations:

$3C + 3O_2 \longrightarrow 3CO_2$ $\quad \Delta H = -1182$ KJ/mol

$4H_2 + 2O_2 \longrightarrow 4H_2O$ $\quad \Delta H = -1144$ KJ/mol

$3CO_2 + 4H_2O \longrightarrow C_3H_8 + 5O_2$ $\quad \Delta H = +2200$ KJ/mol

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$3C + 4H_2 \longrightarrow C_3H_8$ $\quad \Delta H_f = -126$ KJ/mol

Problem 5: ***Calculate the heat of formation of N_2O_4 from the following data:***

(i) $2NO_2 \longrightarrow N_2O_4$ $\quad \Delta H_f = ?$

(ii) $\frac{1}{2} N_2 + O_2 \longrightarrow NO_2$ $\quad \Delta H_f = +33.95$ KJ / mol

(iii) $N_2 + 2O_2 \longrightarrow N_2O_4$ $\quad \Delta H_f = +9.3$ KJ / mol

Solution: ***Karachi Board: 2008***

Multiply eq (ii) by 2 and inverse it: $2NO_2 \longrightarrow 2O_2 + N_2$ $\quad \Delta H_f = -67.90$ KJ/mol .... (iv)

Add eq (iii) and eq (iv):

$2NO_2 \longrightarrow 2O_2 + N_2$ $\quad \Delta H_f = -67.90$ KJ/mol

$N_2 + 2O_2 \longrightarrow N_2O_4$ $\quad \Delta H_f = +9.3$ KJ/mol

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$2NO_2 \longrightarrow N_2O_4$ $\quad \Delta H_f = -58.6$ KJ/mol

Problem 6: ***Calculate the heat of formation of ethane (C_2H_6) at 25°C from the following data:***

Karachi Board: 2007, 2018

(i) $2C + 3H_2 \longrightarrow C_2H_6$ $\quad \Delta H_f = ?$

(ii) $C + O_2 \longrightarrow CO_2$ $\quad \Delta H = -393$ KJ / mol

(iii) $H_2 + \frac{1}{2} O_2 \longrightarrow H_2O$ $\quad \Delta H_f = -286$ KJ / mol

(iv) $C_2H_6 + \frac{7}{2} O_2 \longrightarrow 2CO_2 + 3H_2O$ $\quad \Delta H_f = -1560$ KJ / mol

Solution:

Multiply equation (ii) by 2:

$2C + 2O_2 \longrightarrow 2CO_2$ $\quad \Delta H = -788\ KJ/mol$ ..... (v)

Multiply equation (iii) by 3:

$3H_2 + \frac{3}{2} O_2 \longrightarrow 3H_2O$ $\quad \Delta H = -858\ KJ/mol$ ..... (vi)

Adding equation (v) and (vi) we get:

$2C + 3H_2 + \frac{7}{2} O_2 \longrightarrow 2CO_2 + 3H_2O$ $\quad \Delta H = -1646\ KJ/mol$ ..... (vii)

Now reserve the equation no. (iv):

$2CO_2 + 3H_2O \longrightarrow C_2H_6 + \frac{7}{2} O_2$ $\quad \Delta H = +1560\ KJ/mol$

By adding equation (vii) and (viii) we get:

$2C + 3H_2 + \frac{7}{2} O_2 \longrightarrow 2CO_2 + 3H_2O$ $\quad \Delta H = -1646\ KJ/mol$

$2CO_2 + 3H_2O \longrightarrow C_2H_6 + \frac{7}{2} O_2$ $\quad \Delta H = 1560.60\ KJ/mol$

$2C + 3H_2 \longrightarrow C_2H_6$ $\quad \Delta H_f = -85.36\ KJ/mol$

Result: Heat of formation of ethane is $\Delta H_f = -85.36\ KJ/mol$

Problem 7: ***Calculate the heat of formation of (C_2H_5OH) from the following reaction:***

(i) $C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$ $\quad \Delta H = -1367\ KJ\ mol^{-1}$

(ii) $C + O_2 \longrightarrow CO_2$ $\quad \Delta H = -393.7\ KJ\ mol^{-1}$

(iii) $H_2 + \frac{1}{2} O_2 \longrightarrow H_2O$ $\quad \Delta H = -285.80\ KJ\ mol^{-1}$

