



CHEMISTRY

BOOKS - SURA CHEMISTRY (TAMIL ENGLISH)

THERMODYNAMICS

Evaluation

1. The amount of heat exchanged with the surrounding at constant pressure is given by the quantity.

A. ΔE

B. ΔH

C. ΔS

D. ΔG

Answer: B



[Watch Video Solution](#)

2. All the naturally occurring processes proceed spontaneously in a direction which leads to

- A. decrease in entropy
- B. increase in enthalpy
- C. increase in free energy
- D. decrease in free energy

Answer: D



[Watch Video Solution](#)

3. In an adiabatic process, which of the following is true ?

- A. $q = w$
- B. $q = 0$

C. $\Delta E = q$

D. $P\Delta V = 0$

Answer: B



[Watch Video Solution](#)

4. In a reversible process, the change in entropy of the universe is

A. > 0

B. ≥ 0

C. < 0

D. $= 0$

Answer: D



[Watch Video Solution](#)

5. In an adiabatic expansion of an ideal gas

A. $w = -\Delta u$

B. $w = \Delta u + \Delta H$

C. $\Delta u = 0$

D. $w = 0$

Answer: A



[Watch Video Solution](#)

6.is an intensive property .

A. mass

B. volume

C. enthalpy

D. $\frac{\text{mass}}{\text{volume}}$

Answer: D



[Watch Video Solution](#)

7. An ideal gas expands from the volume of $1 \times 10^{-3} m^3$ to $1 \times 10^{-2} m^3$ at $300K$ against a constant pressure at $1 \times 10^5 Nm^{-2}$. The work done is

A. $-900J$

B. $900kJ$

C. $270kJ$

D. $-900kJ$

Answer: A



[Watch Video Solution](#)

8. Heat of combustion is always

A. positive

B. negative

C. zero

D. either positive or negative

Answer: B

 [Watch Video Solution](#)

9. The heat of formation of CO and CO_2 are $-26.4kCal$ and $-94kCal$, respectively. Heat of combustion of carbon monoxide will be

A. $+26.4kcal$

B. $-67.6kcal$

C. $-120.6kcal$

D. $+52.8kcal$

Answer: B

 [Watch Video Solution](#)

10. $C(\text{diamond}) \rightarrow C(\text{graphite}), \Delta H = -ve$, this indicates that

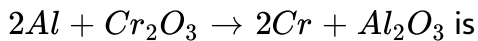
- A. graphite is more stable than diamond
- B. graphite has more energy than diamond
- C. both are equally stable
- D. stability cannot be predicted

Answer: A

 [Watch Video Solution](#)

11. The enthalpies of formation of Al_2O_3 and Cr_2O_3 are $-1596kJ$ and $-1134kJ$, respectively.

ΔH for the reaction.



A. $-1365kJ$

B. 2730 kJ

C. $-2730kJ$

D. $-462kJ$

Answer: D



[Watch Video Solution](#)

12. Which of the following is not a thermodynamic function?

A. internal energy

B. enthalpy

C. entropy

D. frictional energy

Answer: D

 [Watch Video Solution](#)

13. If one mole of ammonia and one mole of hydrogen chloride are mixed in a closed container to form ammonium chloride gas, then

A. $\Delta H > \Delta U$

B. $\Delta H - \Delta U = 0$

C. $\Delta H + \Delta U = 0$

D. $\Delta H < \Delta U$

Answer: D

 [Watch Video Solution](#)

14. Change in internal energy, when 4kJ of work is done on the system and 1 kJ of heat is given out by the system is

A. $+1kJ$

B. $-5kJ$

C. $+3kJ$

D. $-3kJ$

Answer: C

 [Watch Video Solution](#)

15. The work done by the liberated gas when 55.85 g of iron ($molar\ 55.85\text{g}\text{mol}^{-1}$) reacts with hydrochloric acid in an open beaker at 25°C

A. $-2.48kJ$

B. $-2.22kJ$

C. $+2.22kJ$

D. $+2.48kJ$

Answer: A

 [Watch Video Solution](#)

16. The value of ΔH for cooling 2 moles of an ideal monoatomic gas from $125^\circ C$ to $225^\circ C$ at constant pressure will be [given $C_P = \frac{5}{2}R$] _____

A. $-250R$

B. $-500R$

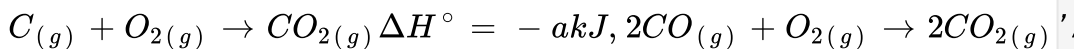
C. $500R$

D. $+250R$

Answer: B

 [Watch Video Solution](#)

17. _____ Given _____ that



=-b kJ, Calculate the ΔH° for the reaction $C_{(g)} + 1/2O_{2(g)} \rightarrow CO_{(g)}$

A. $\frac{b + 2a}{2}$

B. $2a - b$

C. $\frac{2a - b}{2}$

D. $\frac{b - 2a}{2}$

Answer: D



Watch Video Solution

18. When 15.68 litres of a gas mixture of methane and propane are fully combusted at $0^\circ C$ and 1 atmosphere, 32 litres of oxygen at the same temperature and pressure are consumed. The amount of heat released from this combustion in kJ is ($\Delta H_C(CH_4) = -890 \text{ kJ mol}^{-1}$ and $\Delta H_C(C_3H_8) = -2220 \text{ kJ mol}^{-1}$)

A. -889 kJ mol^{-1}

B. $-1390 \text{ kJ mol}^{-1}$

C. -3180KJmol^{-1}

D. -635.47KJmol^{-1}

Answer: D

 [Watch Video Solution](#)

19. The bond dissociation energy of methane and ethane are 360 kJ mol^{-1} and 620 kJ mol^{-1} respectively. Then, the bond dissociation energy of C-C bond is _____

A. 170KJmol^{-1}

B. 50KJmol^{-1}

C. 80KJmol^{-1}

D. 220KJmol^{-1}

Answer: C

 [Watch Video Solution](#)

20. The correct thermodynamic conditions for the spontaneous reaction at all temperature is ____

A. $\Delta H < 0$ and $\Delta S > 0$

B. $\Delta H < 0$ and $\Delta S < 0$

C. $\Delta H > 0$ and $\Delta S = 0$

D. $\Delta H > 0$ and $\Delta S > 0$

Answer: A



[Watch Video Solution](#)

21. The temperature of the system, decreases in an_____.

A. Isothermal expansion

B. Isothermal Compression

C. adiabatic expansion

D. adiabatic compression

Answer: C



[Watch Video Solution](#)

22. In isothermal ideal gas compression

A. +, -, -

B. -, +, -

C. +, -, +

D. -, -, +

Answer: D



[Watch Video Solution](#)

