

Class Room Problems

Problems 1 A certain electric motor produced 15 kJ of energy each second as mechanical work and lost 2 kJ as heat to the surroundings. What is the change in the internal energy of the motor and its power supply each second ?

Sol.

Problems 3 Work done in expansion of an ideal gas from 4 litre to 6 litre against a constant external pressure of 2.5 atm was used to heat up 1 mole of water at 293 K. If specific heat of water is $4.184 \text{ J g}^{-1} \text{ K}^{-1}$ what is the final temperature of water ?

Sol.

Problems 2 The internal energy change in the conversion of 1.0 mole of the calcite form of CaCO_3 to the aragonite form is +0.21 kJ. Calculate the enthalpy change when the pressure is 1.0 bar ; given that the densities of the solid are 2.71 g cm^{-3} and 2.93 g cm^{-3} respectively.

Sol.

MOTION IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
through education

Problems 4 10 g of argon gas is compressed isothermally and reversibly at a temperature of 27°C from 10 L of 5L. Calculate q , W , ΔU and ΔH for this process. $R = 2.0 \text{ cal K}^{-1} \text{ mol}^{-1}$, $\log_{10} 2 = 0.30$, Atomic wt. of Ar = 40.

Sol.

Problems 5 Water is boiled under a pressure of 1.0 atm. When an electric current of 0.50 A from a 12 V supply is passed for 300 s through a resistance in thermal contact with it, it is found that 0.789 g of water is vaporized. Calculate the molar internal energy and enthalpy changes at boiling point (373.15 K.)

Sol.

MOTION IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
Nurturing potential through education

Problem 6 An aeroplane weighing 63,000 kg flies up from sea level to a height of 8000 metre. Its engine run with pure normal octane (C_8H_{18}) has a 30% of efficiency. Calculate the fuel cost of the flight, if octane sells at Rs 3/- per litre. Given density of octane = 0.705 g mL^{-1} , heat of combustion of octane = $1300 \text{ kcal mol}^{-1}$ ($g = 981 \text{ cm/sec}^2$)

Sol.

Problem 8 For a reaction at 25°C enthalpy change (ΔH) and entropy change (ΔS) are $-11.7 \times 10^3 \text{ J mol}^{-1}$ and $-105 \text{ J mol}^{-1} \text{ K}^{-1}$ respectively. Find out whether this reaction is spontaneous or not ?

Sol.

Problem 7 A lead bullet weighing 18.0 g and travelling at 500 m/s is embedded in a wooden block of 1.00 kg. If both the bullet and the block were initially at 25.0°C, what is the final temperature of block containing bullet? Assume no temperature loss to the surroundings. (Heat capacity of wood = 0.5 kcal/kg-K; heat capacity of lead = 0.030 kcal/kg-K)

Sol.

MOTION IIT-JEE|AIEEE
CBSE|SAT|NTSE
OLYMPIADS
through education

Problems 9 Calculate the entropy change when 1 kg of water is heated from 27°C to 200°C forming super heated steam under constant pressure. Given specific heat of water = 4180 J/kg-K and specific heat of steam = $1670 + 0.49 T$ J/kg-K and latent heat of vaporization = 23×10^5 J/kg

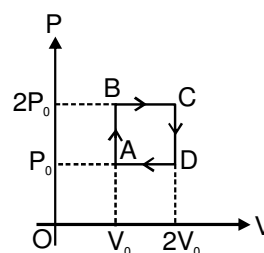
Sol.

Problem 10 Derive a relation showing reversible work of expansion from volume V_1 to V_2 by 'n' moles of a real gas obeying van der Waals' equation at temperature T where volume occupied by molecules may be taken as negligible in comparison to total volume of gas.

Sol.

MOTION IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
Nurturing potential through education

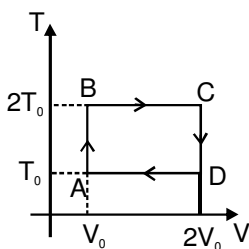
Problem 11 Find out the work done in the given graph. Also draw the corresponding T-V curve and P-T curve.



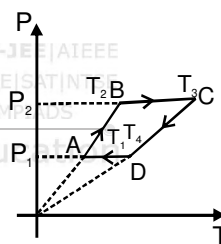
Sol.