To calculate ΔH for the following equation:

$2C + 3H_2 + \frac{1}{2} O_2 \longrightarrow C_2H_5OH$ $\quad \Delta H = ?$

Solution: ***Karachi Board: 2008***

Multiply equation (ii) by 2 and equation (iii) by 3 and then add both of them:

$2C + 2O_2 \longrightarrow 2CO_2$ $\quad \Delta H = -787.4\ KJ/mol$

$3H_2 + \frac{3}{2} O_2 \longrightarrow 3H_2O$ $\quad \Delta H = -857.4\ KJ/mol$

(+) $2C + 3H_2 + \frac{7}{2} O_2 \longrightarrow 2CO_2 + 3H_2O$ $\quad \Delta H = -1644.8\ KJ/mol$ ..... (iv)

Now subtract equation (i) from equation (iv):

$2C + 3H_2 + \frac{7}{2} O_2 \longrightarrow 2CO_2 + 3H_2O$ $\quad \Delta H = -1644.8\ KJ/mol$

$C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$ $\quad \Delta H = -1367.0\ KJ/mol$

$2C + 3H_2 + \frac{1}{2} O_2 \longrightarrow C_2H_5OH$ $\quad \Delta H = -277.8\ KJ/mol$

Result: $\Delta H_f = -277.8\ KJ/mol$

Problem 8: ***Calculate the Heat of formation of Fe_2O_3 at 25° C:*** ***Karachi Board: 2019***

(i) $2Fe + \frac{3}{2} O_2 \longrightarrow Fe_2O_3$ $\quad \Delta H_f = ?$

(ii) $H_2 + \frac{1}{2} O_2 \longrightarrow H_2O$ $\quad \Delta H = -286\ KJ/mole$

(iii) $Fe_2O_3 + 3H_2O \longrightarrow 2Fe(OH)_3$ $\quad \Delta H = +289\ KJ/mole$

(iv) $Fe + 3H_2O \longrightarrow Fe(OH)_3 + \frac{3}{2} H_2$ $\quad \Delta H = +161\ KJ/mole$

Solution:

(i) $H_2 + \frac{1}{2} O_2 \longrightarrow H_2O$ $\Delta H = -286$kj/mole

(ii) $Fe_2O_3 + 3H_2O \longrightarrow 2Fe(OH)_3$ $\Delta H = +289$kj/mole

(iii) $Fe + 3H_2O \longrightarrow Fe(OH)_3 + \frac{3}{2} H_2$ $\Delta H = +161$kj/mole

Muliplyig equation (i) by 3 and equation (iii) by 2, we get:

(iv) $3H_2 + \frac{3}{2} O_2 \longrightarrow 3H_2O$ $\Delta H = -858$kj/mole

(v) $2Fe + 6H_2O \longrightarrow 2Fe(OH)_3 + 3H_2$ $\Delta H = +323$kj/mole

Re-arranging equation (ii):

(vi) $2Fe(OH)_3 \longrightarrow Fe_2O_3 + 3H_2O$ $\Delta H = -289$kj/mole

Now, adding equation (iv), (v) and (vi), we get:

$3H_2 + \frac{3}{2} O_2 \longrightarrow 3H_2O$ $\Delta H = -858$ kj/mole

$2Fe + 6H_2O \longrightarrow 2Fe(OH)_3 + 3H_2$ $\Delta H = +323$ kj/mole

$2Fe(OH)_3 \longrightarrow Fe_2O_3 + 3H_2O$ $\Delta H = -289$ kj/mole

(vii) $2Fe + \frac{3}{2} O_2 \longrightarrow Fe_2O_3$ $\Delta H = -824$kj/mole

Problem 9: ***Calculate the heat of formation from the following data:*** ***Karachi Board: 2014***

$4AX_3 + 5Y_2 \longrightarrow 4AY + 6X_2Y$ $\Delta H_f = ?$

$\frac{1}{2} A_2 + \frac{3}{2} X_2 \longrightarrow AX_3$ $\Delta H = -11.0$ KJ / mole