23. Molar heat of vapourisation of a liquid is 4.8kJmol^{-1} . If the entropy change is $16\text{Jmol}^{-1}\text{K}^{-1}$, the boiling point of the liquid is

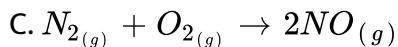
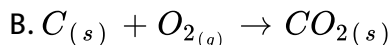
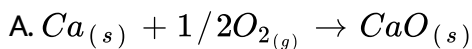
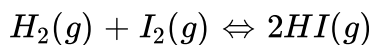
- A. 323 K
- B. 27°C
- C. 164 K
- D. 0.3K

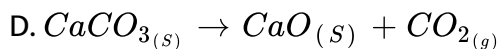
Answer: B



Watch Video Solution

24. Do you expect ΔS to be +ve, -ve, or zero for the reaction





Answer: D

 [Watch Video Solution](#)

25. The values of ΔH and ΔS for a reaction are respectively 30 kJ mol^{-1} and $100 \text{ KJ}^{-1} \text{ mol}^{-1}$. Then the temperature above which the reaction will become spontaneous is ____

A. 300 K

B. 30 K

C. 100 K

D. 200 C

Answer: A

 [Watch Video Solution](#)

ii Write Brief Answer To The Following Questions

1. State the first law of thermodynamics.

 [Watch Video Solution](#)

2. Define Hess's law of constant heat summation.

 [Watch Video Solution](#)

3. Hess's law states,

 [Watch Video Solution](#)

4. Explain intensive properties with two examples .

 [Watch Video Solution](#)

5. In an isothermal process



[Watch Video Solution](#)

6. ADIABATIC PROCESS



[Watch Video Solution](#)

7. Define the following terms :

isobaric process



[Watch Video Solution](#)

8. Define the following terms :

isochoric process



[Watch Video Solution](#)

9. what is the usual definition of entropy ? What is the unit of entropy ?

 [Watch Video Solution](#)

10. Predict the sign of ΔG for the reaction at a very low temperature for which ΔH is +ve and ΔS is positive.

 [Watch Video Solution](#)

11. Predict the feasibility of a reaction when

(i) both ΔH and ΔS positive

 [Watch Video Solution](#)

12. Predict the feasibility of a reaction when

(i) both ΔH and ΔS positive

 [Watch Video Solution](#)

13. Define Gibb's free energy .

 [Watch Video Solution](#)

14. Define enthalpy of combustion.

 [Watch Video Solution](#)

15. The molar heat capacity of water is

 [Watch Video Solution](#)

16. Define the calorific value of food. What is the unit of calorific value?

 [Watch Video Solution](#)

17. Enthalpy of neutralization of H_3PO_3 with $NaOH$ is -106.68 kJ/mol . If enthalpy of neutralization of HCl with $NaOH$ is -55.84 kJ/mole , then calculate enthalpy of ionization of H_3PO_3 in to its ions in kJ .

 [Watch Video Solution](#)

18. What is lattice energy?

 [Watch Video Solution](#)

19. Give two examples which are path dependent quantities. Are they properties of the system ?

 [Watch Video Solution](#)

20. State Kelvin- Planck statement of second law of thermodynamics.

 [Watch Video Solution](#)

21. The equilibrium constant of a reaction is 10, what will be the sign of ΔG ? Will this reaction be the sign of ΔG ? Will this reaction be spontaneous ?

 [Watch Video Solution](#)

22. Enthalpy of neutralization is always a constant when a strong acid is neutralized by a strong base: account for the statement.

 [Watch Video Solution](#)

23. a) State the third law of thermodynamics. B) Define entropy.

 [Watch Video Solution](#)

24. Write down the Born-Haber cycle for the formation of $CaCl_2$

 [Watch Video Solution](#)

25. Identify the state and path functions out of the following a) Enthalpy
b) Entropy c) Heat d) Temperature e) Work f) Free energy.

 [Watch Video Solution](#)

26. State the various statements of second law of thermodynamics.

 [Watch Video Solution](#)

27. The condition for spontaneity of process is

 [Watch Video Solution](#)

28. List the characteristics of internal energy.

 [Watch Video Solution](#)

29. Explain how heat absorbed at constant pressure is measured using coffee calorimeter with neat diagram.

 [Watch Video Solution](#)

30. Calculate the work involved in expansion and compression process.

 [Watch Video Solution](#)

31. Give the relation between ΔU and ΔH .

 [Watch Video Solution](#)

32. Suggest and explain an indirect method to calculate lattice enthalpy of sodium chloride crystal.

 [Watch Video Solution](#)

33. List the characteristics of Gibbs free energy.

 [Watch Video Solution](#)

34. Calculate the work done when 2 moles of an ideal gas expands reversibly and isothermally from a volume of 500 ml to a volume of 2L at $25^{\circ}C$ and normal pressure.

 [Watch Video Solution](#)

35. In a constant volume calorimeter, 3.5g of a gas with molecular weight 28 was burnt in excess oxygen at 298.0K. The temperature of the

calorimeter was found to increase from $298.0K \rightarrow 298.45K$ due to the combustion process. Given that the heat capacity of the calorimeter is $2.5kJK^{-1}$, find the numerical value for the enthalpy of combustion of the gas in $kJmol^{-1}$

 [Watch Video Solution](#)

36. Calculate the entropy change in the system , and surroundings , and the total entropy changes in the universe during a process in which 245 J of heat flow out of the system $77^{\circ}C$ to the surrounding at $30^{\circ}C$.

 [Watch Video Solution](#)

37. 1 mole of an ideal gas, maintained at 4.1 atm and at a certain temperature , absorbs heat 3710 J and expands to 2 litres . Calculate the entropy changes in expansion process.

 [Watch Video Solution](#)

38. 30.4 KJ is required to melt one mole of sodium chloride . The entropy change during melting is $28.4JK^{-1}mol^{-1}$.Calculate the melting point of sodium chloride .

 [Watch Video Solution](#)

39. Calculate the standard heat of formation of propane, if its heat of combustion is $-2220.2 \text{ kJ mol}^{-1}$, the heats of formation of $CO_{2(g)}$ and $H_2O_{(l)}$ are -393.5 and $-285.8 \text{ kJ mol}^{-1}$ respectively.

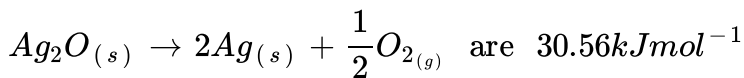
 [Watch Video Solution](#)

40. you are given normal boiling points and standard enthalpies of vapourisation . Calculate the entropy of vapourisation of liquids listed below.



 [View Text Solution](#)

41. ΔH and ΔS for the reaction



and $66.0Jk^{-1}mol^{-1}$ respectively. Calculate the temperature at which the free energy for this reaction will be zero. What will be the direction of reaction at this temperature and at temperature below this and why?