Sol.

Problem 12 T-V curve of cyclic process is shown below, number of moles of the gas n find the total work done during the cycle.



Problem 13 P-T curve of a cyclic process is shown. Find out the work done by the gas in the given process if number of moles of the gas are n .



Sol.

Problem 14 Consider the cyclic process ABCA on a sample of 2.0 mol of an ideal gas as shown in figure. The temperatures of the gas at A and B are 300 K and 500 K respectively. A total of 1200 J heat is withdrawn from the sample in the process. Find the work done by the gas in part BC. Take $R = 8.3 \text{ J/mol-K}$.

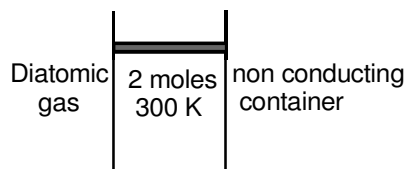
Sol.

Problem 15 1 gm water at 100°C is heated to convert into steam at 100°C at 1 atm. Find out change in internal energy of water. It is given that volume of 1 gm water at $100^\circ\text{C} = 1 \text{ cc}$. volume of 1 gm steam at $100^\circ\text{C} = 1671 \text{ cc}$. Latent heat of vaporization = 540 cal/g. (Mechanical equivalent of heat $J = 4.2 \text{ J/cal}$.)

Sol.

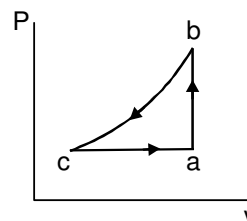
MOTION IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
Nurturing potential through education

Problem 16 Two moles of a diatomic gas at 300 K are kept in a nonconducting container enclosed by a piston. Gas is now compressed to increase the temperature from 300 K to 400 K. Find work done by the gas



Sol.

Problem 17 A sample of an ideal gas is taken through the cyclic process abca (figure). It absorbs 50 J of heat during the part ab, no heat during bc and reflects 70 J of heat during ca. 40 J of work is done on the gas during the part bc. (a) Find the internal energy of the gas at b and c if it is 1500 J at a. (b) Calculate the work done by the gas during the part ca.



Sol.

MOTION IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
Nurturing potential through education

Problem 18 The internal energy of a monatomic ideal gas is $1.5 nRT$. One mole of helium is kept in a cylinder of cross-section 8.5 cm^2 . The cylinder is closed by a light frictionless piston. The gas is heated slowly in a process during which a total of 42 J heat is given to the gas. If the temperature rises through 2°C , find the distance moved by the piston. Atmospheric pressure = 100 kPa .

Sol.

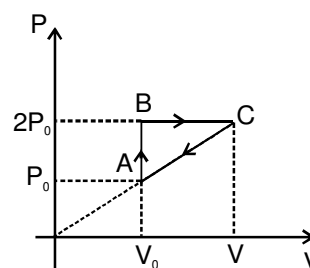
Problem 19 A sample of an ideal gas has pressure p_0 , volume v_0 and temperature T_0 . It is isothermally expanded to twice its original volume. It is then compressed at constant pressure to have the original volume V_0 . Finally, the gas is heated at constant volume to get the original temperature. (a) Show the process in a $V - T$ diagram (b) Calculate the heat absorbed in the process.

Sol.

MOTION IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
Nurturing potential through education

Problem 20 A sample of ideal gas ($f = 5$) is heated at constant pressure. If an amount 140 J of heat is supplied to the gas, find (a) the change in internal energy of the gas (b) the work done by the gas.

Sol.



- (i) Volume at C?
- (ii) Maximum temperature?
- (iii) Total heat given to gas?
- (iv) is heat rejected by the gas, if yes how much heat is rejected ?
- (v) Find out the efficiency

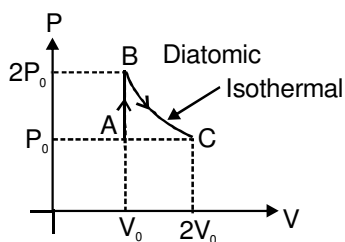
Sol.

Problem 21 n moles of a diatomic gas has undergone a cyclic process ABC as shown in figure. Temperature at A is T_0 .