$X_2 + \frac{1}{2} Y_2 \longrightarrow X_2Y$ $\Delta H = 57.8$ KJ / mole

$\frac{1}{2} A_2 + \frac{1}{2} Y_2 \longrightarrow AY$ $\Delta H = 21.6$ KJ / mole

Solution:

$4AX_3 - 5Y_2 \longrightarrow 4AY + 6X_2Y$ $\Delta H_f = ?$

$\frac{1}{2} A_2 + \frac{3}{2} X_2 \longrightarrow AX_3$ $\Delta H = -11.0$ KJ / mole ..... (i)

$X_2 + \frac{1}{2} Y_2 \longrightarrow X_2Y$ $\Delta H = 57.8$ KJ / mole ..... (ii)

$\frac{1}{2} A_2 + \frac{1}{2} Y_2 \longrightarrow AY$ $\Delta H = 21.6$ KJ / mole ..... (iii)

Multiply equation (i) by 4, we get:

$2A_2 + 6X_2 \longrightarrow 4AX_3$ $\Delta H = -44.0$ KJ / mole ..... (iv)

Multiply equation (ii) by 6, we get:

$6X_2 + 3Y_2 \longrightarrow 6X_2Y$ $\Delta H = -346.8$ KJ / mole ..... (v)

Multiply equation (iii) by 4, we get:

$2A_2 + 2Y_2 \longrightarrow 4AY$ $\Delta H = +86.4$ KJ / mole ..... (vi)

Adding equation (v) and (vi):

$6X_2 + 3Y_2 \longrightarrow 6X_2Y$ $\Delta H = -346.8$ KJ / mole

$2A_2 + 2Y_2 \longrightarrow 4AY$ $\Delta H = +86.4$ KJ / mole

$6X_2 + 2A_2 + 5Y_2 \longrightarrow 6X_2Y + 4AY$ $\Delta H = -260.4$ KJ / mole ..... (vii)

Subtract equation (vi) from equation (vii):

$6X_2 + 2A_2 + 5Y_2 \longrightarrow 6X_2Y + 4AY$ $\Delta H = -260.4$ KJ / mole

$\pm 2A_2 \pm 6X_2 \longrightarrow \pm 4AX_3$ $\Delta H = \mp 44.0$ KJ / mole

$5Y_2 + 4AX_3 \longrightarrow 6X_2Y + 4AY$ $\Delta H = -216.4$ KJ / mole **Ans.**

Problem 10: *Calculate the heat of formation of CH_3OH from following data:*

$C + 2H_2 + \frac{1}{2} O_2$	⟶	CH_3OH	ΔH_f = ?
$C + \frac{1}{2} O_2$	⟶	CO	ΔH_f = -111 KJ / mole
$H_2 + \frac{1}{2} O_2$	⟶	H_2O	ΔH_f = 286 KJ / mole
$CH_3OH + O_2$	⟶	$CO + 2H_2O$	ΔH_f = 561 KJ / mole

Solution: *Karachi Board: 2015*

$C + 2H_2 + \frac{1}{2} O_2$	⟶	CH_3OH	ΔH_f = ?
$C + \frac{1}{2} O_2$	⟶	CO	ΔH_f = -111 KJ / mole ..... (i)
$H_2 + \frac{1}{2} O_2$	⟶	H_2O	ΔH_f = -286 KJ / mole ..... (ii)
$CH_3OH + O_2$	⟶	$CO + 2H_2O$	ΔH_f = -561 KJ / mole ..... (iii)

Multiply equation (ii) by 2, we get:

$2H_2 + O_2$	⟶	H_2O	ΔH_f = -572 KJ / mole ..... (iv)

Adding equation (iv) and (i):

$2H_2 + O_2$	⟶	H_2O	ΔH_f = -572 KJ / mole
$C + \frac{1}{2} O_2$	⟶	CO	ΔH_f = -111 KJ / mole ..... (i)
$2H_2 + C + \frac{3}{2} O_2$	⟶	$CO + 2H_2O$	ΔH_f = -683 KJ / mole ..... (v)

Reverse equation (iii) and adding equation (v):