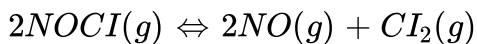
$$\text{Given: } \Delta H = 30.56kJmol^{-1} = 30560Jmol^{-1}$$

$$\Delta S = 66.0JK^{-1}mol^{-1}$$

$$\Delta G = 0$$

 [Watch Video Solution](#)

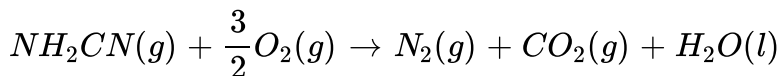
42. What is the equilibrium constant K_c for the following reaction at 400K?



$$\Delta H^\ominus = 77.2kJmol^{-1} \text{ and } \Delta S^\ominus = 122JK^{-1}mol^{-1} \text{ at } 400K.$$

 [Watch Video Solution](#)

43. The reaction of cyanamide, $NH_2CN(s)$, with dioxygen was carried out in a bomb calorimeter, and ΔU was found to be $-742.7kJmol^{-1}$ at $298K$. Calculate enthalpy change for the reaction at $298K$.

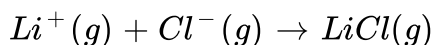


 [Watch Video Solution](#)

44. Calculate the enthalpy of hydrogenation of ethylene from the following data. Bond energies of C-H , C-C , C=C and H-H are 414,347,618 and 435 $kJ mol^{-1}$.

 [Watch Video Solution](#)

45. Calculate lattice energy for the change,



Given that

$$\Delta H_{\text{sublimation}} \text{ of } Li = 160.67kJmol^{-1},$$

$$\Delta H_{\text{ionisation}} \text{ of } Li(g) = 520.07kJmol^{-1},$$

$$\Delta H_f \text{ of } LiCl(s) = -401.66kJmol^{-1},$$

$$\Delta H_{\text{Dissociation}} \text{ of } Cl_2 = 244.$$

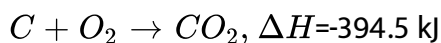
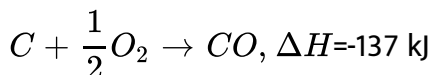
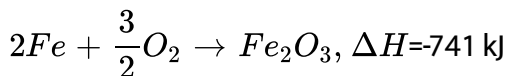
$$\Delta H_{E.A} \text{ of } Cl(g) = -365.$$



Watch Video Solution

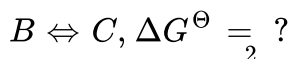
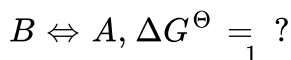
46. Calculate the enthalpy change for the reaction

$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$ from the following data.



Watch Video Solution

47. When 1-pentyne (*A*) is treated with 4*N* alcoholic *KOH* at 175°C, it is slowly converted into an equilibrium mixture of 1.3% of 1-pentyne (*A*), 95.2% 2-pentyne (*B*) and 3.5% of 1,2-pentadiene (*C*). The equilibrium was maintained at 175°C. Calculate ΔG^\ominus for the following equilibria:



From the calculated value of ΔG^\ominus_1 and ΔG^\ominus_2 , indicate the order of stability of A , B and C .

 [Watch Video Solution](#)

48. At 33K, N_2O_4 is fifty percent dissociated. Calculate the standard free energy change at this temperature and at one atmosphere.

 [Watch Video Solution](#)

49. The standard enthalpies of formation of SO_2 and SO_3 are -297 kJ mol^{-1} and -396 kJ mol^{-1} respectively. Calculate the standard enthalpy of reaction for the reaction: $SO_2 + 1/2O_2 \rightarrow SO_3$

 [Watch Video Solution](#)

50. For the reaction at 298K



$$\Delta H = 400 \text{ kJ mol}^{-1} \text{ and } \Delta S = 0.2 \text{ kJ K}^{-1} \text{ mol}^{-1}$$

At what temperature will the reaction becomes spontaneous considering ΔH and ΔS to be constant over the temperature range.

 [Watch Video Solution](#)

51. Find out the value of equilibrium constant for the following reaction at 298 K.



Standard Gibbs energy change, $\Delta_r G^\ominus$ at the given temperature is $-13.6 \text{ kJ mol}^{-1}$

 [Watch Video Solution](#)

52. A gas mixture of 3.67 L of ethylene and methane on complete combustion at 25°C produces 6.11 L of CO₂. Find out the heat evolved on burning 1 L of the gas mixture. The heats of combustion of ethylene and methane are -1423 and -891 kJ mol^{-1} , respectively, at 25°C.

 [Watch Video Solution](#)

Additional Questions

1. Which of the following is an extensive property?

- A. Molar Volume
- B. Molality
- C. Gibbs free energy
- D. Free energy change

Answer: C



Watch Video Solution

2. The molar heat of sublimation is equal to

- A. sum of molar heats of fusion and vaporization

B. molar heat of vaporization

C. molar heat of fusion

D. molar heat of neutralization

Answer: A



Watch Video Solution

3. An ideal gas occupying volume of $2dm^3$ and a pressure of 5 bar undergoes isothermal and irreversible expansion against external pressure of 1 bar. The final volume of the system and the work involved in the process is

A. $-2.303nRT \log\left(\frac{V_f}{V_i}\right)$

B. $2.303nRT \log\left(\frac{V_f}{V_i}\right)$

C. $-\int_{V_i}^{V_f} V dV$

D. $\left(\frac{\Delta V}{\Delta T}\right)$

Answer: B

 [Watch Video Solution](#)

4. Statement-1: In a mixture containing Br^- and I^- , violet colour (of I_2) appears first in chloroform layer, when chlorine gas is passed through the mixture dissolves in water.

Statement-2: The order of the strength of reducing properties is as follows $I^- > Br^- > Cl^- > F^-$.