Find

MOTION
IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
Nurturing potential through education

Problem 22 P-V curve of a diatomic gas is shown in the figure. Find the total heat given to the gas in the process AB and BC



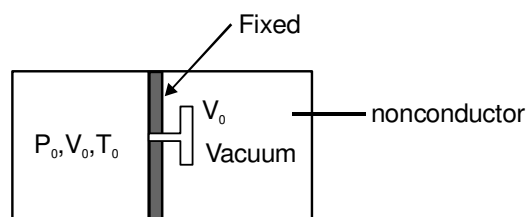
Sol.

Problem 23 A quantity of air is kept in a container having walls which are slightly conducting. The initial temperature and volume are 27°C (equal to the temperature of the surrounding) and 800 cm^3 respectively. Find the rise in the temperature if the gas is compressed to 200 cm^3 (a) in a short time (b) in a long time. Take $\gamma = 1.4$.

Sol.

Problem 24 A monoatomic gas is enclosed in a nonconducting cylinder having a piston which can move freely. Suddenly gas is compressed to $1/8$ of its initial volume. Find the final pressure and temperature if initial pressure and temperature are P_0 and T_0 respectively.

Sol.



Sol.

MOTION IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
Nurturing potential through education

Problem 25 A nonconducting cylinder having volume $2V_0$ is partitioned by a fixed nonconducting wall in two equal part. Partition is attached with a valve. Right side of the partition is a vacuum and left part is filled with a gas having pressure and temperature P_0 and T_0 respectively. If valve is opened find the final pressure and temperature of the two parts.

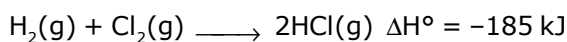
Exercise - I**(only one option is correct)**

1. Out of boiling point (I), entropy (II), pH (III) and density (IV), Intensive properties are :

- (A) I, II (B) I, II, III
(C) I, III, IV (D) All of these

Sol.

2. Consider the reaction at 300 K



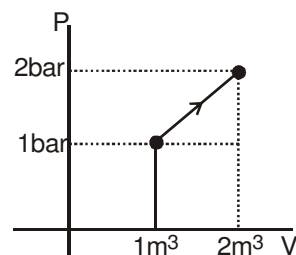
If 3 mole of H_2 completely react with 3 mole of Cl_2 to form HCl. What is ΔU° for this reaction ?

- (A) 0 (B) -185 kJ
(C) 555 kJ (D) None of these

Sol.

Sol.

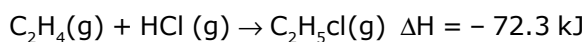
4. What is ΔU for the process described by figure.
Heat supplied during the process $q = 100 \text{ kJ}$.



- (A) +50 kJ (B) -50 kJ
(C) -150 kJ (D) +150 kJ

Sol.

3. Ethyl chloride ($\text{C}_2\text{H}_5\text{Cl}$), is prepared by reaction of ethylene with hydrogen chloride :



What is the value of ΔE (in kJ), if 70 g of ethylene and 73 g of HCl are allowed to react at 300 K.

- (A) -69.8 (B) -180.75
(C) -174.5 (D) -139.6

5. One mole of ideal gas is allowed to expand reversibly and adiabatically from a temperature of 27°C . If the work done by the gas in the process is 3 kJ, the final temperature will be equal to ($C_v = 20 \text{ J/K mol}$)

- (A) 100 K (B) 450 K
(C) 150 K (D) 400 K

Sol.

6. What is the change in internal energy when a gas contracts from 377 ml to 177 ml under a constant pressure of 1520 torr, while at the same time being cooled by removing 124 J heat?

[Take : (1 L atm) = 100 J]

- (A) -24 J (B) -84 J (C) -164 J (D) -248 J

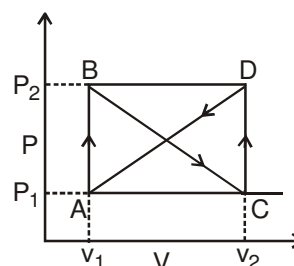
Sol.

7. The heat capacity of liquid water is 75.6 J/mol K , while the enthalpy of fusion of ice is 6.0 kJ/mol . What is the smallest number of ice cubes at 0°C , each containing 9.0 g of water, needed to cool 500 g of liquid water from 20°C to 0°C ?