$CO + 2H_2O$	⟶	$CH_3OH + O_2$	ΔH_f = -561 KJ / mole
$2H_2 + C + \frac{3}{2} O_2$	⟶	$CO + 2H_2O$	ΔH_f = -683 KJ / mole
$C + 2H_2 + \frac{1}{2} O_2$	⟶	CH_3OH	ΔH_f = -122 KJ / mole **Ans.**

Problem 11: *Calculate the heat of formation of M_2A at 25°C.* *Karachi Board: 2016*

$2M + \frac{1}{2} A_2$	⟶	M_2A	ΔH_f = ?
$M + Y_2A$	⟶	$MAY + \frac{1}{2} Y_2$	ΔH_f = -43.2 KJ / mole
$Y_2 + \frac{1}{2} A_2$	⟶	Y_2A	ΔH_f = -68.5 KJ / mole
$M_2A + Y_2A$	⟶	$2MAY$	ΔH_f = -63.2 KJ / mole

Solution:

$M + Y_2A$	⟶	$MAY + \frac{1}{2} Y_2$	ΔH_f = -43.2 KJ / mole ..... (i)
$Y_2 + \frac{1}{2} A_2$	⟶	Y_2A	ΔH_f = -68.5 KJ / mole ..... (ii)
$M_2A + Y_2A$	⟶	$2MAY$	ΔH_f = -63.2 KJ / mole ..... (iii)

Multiplying equation (i) by 2, we get,

$2M + 2Y_2A$	⟶	$2MAY + Y_2$	ΔH_f = -86.4 KJ / mole ..... (iv)

Reverse equation (iii):

$2MAY$	⟶	$M_2A + Y_2A$	ΔH_f = -63.2 KJ / mole ..... (v)

Adding equation (iv), (v) and (ii):

$2M + 2Y_2A \longrightarrow 2MAY + Y_2$ $\quad \Delta H_f = -86.4$ KJ / mole

$2MAY \longrightarrow M_2A + Y_2A$ $\quad \Delta H_f = -63.2$ KJ / mole

$Y_2 + \frac{1}{2} A_2 \longrightarrow Y_2A$ $\quad \Delta H_f = -68.5$ KJ / mole

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$2M + \frac{1}{2} A_2 \longrightarrow M_2A$ $\quad \Delta H_f = -91.7$ KJ / mole **Ans.**

Problem 12: ***Calculate the heat of formation of benzene at 25°C :***

(i) $6C_{(s)} + 3H_{2(g)} \longrightarrow C_6H_{6(l)}$ $\quad \Delta H_f = ?$

(ii) $C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$ $\quad \Delta H = -394$ KJ

(iii) $H_{2(g)} + \frac{1}{2} O_{2(g)} \longrightarrow H_2O_{(l)}$ $\quad \Delta H = -286$ KJ

(iv) $C_6H_{6(l)} + \frac{15}{2} O_{2(g)} \longrightarrow 6CO_{2(g)} + 3H_2O_{(l)}$ $\quad \Delta H = -3267$ KJ

Solution: ***Karachi Board: 2017***

$6C + 3H_2 \longrightarrow C_6H_6$ $\quad \Delta H_f = ?$

(i) $C + O_2 \longrightarrow CO_2$ $\quad \Delta H = -394$ KJ / mole

(ii) $H_2 + \frac{1}{2} O_2 \longrightarrow H_2O$ $\quad \Delta H = -286$ KJ / mole

(iii) $C_6H_6 + \frac{15}{2} O_2 \longrightarrow 6CO_2 + 3H_2O$ $\quad \Delta H = -3267$ KJ / mole

Multiply equation No. (i) by 6, equation No. (ii) by 3 and reverse equation No. (iii) and add all of these.