A. 1,3,4

B. 4 only

C. 1,2,3

D. 2 and 3

Answer: A

 [Watch Video Solution](#)

5. The initial and final temperature of a heat engine are $816^{\circ}C$ and $21^{\circ}C$ respectively . The percentage efficiency is

A. 73 %

B. 23 %

C. 45 %

D. 37 %

Answer: A



[Watch Video Solution](#)

6. The branch of science which deals the relation between energy , heat , work and accompanying changes around us is 'called '

A. Thermodynamics

B. Chemical kinetics

C. Calorimetry

D. Potentiometer

Answer: A



[Watch Video Solution](#)

7. The first law of thermodynamics is not adequate in predicting the direction of a process. (*True/False*)

A. reversibility

B. rate

C. spontaneity

D. none of these

Answer: C



[Watch Video Solution](#)

8. A portion of matter under consideration, which is separated from rest of universe by real or imaginary boundaries is called

- A. surroundings
- B. system
- C. boundary
- D. Universe

Answer: B

 [Watch Video Solution](#)

9. An example of closed system is :

- A. Solution of $CuSO_4$ in a beaker
- B. A gas contained in a cylinder fitted with piston
- C. Hot water contained in a thermos flask
- D. Tea in a cup

Answer: B



[Watch Video Solution](#)

10. For an adiabatic process

A. $q = 0$

B. $dP = 0$

C. $dT = 0$

D. $dP = 0$

Answer: D



[Watch Video Solution](#)

11. A process in which volume remains constant is called

A. isobaric

B. cyclic

C. isothermal

D. isochoric

Answer: D



Watch Video Solution

12. Internal energy is denoted by the symbol

A. H

B. S

C. G

D. U

Answer: D



Watch Video Solution

13. Which of the following is an extensive property?

- A. Volume
- B. Internal energy
- C. Mass
- D. Temperature

Answer: D



[Watch Video Solution](#)

14. Which of the following is an intensive property?

- A. free energy
- B. heat capacity
- C. volume
- D. molar volume

Answer: D

 [Watch Video Solution](#)

15. All the naturally occurring processes proceed spontaneously in a direction which leads to

- A. reversible
- B. irreversible
- C. cyclic process
- D. isochoric process

Answer: D

 [Watch Video Solution](#)

16. The process in which no heat enters or leaves the system is termed as

A. isothermal

B. isobaric

C. isochoric

D. adiabatic

Answer: D



Watch Video Solution

17. The process in which temperature of the system remains constant is called Process

A. isobaric

B. isothermal

C. adiabatic

D. isochoric

Answer: B

 [Watch Video Solution](#)

18. For an isothermal process

A. $q = 0$

B. $dV = 0$

C. $dT = 0$

D. $dP = 0$

Answer: C

 [Watch Video Solution](#)

19. Which among the following is not a state function?

A. Pressure

B. volume

C. Temperature

D. Work

Answer: D



[Watch Video Solution](#)

20. ISOCHORIC PROCESS

A. w

B. $q + w$

C. q

D. 0

Answer: C



[Watch Video Solution](#)

21. Which one of the following is a state function?

- A. Pressure
- B. Enthalpy
- C. Heat
- D. Both (a) and (b)

Answer: D

 [Watch Video Solution](#)

22. Which of the following is a path function

- A. Enthalpy
- B. Free energy
- C. Internal energy
- D. Work

Answer: D

 [Watch Video Solution](#)

23. CYCLIC PROCESS

- A. maximum
- B. minimum
- C. zero
- D. does not change

Answer: C



Watch Video Solution

24. SI unit of heat is

- A. Joule
- B. Calorie
- C. mole

D. $Jmol^{-1}$

Answer: A



[Watch Video Solution](#)

25. If the heat flows out of the system into the surrounding, the q value becomes

A. $+Ve$

B. $-Ve$

C. equal to zero

D. maximum

Answer: B



[Watch Video Solution](#)

26. $1\text{KJ} = \dots\dots\dots\text{J}$

A. 1000

B. 100

C. 10

D. 10000

Answer: A



[Watch Video Solution](#)

27. The gravitational work done by an object is

A. Qv

B. fx

C. PV

D. mgh

Answer: D



Watch Video Solution

28. In a compression process, P_{ext} is

A. $(P_{\text{int}} + dP)$

B. $(P_{\text{int}} - dP)$

C. $(dP - P_{\text{int}})$

D. $(-P_{\text{int}} + dP)$

Answer: A



View Text Solution

29. In an isothermal process for an ideal gas

A. $\Delta U = qV$

B. $\Delta U = w$

C. $\Delta U = q + w$

D. $\Delta U = 0$

Answer: D

 [Watch Video Solution](#)

30. Explain extensive and intensive properties.

A. entropy, enthalpy

B. entropy, temperature

C. enthalpy, entropy

D. temperature ,entropy

Answer: B

 [Watch Video Solution](#)

31. Which of the following is a state function ?

A. q

B. w

C. $q + w$

D. All of these

Answer: C

 [Watch Video Solution](#)

32. For the reaction $PCl_{5(g)} \rightarrow PCl_{3(g)} + Cl_{2(g)}$

A. $\Delta H > \Delta U$

B. $\Delta H < \Delta U$

C. $\Delta H = \Delta U$

D. Un predictable

Answer: A



Watch Video Solution

33. Pick out true statements (s)

(i) q and w are path functions

(ii) $q + w$ is a state function

A. Only (i)

B. Only (ii)

C. Both (i) and (ii)

D. Both are incorrect statements

Answer: C



View Text Solution

34. Identify the suitable conditions (s) which helps the adiabatic process to occur ?

(i) $\Delta T = 0$ (ii) $\Delta P = 0$

(iii) $q = 0$ (iv) $w = 0$

A. Only (i)

B. Only (iii)

C. (i) and (ii)

D. (i) , (ii) and (iv)

Answer: B



Watch Video Solution

35.is an intensive property .

A. internal energy

B. volume

C. temperature

D. mass

Answer: C

 [Watch Video Solution](#)

36. State the first law of thermodynamics .

A. spontaneity

B. feasibility

C. both (a) & (b)

D. neither (a) nor (b)

Answer: C

 [Watch Video Solution](#)

37. ΔH° of $H_2O_{(l)}$ is KJ/mol.

A. -74.85

B. $+281$

C. $+242$

D. $+74.85$

Answer: B



[Watch Video Solution](#)

38. Heat of combustion of methane is KJ/ mol .

A. -87.78

B. $+87.78$

C. -394.55

D. $+394.55$

Answer: A



View Text Solution

39. The SI unit of Molar heat capacity is :

A. J mol^{-1}

B. KJ mol^{-1}

C. $\text{KJ}^{-1}\text{mol}^{-1}$

D. JK^{-1}

Answer: C



Watch Video Solution

40. Molar heat capacity at constant volume is

A. $\left(\frac{dH}{dT}\right)_V$

B. $\left(\frac{dU}{dT}\right)_V$

C. $\left(\frac{dq}{dT}\right)_V$

D. $\left(\frac{dV}{dT}\right)_V$

Answer: B



Watch Video Solution

41. The relation between C_P and C_V is

A. $C_P = C_V - R$

B. $C_P + C_V = R$

C. $C_P - C_V = R$

D. $C_V = C_P - R$

Answer: C



Watch Video Solution

42. The branch of science associated with determining the changes in energy of a system by measuring the heat exchanges with surrounding is called