- (A) 1 (B) 7
(C) 14 (D) None of these

Sol.

8. An ideal gas is taken around the cycle ABCDA as shown in figure. The net work done during the cycle is equal to :



- (A) zero (B) positive
(C) negative (D) we cannot predict

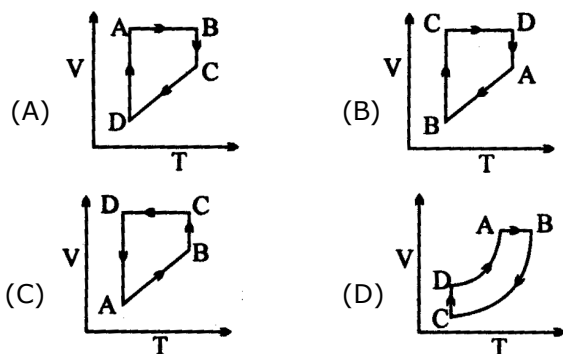
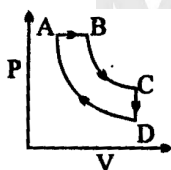
Sol.

9. Molar heat capacity of water in equilibrium with ice at constant pressure is

- (A) zero (B) ∞
 (C) $40.45 \text{ kJ K}^{-1} \text{ mol}^{-1}$ (D) $75.48 \text{ J K}^{-1} \text{ mol}^{-1}$

Sol.

10. A cyclic process ABCD is shown in PV diagram for an ideal gas. Which of the following diagram represents the same process ?



Sol.

11. A diatomic ideal gas initially at 273 K is given 100 cal heat due to which system did 209 J work. Molar heat capacity (C_m) of gas for the process is :

- (A) $\frac{3}{2}R$ (B) $\frac{5}{2}R$
 (C) $\frac{5}{4}R$ (D) $5R$

Sol.

12. One mole of an ideal monoatomic gas expanded irreversibly in two stage expansion.

State-1 (8.0 bar, 4.0 litre, 300 K)

State-2 (2.0 bar, 16 litre, 300 K)

State-3 (1.0 bar, 32 litre, 300 K)

Total heat absorbed by the gas in the process is :

- (A) 116 J (B) 40 J
(C) 4000 J (D) None of these

Sol.

14. A gas ($C_{v,m} = \frac{5}{2}R$) behaving ideally was allowed to expand reversibly and adiabatically from 1 litre to 32 litre. It's initial temperature was 327°C. The molar enthalpy change (in J/mole) for the process is

- (A) -1125 R (B) -575 R
(C) -1575 R (D) None of these

Sol.

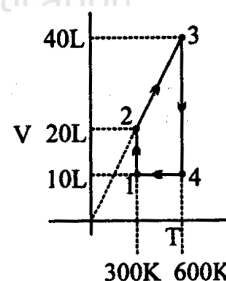
13. For an ideal monoatomic gas during any process $T = kV$, find out the molar heat capacity of the gas during the process. (Assume vibrational degree of freedom to be active)

- (A) $\frac{5}{2}R$ (B) 3R (C) $\frac{7}{2}$ (D) 4R

Sol.

15. What is the net work done (**in calories**) on 1 mole of monoatomic ideal gas in a process described by 1,2,3,4 in given V-T graph.

Use : $R = 2\text{cal/mole K}$



$\ln 2 = 0.7$

- (A) -600 cal (B) -660 cal
(C) +660 cal (D) +600 cal

Sol.

- 16.** Two moles of an ideal gas ($C_v = \frac{5}{2}R$) was compressed adiabatically against constant pressure of 2 atm. Which was initially at 350 K and 1 atm pressure. The work involve in the process is equal to
(A) 250 R (B) 300 R (C) 400 R (D) 500 R

Sol.