$6C + 6O_2 \longrightarrow 6CO_2$ $\quad \Delta H = -2364$ KJ / mole

$3H_2 + \frac{3}{2} O_2 \longrightarrow 3H_2O$ $\quad \Delta H = -858$ KJ / mole

$6CO_2 + 3H_2O \longrightarrow C_6H_6 + \frac{15}{2} O_2$ $\quad \Delta H = 3267$ KJ / mole

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$6C + 3H_2 \longrightarrow C_6H_6$ $\quad \Delta H_f = 45$ KJ / mole

Calculation of Change in Energy

Problem 13: ***When 5400 joules of heat is added to a system of gas at constant pressure, its internal energy increases by 1000 joules. Calculate the change in the volume of the system.*** ***Karachi Board: 2013***

Solution:

Data:

$q = 5400$ joules (at constant pressure)

$\Delta E = 1000$ joules

$\Delta V = ?$

We know that

$$q = \Delta E + P\Delta V$$
$$5400 = 1000 + (1)\Delta V$$
$$\Delta V = 5400 - 1000$$
$$\Delta V = 4400$$ **Ans.**

Problem 14: ***A system absorbs 2000 J of heat from the surrounding and does 1200 J of work on the surrounding by expansion. Find the internal energy change (ΔE) of the system.*** ***Karachi Board: 2012***

Solution:

Data:

$q = 2000\ J$
$W = 1200\ J$
$\Delta E = ?$

Calculation:

$$q = \Delta E + \Delta W$$
$$\Delta E = q - W$$
$$\Delta E = 2000 - 1200$$
$$\Delta E = 800\ J$$ **Ans.**

Problem 15: ***A system absorbs 200J of heat from the surroundings and does 120 J of work on the surrounding by expansion. Find the internal energy of the system.*** ***Karachi Board: 2011***

Solution:

Data:

$q = 200$ joules
$W = 120$ joules
$\Delta E = ?$
$$q = \Delta E + P\Delta V$$
$$\Delta E = q - W$$
$$\Delta E = 200 - 120$$
$$\Delta E = 80\ J$$ **Ans.**

Problem 16: ***600 J of heat was given to a gas at $1.01\times10^5\ N/m^2$ pressure. The internal energy was increased by 300 J. Find the increase in volume.*** ***Karachi Board: 2011***

Solution:

Data:

Pressure = P = $1.01\times10^5\ N/m^2$
$\Delta E = 300\ J$
Heat absorbed = q = $600\ J$
$\Delta V = ?$

Calculation:

$$\Delta E = q - P\Delta V \quad \text{(The first law of thermodynamics)}$$

$$P\Delta V = q - \Delta E$$

$$\Delta V = \frac{q - \Delta E}{P}$$

$$\Delta V = \frac{600\ J - 300\ J}{1.01 \times 10^5\ N/m^2}$$

$$\Delta V = 2.97 \times 10^{-3}\ m^3 \quad \textbf{Ans.}$$

Problem 17: ***800 J work is done on a system which gives 500 J of heat. What is the value of ΔE for the process.*** ***Karachi Board: 2011***

Solution:

Data:

$q = 500\ J$
$W = 800\ J$
$\Delta E = ?$

Calculation:

As work is done on the system with the evolution of heat, hence q has negative sign. Then the equation will be:

$$\Delta E = q - W \quad \text{(The first law of thermodynamics)}$$

Here:

$$\Delta E = -q - (-W)$$
$$\Delta E = -q + W$$
$$\Delta E = -500 + 800$$
$$\Delta E = 300\ J \quad \textbf{Ans.}$$

Problem 18: ***If 1500 calories of heat are added to a system, while system does the work equivalent to 2500 calories by expanding against the surrounding. Find the value of ΔE for the system.*** ***Karachi Board: 2005***

Solution:

Data:

$q = 1500$ joules
$W = 2500$ cals
$\Delta E = ?$

Calculation:

According to first law of thermodynamics

$$\Delta E = q - W$$
$$\Delta E = q - (+W)$$
$$\Delta E = 1500 - 2500 = -1000\ cals$$

Result: The value of $\Delta E = -1000$ cals. **Ans.**

Problem 19: ***In a certain process 848 J of heat is absorbed by a system, while 394 J of work is done on the system. What is the change in the internal energy of the process?***

Karachi Board: 2004

Solution:

Data:

$q = 848$ joules

$W = -394$ J

$\Delta E = ?$

Formula used:

$\Delta E = q - (-W)$

$\Delta E = q + W$

$\Delta E = 848 + 394$

$\Delta E = 1242$

Result: The change in the internal energy = 1242 J **Ans.**

Problem 20: ***When 4000 J of heat is added to a gaseous system at a constant pressure of 101300 N/m², its internal energy increases by 500 J. Calculate the change in the volume of the system.***