- A. Mechanics
- B. aerodynamics
- C. Kinetics
- D. Thermodynamics

Answer: B

 [View Text Solution](#)

43. Heat absorbed at constant volume is measured in Calorimeter.

- A. Coffee cup
- B. Differential scanning
- C. Bomb

D. Adiabatic

Answer: C



[Watch Video Solution](#)

44. For an exothermic reaction ΔH_r value will be

A. $+Ve$

B. $-Ve$

C. Zero

D. infinity

Answer: B



[Watch Video Solution](#)

45. The heat of neutralisation of strong acid and strong base is

A. $+57.32\text{KJ}$

B. $+75.32\text{KJ}$

C. -75.32KJ

D. -57.32KJ

Answer: D

 [View Text Solution](#)

46. The SI unit of entropy is

A. JK

B. JK^{-1}

C. KJK^{-1}

D. KJ/mole

Answer: B

 [Watch Video Solution](#)

47. The change in enthalpy when one mole of C_{diamond} to C_{graphite} is called

- A. Molar heat of vaporisation
- B. Molar heat of sublimation
- C. Molar heat of transition
- D. Molar heat of fusion

Answer: C



[View Text Solution](#)

48. Hess's law can be applied to calculateof reactions.

- A. enthalpy
- B. entropy
- C. free energy

D. internal energy

Answer: A



[Watch Video Solution](#)

49. Change in enthalpy is

A. Heat absorbed at constant pressure

B. The total energy change at constant pressure and temperature

C. Equal to change in internal energy at constant volume

D. All the above

Answer: A



[View Text Solution](#)

50. The change in enthalpy of

$NaOH + HCl \rightarrow NaCl + H_2O$ is called

- A. Heat of reaction
- B. Heat of neutralization
- C. Heat of formation
- D. Heat of liquid

Answer: B



[View Text Solution](#)

51. % efficiency can be calculated using the formula

- A. $\frac{\text{output}}{\text{input}}$
- B. $\frac{\text{input}}{\text{output}} \times 100$
- C. $\frac{\text{input}}{\text{output}}$
- D. $\frac{\text{output}}{\text{input}} \times 100$

Answer: D

 [Watch Video Solution](#)

52. If an automobile engine burns petrol at a temperature of $816^{\circ}C$ and if surrounding temperature is $21^{\circ}C$, what is its maximum percentage ?

A. 37 %

B. 73 %

C. 83 %

D. 33 %

Answer: B

 [Watch Video Solution](#)

53. which of the following processes are accompanied by an increase of entropy .

(i) Dissolution of iodine in solvent

(ii) HCl added to $AgNO_3$ solution and precipitate of AgCl is obtained

(iii) A partition is removed to allow two gases to mix.

A. (i) & (ii)

B. (ii) & (iii)

C. (i) & (iii)

D. all the above

Answer: C



[View Text Solution](#)

54. The enthalpies of all elements in their standard states are _____

A. 1

B. 0

C. < 0

D. different for each elements

Answer: B



[Watch Video Solution](#)

55. A reaction , $A + B \rightarrow C + D + q$ is found to have a positive entropy change . The reaction will be

- A. Possible at high temperature
- B. Possible only at low temperature
- C. Not possible at any temperature
- D. Possible at any temperature

Answer: D



[Watch Video Solution](#)

56. Thermodynamics does not deal with

- A. the feasibility of a chemical reaction
- B. energy changes involved in chemical reaction
- C. the extent to which a chemical reaction process
- D. the rate at which a reaction occurs

Answer: D



[View Text Solution](#)

57. Which of the following statement is /are correct ?

- (i) The presence of reacting species in a covered beaker is an example of open system.
- (ii) There is an exchange of energy as well as matter between system and the surroundings in a closed system.
- (iii) The presence of reactants in a closed vessel is an example of closed system.

(iv) The presence of reactants in a thermos flask is an example of closed system.

- A. (ii) &(iii)
- B. (ii) alone
- C. (iii) alone
- D. (i),(ii) & (iv)

Answer: C



View Text Solution

58. When water freezes in a glass beaker , ΔS of the system

- A. $\Delta S > 0$
- B. $\Delta S < 0$
- C. $\Delta S = 0$
- D. $\Delta S \geq 0$

Answer: B

 [Watch Video Solution](#)

59. What is correct about ΔG ?

- A. It is zero for reversible reaction
- B. It is positive for spontaneous reactions
- C. It is negative for non-spontaneous reactions
- D. It is zero for non-spontaneous reactions

Answer: A

 [Watch Video Solution](#)

60. ΔG° of reversible reaction at its equilibrium is

- A. positive

B. negative

C. Always zero

D. Both (a) & (b)

Answer: C



Watch Video Solution

61. In an exothermic reaction, heat is evolved and system loses heat to the surroundings . For such system.

(i) q_p will be negative (ii) $\Delta_r H$ will be positive

(iii) q_p will be positive

(iv) $\Delta_r H$ will be negative

A. (i) , (ii)

B. (iii), (iv)

C. (i) &(iv)

D. (ii) & (iii)

Answer: C



View Text Solution

62. In an endothermic reaction , the value of ΔH is always

A. = 0

B. > 0

C. < 0

D. constant

Answer: B



Watch Video Solution

63. Statement I : Combustion of all organic compounds is exothermic in nature.

Statement II : The enthalpies of all elements in their standard states are zero.

- A. Both the statement are individually true but statement II is not the correct explanations of I.
- B. Both the statement are individually true and statement II is the correct explanations of I.
- C. Statement I is true but II is false.
- D. Statement I is false but II is true.

Answer: A



[Watch Video Solution](#)

64. For a given reaction ΔG obtained was having positive sign convention . State whether the reaction was spontaneous or non-spontaneous.

- A. spontaneous

B. non- spontaneous

C. reversible

D. equilibrium

Answer: B

 [Watch Video Solution](#)

65. Pick out the suitable condition in which a spontaneous endothermic reaction occurs.

A. $\Delta G > 0$

B. $\Delta G < 0$

C. $\Delta G = 0$

D. ΔG may be + ve or - ve

Answer: B

 [Watch Video Solution](#)

66. Statement I : Flow of heat from colder of hotter object is spontaneous.

Statement II : entropy is a measure of randomness or disorderliness of the system .

- A. Both the statement are individually true but statement II is not the correct explanations of I.
- B. Both the statement are individually true and statement II is the correct explanations of I.
- C. Statement I is true but II is false.
- D. Statement I is false but II is true.

Answer: D



[Watch Video Solution](#)

67. Which is true about cyclic process ?

A. $\Delta U = 0, \Delta H = 0$

B. $\Delta U < 0, \Delta H < 0$

C. $\Delta H = 0, \Delta U < 0$

D. $\Delta U = 0, \Delta H < 0$

Answer: A



Watch Video Solution

68. The standard free energy change ΔG° is related to k (equilibrium constant) as

A. $\Delta G^\circ = Rt \log k$

B. $\Delta G^\circ = Rt \log k$

C. $\Delta G^\circ = -2.303RT \log k$

D. $\Delta G^\circ = 2.303RT \log k$

Answer: C

 [Watch Video Solution](#)

69. The enthalpy and entropy change for a chemical reaction are -5.3×10^3 cal and 4.7 cal K^{-1} respectively . Predict the nature of the reaction at 298 k.

- A. Non feasible
- B. Reversible
- C. Non - spontaneous
- D. Spontaneous

Answer: D

 [View Text Solution](#)

70. This quantity is the energy associated with a chemical that can be used to do work is

- A. entropy
- B. enthalpy
- C. Internal energy
- D. Free energy change

Answer: D

 [View Text Solution](#)

71. Identify the incorrect statement among the following .

- A. Entropy $ds = dq_{\text{rev}}/T$
- B. ΔS is maximum for a reversible process
- C. Entropy is a measure of randomness
- D. Entropy of pure crystal is zero

Answer: B

 [View Text Solution](#)

72. Hot water contained in a closed beaker is an example for a System.

- A. Closed
- B. Open
- C. Isolated
- D. Isothermal

Answer: A



[Watch Video Solution](#)

73. Which of the following does not result in an increase in the entropy ?

- A. Crystallisation of sucrose from solution
- B. rusting of iron
- C. conversion of ice to water

D. Vapourisation of camphor

Answer: A



Watch Video Solution

74. The condition for standard free energy is

A. 298 K , 1 atm

B. 273 K , 1 atm

C. 298° C, 5 atm

D. 25 K, 1 atm

Answer: A



Watch Video Solution

75.

Solve

:

$\Delta H = 10k \text{ cal mol}^{-1}$, $\Delta S = 20 \text{ cal deg}^{-1} \text{ mol}^{-1}$ and $T = 300k$. Then

A. $-18,000 \text{ cal mol}^{-1}$

B. $18,000 \text{ cal mol}^{-1}$

C. $-16,000 \text{ cal mol}^{-1}$

D. $4,000 \text{ cal mol}^{-1}$

Answer: D



[Watch Video Solution](#)

76. Consider the following statement(s) and identify the true statement(s) with respect to entropy .

(s) with respect to entropy .

(i) The SI unit of entropy is JK^{-1}

(ii) For a reversible process $\Delta S_{\text{universe}} = 0$

A. Only (i)

B. Only (iii)

C. Both (i) and (ii)

D. (i) , (ii) and (iii)

Answer: D



View Text Solution

77. Assertion : $3H_{2(g)} + N_{2(g)} \rightarrow 2NH_{3(g)}$ is exothermic.

Reason : The process passes into equilibrium state when $\Delta G_{T,P}$ becomes zero.

- A. Both assertion and reason are true and reason is the correct explanation of the assertion
- B. Both assertion and reason are true and reason is not the correct explanation of the assertion
- C. Assertion is true but reason are false
- D. Both assertion and reason are false.

Answer: B



[View Text Solution](#)

78. Assertion : Enthalpy of neutralisation of 1 equivalent each of HCl and H_2SO_4 with NaOH is same

Reason : Enthalpy of neutralisation is always the heat evolved when 1 mole acid is neutralised by a base.

- A. Both assertion and reason are true and reason is the correct explanation of the assertion
- B. Both assertion and reason are true and reason is not the correct explanation of the assertion
- C. Assertion is true but reason are false
- D. Both assertion and reason are false.

Answer: C



[Watch Video Solution](#)

79. Which laws can be used to predict whether a particle reaction is feasible or not under a given set of conditions ?

- A. Chemical Kinetics
- B. Thermodynamics
- C. Chemical Equilibrium
- D. a & c

Answer: B



[View Text Solution](#)

80. Which of the following is incorrect ?

- A. The process in which the system and surrounding can be restored to the initial state from the final state without producing any charges

in the thermodynamic properties of the universe is called a reversible process.

B. There are two important conditions for the reversible process to occur.

C. The process should occur infinitesimally fastly

D. All the above are incorrect.

Answer: D



[View Text Solution](#)

81. In which process there is no exchange of heat between the system and surrounding during the process ?

A. Reversible process

B. Irreversible process

C. Adiabatic process

D. Cyclic process

Answer: C



Watch Video Solution

82. The internal energy of a system is Property andfunction.

A. Intensive , state

B. Extensive path

C. Intensive , path

D. Extensive state

Answer: D



View Text Solution

83. Which thermodynamic law used in thermometers ?

- A. Zeroth law of thermodynamics
- B. First law of thermodynamics
- C. Second law of thermodynamics
- D. Third law of thermodynamics

Answer: A

 [Watch Video Solution](#)

84. A thermo chemical equation is a balancedchemical equation that includes the enthalpy change.

- A. Stoichiometric
- B. Thermodynamic
- C. Kinetics
- D. Mechanics

Answer: A

 [View Text Solution](#)

85. The enthalpy change of combustion reaction are always

- A. positive
- B. negative
- C. neutral
- D. zero

Answer: B

 [Watch Video Solution](#)

86. The system would required heat to effect a given temperature rise than at constant volume .

- A. less
- B. more

C. small

D. lower

Answer: B



[View Text Solution](#)

87. Absolute zero is a temperature that an object can get arbitrarily close to but will remain unattainable.

A. absolute zero

B. temperature

C. pressure

D. volume

Answer: A



[View Text Solution](#)

1. Given the relation between enthalpy (H) and internal energy (U).

 [View Text Solution](#)

2. Calculate ΔH_f^0 for the reactions.

$CO_{2(g)} + H_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(g)}$ given that ΔH_f^0 for $CO_{2(g)}$, $CO_{(g)}$ respectively .

 [View Text Solution](#)

3. Which law of thermodynamics deals with equivalence of different forms of energies?

 [Watch Video Solution](#)

4. One mole of an ideal gas is put through a series of changes as shown below in a cyclic process. Name the process $A \rightarrow B$, $B \rightarrow C$ and $C \rightarrow A$.

 [View Text Solution](#)

5. For a reaction $2Cl_{(g)} \rightarrow Cl_2$ What are the signs of ΔH and ΔS ?

 [View Text Solution](#)

6. Define the following terms.

 [View Text Solution](#)

7. Define the term thermodynamics process .

 [View Text Solution](#)

8. State zeroth law of thermodynamics.

 [View Text Solution](#)

9. Predict the change in internal energy for an isolated system at constant volume.

 [View Text Solution](#)

10. One mole of a gaseous system absorbs 100 J of heat and does work equivalent to 50 . J . Calculate the change in the internal energy of the system.