Karachi Board: 2015

Solution:

Data:

$q = 4000$ J

$P = 1.013 \times 10^5$ N/m²

$\Delta E = 500$ J

$\Delta V = ?$

We know that:

$$\Delta E = q - P\Delta V$$

$$500 = 4000 - (1.013 \times 10^5)\ \Delta V$$

$$500 - 4000 = -(1.013 \times 10^5)\ \Delta V$$

$$-3500 = -(1.013 \times 10^5)\ \Delta V$$

$$\Delta V = \frac{3500}{1.013 \times 10^5}$$

$$\Delta V = 3.455 \times 10^{-2}\ m^3$$ **Ans.**

Solution of Textbook Progress Test - 5

Q.01 ***What do you understand by the terms system, surroundings and states? Illustrate with one example.***

Ans. See Q 9 on page 175 and Q 12 on page 176.

Q.02 ***(a) What are intensive and extensive properties of a system?***

Ans. See Q 11 on page 175.

(b) Catagorize the following properties of a system into extensive and intensive properties. Free energy, vapour pressure, temperature, surface tension, mass, internal energy, melting point.

Ans. See Q 11 (examples) on page 175.

Q.03 ***State the first law of thermodynamics and also give its mathematical statement, $\Delta E = q - W$.***

Ans. See Q 13 on page 176.

Q.04 ***(a) State and explain Hess's law of constant heat summation. Give its application.***

Ans. See Q 19 on page 178.

(b) Calculate the heat of formation of acetic acid from the following data:

$2C + 2H_2 + O_2$	$\longrightarrow$	CH_3COOH	ΔH_f = ?
$C + O_2$	$\longrightarrow$	CO_2	ΔH = -394 KJ/mol
$H_2 + \frac{1}{2} O_2$	$\longrightarrow$	H_2O	ΔH = -286 KJ/mol
$CH_3COOH + 2O_2$	$\longrightarrow$	$2CO_2 + 2H_2O$	ΔH = -870.8 KJ/mol

Ans. See Problem 8 on page 184.

Q.05 ***(a) Define and explain the terms:***
(i) Exothermic process (ii) Endothermic process (iii) Heat of formation.

Ans. See Q 6 on page 174 and Q 7 on page 175 and Q 21 on page 179.

(b) ***Calculate the heat of formation of Ethane at 25°C from the following data:***

(i)	$2C + 3H_2$	⟶	C_2H_6	$\Delta H_f = ?$
(ii)	$C + O_2$	⟶	CO_2	$\Delta H = -393\ KJ/mol$
(iii)	$H_2 + \frac{1}{2} O_2$	⟶	H_2O	$\Delta H_f = -286\ KJ/mol$
(iv)	$C_2H_6 + \frac{7}{2} O_2$	⟶	$2CO_2 + 3H_2O$	$\Delta H_f = -1560.6\ KJ/mol$

Ans. see problem 6 on page 183.

Q.06 **(a)** ***Show that the product of pressure and volume, PV has the dimension of energy.***

Ans. See Q 13 on page 176.

(b) ***In a certain process 848 J of heat is absorbed by a system, while 394 J of work done on the system. What is the change in the internal energy for the process?***

Ans. See problem 19 on page 190.

Q.07 **(a)** ***If 1800 cals of heat is added to a system while system does work equivalent to 2800 cals by expanding against the surrounding. What is the value of ΔE for the system?***

Ans. **Data:**

q = 1800 cals
W = 2800 cals
ΔE = ?

Formula: According to the first law of thermodynamics:

ΔE = q - W
ΔE = 1800 - 2800
ΔE = - 1000 cals **Ans.**

(b) ***In a certain process, 500 J of work is done on a system which gives off 200 J of heat, What is the value of ΔE for the process?***

Ans. **Data:**

q = 200 J
W = 500 J
ΔE = ?

Formula: According to the first law of thermodynamics:

ΔE = q - W

As work is done on the system with the evolution of heat, q and W have negative sign. Then the above equation will be:

ΔE = (- q) - (- W)
ΔE = - q + W
ΔE = - 200 + 500
ΔE = 300 J **Ans.**