 [Watch Video Solution](#)

11. Bring out the difference between extensive and intensive properties.

 [View Text Solution](#)

12. Distinguish the thermodynamic process depending upon heat absorbed or evolved in the overall process.

 [View Text Solution](#)

13. Answer the following questions with respect to I law of thermodynamics.

- (i) State the law
- (ii) Give its mathematical expression
- (iii) List out its limitations

 [View Text Solution](#)

14. Segregated the following as open , closed or isolated systems.

- (i) Tiger
- (ii) The earth
- (iii) Tea in a thermos flask

(iv) Tin in a carbonated drink

(v) Helium filled balloon.

(vi) Ice cube tray filled with water.



[View Text Solution](#)

15. Identify processes under the following conditions

(i) $dt = 0$ (ii) $dP = 0$ (iii) $dV = 0$



[View Text Solution](#)

16. Identify the steps involved in the following cyclic process .

Temperature at A , B and F is T_1 , and at C, D and E is T_2 Given $T_1 > T_2$



[View Text Solution](#)

17. Define standard heat of formation .

 [View Text Solution](#)

18. Give the application of Hess's law.

 [View Text Solution](#)

19. Heat is considered as a path function, but in an endothermic process , the heat absorbed by the system under certain specific conditions is independent of path. What are those conditions ?

 [View Text Solution](#)

20. Give the relation between ΔU and ΔH .

 [Watch Video Solution](#)

21. Define enthalpy .

 [View Text Solution](#)

22. Define standard enthalpy changes .

 [View Text Solution](#)

23. Application of the heat of combustion ?

 [View Text Solution](#)

24. Define the following.

- (a) Molar Heat of fusion
- (b) Molar Heat of vapourisation
- (c) Molar Heat of sublimation
- (d) Heat of Transition

 [View Text Solution](#)

25. What are the applications of Bomb Calorimeter?

 [Watch Video Solution](#)

26. For an isolated system, $\Delta U = 0$ What will be ΔS ?

 [View Text Solution](#)

27. What happens to work when

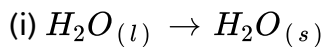
- (i) gas expands against external pressure
- (ii) gas is compressed
- (iii) gas expands into vacuum
- (iv) an ideal gas expands reversibly and isothermally.

 [View Text Solution](#)

28. What information is observed from positive, zero and negative volumes of change in entropy?

 [View Text Solution](#)

29. Consider the following changes in the physical state of water and state whether orderliness has increased or decreased and consequently predict the direction of entropy of the system.



(ii) Steam \rightarrow water

 [View Text Solution](#)

30. what is the need for second Law of thermodynamics.

 [View Text Solution](#)

31. Define standard entropy change.

 [View Text Solution](#)

32. Define entropy of transition.

 [Watch Video Solution](#)

33. What is entropy of Vaporization?

 [Watch Video Solution](#)

34. Define entropy of transition.

 [Watch Video Solution](#)

35. What are spontaneous process ?

 [View Text Solution](#)

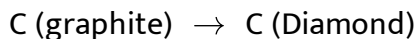
36. Predict the sign of entropy change in each of the following:

A liquid crystallises into solid.



[View Text Solution](#)

37. Predict the sign of entropy change in each of the following:



[View Text Solution](#)

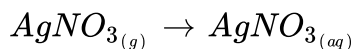
38. Predict the sign of entropy change in each of the following:

Temperature of perfectly crystalline solid is raised from 0 K to 115 K.



[View Text Solution](#)

39. Predict the sign of entropy change in each of the following:



[View Text Solution](#)

40. what is the nature of the reaction for the following ?

$$\Delta G > 0$$

 [View Text Solution](#)

41. what is the nature of the reaction for the following ?

$$\Delta G < 0$$

 [View Text Solution](#)

42. what is the nature of the reaction for the following ?

$$\Delta G = 0$$

 [View Text Solution](#)

43. Explain the relationship between free energy and equilibrium constant.

 [View Text Solution](#)

44. How does entropy vary when external pressure is less than internal pressure of the gaseous system ?

 [View Text Solution](#)

45. Give one example for spontaneous combustion.

 [Watch Video Solution](#)

46. Why C_p is always greater than C_v ?

 [View Text Solution](#)

[Additional Long Answers](#)

1. Write a short note on the following terms.

Open System



[View Text Solution](#)

2. Write a short note on the following terms.

Closed System



[View Text Solution](#)

3. Write a short note on the following terms.

Isolated System



[View Text Solution](#)

4. Write a short note on the following terms.

Homogeneous System





[View Text Solution](#)

5. Write a short note on the following terms.

Heterogeneous System



[View Text Solution](#)

6. State and five ways of enunciating the first law of thermodynamics.



[View Text Solution](#)

7. Discuss in detail about the variation of internal energy with respect to variation thermodynamic processes.



[View Text Solution](#)

8. Write down the conventions that are followed while framing a thermochemical equations.

 [View Text Solution](#)

9. The enthalpy of combustion for H_2 , C_{graphite} and CH_4 are -285.8 , -39.5 and $-890.4 \text{ kJ mol}^{-1}$ respectively. Calculate the standard enthalpy of formation ΔH_f^0 for CH_4

 [View Text Solution](#)

10. Calculate the lattice energy of $MgBr_2$ from the given data

 [View Text Solution](#)

11. Example The measurement of heat change at constant pressure with a neat diagram.

[View Text Solution](#)

12. What is meant by reversible and irreversible processes ?

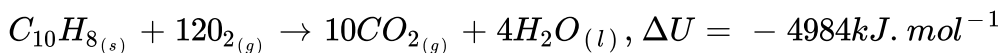
[Watch Video Solution](#)

Numerical Problems

1. The entropy change in the conversion of water to ice at 272 k for the system is $-22.88JK^{-1}mol^{-1}$ and that of surrounding is $+24.85JK^{-1}mol^{-1}$ State whether the process is spontaneous or not ?

[Watch Video Solution](#)

2. The heat of combustion of solid naphthalene. ($C_{10}H_{10}$) at constant volume was $-4984kJmol^{-1}$ at 298K. Calculate the value of enthalpy change. Given:



$$\Delta U = -4984 \text{ kJ mol}^{-1}, R = 8.314 \text{ JK}^{-1} \text{ mol}^{-1}$$

$$T = 298 \text{ K}$$

 [Watch Video Solution](#)

3. Calculate the standard entropy of formation ΔS_f° of $\text{CO}_{2(g)}$. Given the standard entropies of $\text{CO}_{2(g)}$, $\text{C}_{(s)}$, $\text{O}_{2(g)}$ as 218.8, 8.740 and 205.60 J K^{-1} respectively.

 [Watch Video Solution](#)

4. The standard heat of formation of $\text{H}_2\text{O}_{(l)}$ from its elements H_2 and O_2 is $-290.83 \text{ kJ mol}^{-1}$ and the standard entropy change for the same reaction is -330 JK^{-1} at 25°C . Will the reaction be spontaneous at 25°C .

$$\text{Given: } \Delta H^\circ = -290.83 \text{ kJ mol}^{-1}$$

$$= -290830 \text{ J mol}^{-1}$$

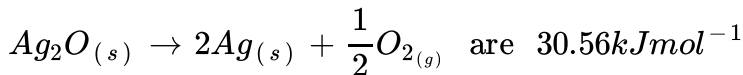
$$\Delta S^\circ = -330 \text{ JK}^{-1}$$

$$T = 25^\circ \text{C} = 298 \text{ K}$$



Watch Video Solution

5. ΔH and ΔS for the reaction



and $66.0 \text{ J K}^{-1} \text{ mol}^{-1}$ respectively. Calculate the temperature at which the free energy for this reaction will be zero. What will be the direction of reaction at this temperature and at temperature below this and why?

$$\text{Given: } \Delta H = 30.56 \text{ kJ mol}^{-1} = 30560 \text{ J mol}^{-1}$$

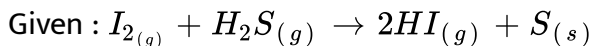
$$\Delta S = 66.0 \text{ J K}^{-1} \text{ mol}^{-1}$$

$$\Delta G = 0$$



Watch Video Solution

6. will the reaction, $I_{2(g)} + H_2S_{(g)} \rightarrow 2HI_{(g)} + S_{(s)}$ proceed spontaneously in the forward direction at 298K? You are given with ΔG° for HI and H_2S as 1.8 and $-33.8 \text{ kJ mol}^{-1}$ respectively.



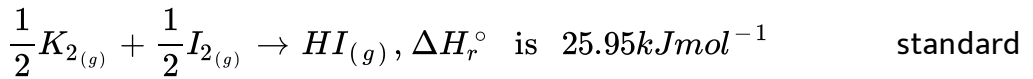
$$\Delta G_{HI}^{\circ} = 1.8kJmol^{-1}$$

$$\Delta G_{H_2S}^{\circ} = 1.8kJmol^{-1}$$

 [Watch Video Solution](#)

7. Calculate the standard free energy change (ΔG°) of the following

reaction and say whether it is feasible at 373 K or not



entropies of $HI_{(g)}, H_{2(g)}$ and $I_{2(g)}$ are

$$206.3, 140.6 \text{ and } 118.7JK^{-1}mol^{-1}$$

$$\text{Given } S_{I_2}^{\circ} = 118.7JK^{-1}mol^{-1}, S_{HI}^{\circ} = 206.3JK^{-1}$$

$$mol^{-1}, S_{H_2}^{\circ} = 140.6JK^{-1}mol^{-1}$$

$$\text{Formula : } \Delta S^{\circ} = S_{HI}^{\circ} - \frac{1}{2}(S_{H_2}^{\circ} + S_{I_2}^{\circ})$$

$$\Delta G^{\circ} = \Delta H^{\circ} - T\Delta S^{\circ}$$

 [Watch Video Solution](#)

8. Calculate the maximum % efficiency of thermal engine operating

between 110° and 25° .



[Watch Video Solution](#)

9. Calculate the entropy change in the system, and in the surroundings and the total entropy change in the universe when during a process 75 J of heat flow out of the system at $55^{\circ}C$ to the surrounding at $20^{\circ}C$.



[Watch Video Solution](#)

10. Calculate the entropy change of process $H_2O_{(l)} \rightarrow H_2O_{(g)}$ at 373K. Enthalpy of vaporization of water is 40850J Mole^{-1}



[Watch Video Solution](#)

11. The boiling point of water at a pressure of 50 atm is 538 K. Compare the theoretical efficiencies of a stem engine operating between the boiling point of water at 1 atm pressure



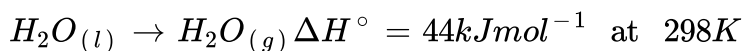
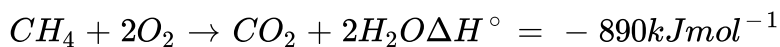
[Watch Video Solution](#)

 [Watch Video Solution](#)

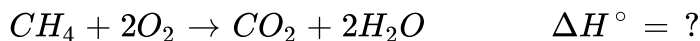
12. The boiling point of water at a pressure of 50 atm is 538 K. Compare the theoretical efficiencies of a stem engine operating between the boiling point of water at 50 atm pressure, assuming the temperature of the sink to be $35^{\circ}C$ in each case.

 [Watch Video Solution](#)

13. From the following data.

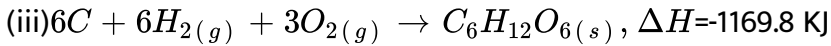
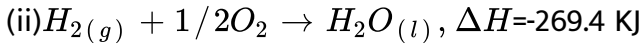
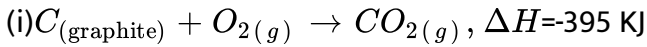


Calculate the enthalpy of the reaction



 [View Text Solution](#)

14. Calculate the heat of glucose and its calorific value from following data :



 [Watch Video Solution](#)

15. Calculate the entropy change in the engine that receives 957.5 kJ of heat reversibly at 110°C temperature.

 [Watch Video Solution](#)

16. Calculate the entropy change of a process possessing $\Delta H_t = 2090 \text{ J mol}^{-1}$.

 [Watch Video Solution](#)

17. 250 J of work is done on the system and at the same time 100 J of heat is given out. What is the change in the internal energy ?

Given

$$w = 250J$$

[Work done on the system, $w > 0$ Heat given out of the system, $q < 0$]

$$q = 100J$$

 [Watch Video Solution](#)

18. The heat of combustion of ethyl alcohol is 34,600 cal. The heat of formation of CO_2 and water are -96.200 and -68.000 calories respectively at constant pressure. What is the heat formation of ethyl alcohol ?

Given :

$$\Delta H_f^\circ, CO_2 = -96200 \text{ cal}, \Delta H_f^\circ, H_2O = -68000 \text{ cal}$$

$$\Delta H_c^\circ, C_2H_5OH = 34.600 \text{ cal}$$

 [Watch Video Solution](#)

19. Calculate the change of entropy for the process , water (liq) to water (vapor,373) involving $\Delta H_{\text{vap}} = 40850 \text{ J mol}^{-1}$ at 373 K .



[Watch Video Solution](#)