17. An insulated container of gas has two chambers separated by an insulating partition. One of the chambers has volume V_1 and contains ideal gas at pressure P_1 and temperature T_1 . The other chambers has volume v_2 and contains ideal gas at pressure P_2 and temperature T_2 . If the partion is removed without doing any work on the gas, the final equilibrium temperature of the gas in the container will be

- (A) $\frac{T_1 T_2 (P_1 V_1 + P_2 V_2)}{P_1 V_1 T_2 + P_2 V_2 T_1}$ (B) $\frac{P_1 V_1 T_1 + P_2 V_2 T_2}{P_1 V_1 + P_2 V_2}$
(C) $\frac{P_1 V_1 T_2 + P_2 V_2 T_1}{P_1 V_1 + P_2 V_2}$ (D) $\frac{T_1 T_2 (P_1 V_1 + P_2 V_2)}{P_1 V_1 T_1 + P_2 V_2 T_2}$

Sol.

MOTION IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
Nurturing potential through education

18. The maximum efficiency of a heat engine operating between 100°C and 25°C is

- (A) 20.11% (B) 22.2%
(C) 25.17% (D) None

Sol.

19. A heat engine operating between 227°C and 27°C absorbs 2 Kcal of heat from the 227°C reservoir reversibly per cycle. The amount of work done in one cycle is :

- (A) 0.4 Kcal (B) 0.8 Kcal (C) 4 Kcal (D) 8 Kcal

Sol.

and B are the same then the temperature T_2 is

- (A) 680 K (B) 640 K (C) 600 K (D) None

Sol.

21. For the reaction at 300 K

$\text{A(g)} + \text{B(g)} \rightarrow \text{C(g)}$ $\Delta E = -3.0 \text{ kcal}$; $\Delta S = -10.0 \text{ cal/K}$
value of ΔG is

- (A) -600 cal (B) -6600 cal (C) -6000 cal (D) None

Sol.

20. A reversible heat engine A (based on Carnot cycle) absorbs heat from a reservoir at 1000 K and rejects heat to a reservoir at T_2 . A second reversible engine B absorbs the same amount of heat as rejected by the engine A, from the reservoir at T_2 and rejects energy to a reservoir at 360 K. If the efficiencies of engines A

MOTION IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
Nurturing potential through education

22. The entropy change when two moles of ideal monoatomic gas is heated from 200 to 300°C reversibly and isochorically

- (A) $\frac{3}{2}R \ln \left(\frac{300}{200} \right)$ (B) $\frac{5}{2}R \ln \left(\frac{573}{273} \right)$
 (C) $3R \ln \left(\frac{573}{473} \right)$ (D) $\frac{3}{2}R \ln \left(\frac{573}{473} \right)$

Sol.

23. What is the free energy change (ΔG) when 1.0 mole of water at 100° C and 1 pressure is converted into steam at 100°C and 1 atm pressure ?

- (A) 80 cal (B) 540 cal (C) 620 cal (D) zero

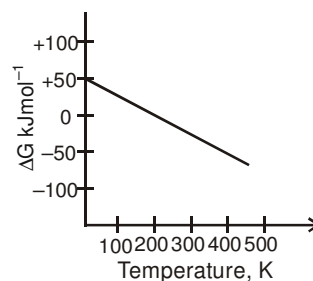
Sol.

24. What if the free energy change (ΔG) when 1.0 mole of water at 100°C and 1 atm pressure is converted into steam at 100°C and 2 atm pressure ?

- (A) zero cal (B) 540 cal
 (C) 517.13 cal (D) 510 cal

Sol.

25. What can be concluded about the values of ΔH and ΔS from this graph ?



- (A) $\Delta H > 0, \Delta S > 0$ (B) $\Delta H > 0, \Delta S < 0$
 (C) $\Delta H < 0, \Delta S > 0$ (D) $\Delta H < 0, \Delta S < 0$

Sol.

26. If $\Delta H_{\text{vaporisation}}$ of substance X (l) (molar mass : 30 g/mol) is 300 J/g at its boiling point 300 K, then molar entropy change for reversible condensation process is

- (A) 30 J/mol.K (B) -300 J/mol K
(C) -30 J/mol K (D) None of these

Sol.

27. Pressure of 10 moles of an ideal gas is changed from 2 atm to 1 atm against constant external pressure without change in temperature. If surrounding temperature (300K) and pressure (1 atm) always remains constant then calculate total entropy change ($\Delta S_{\text{system}} + \Delta S_{\text{surrounding}}$) for given process.

[Given : $\ln 2 = 0.70$ and $R = 8.0 \text{ J/mol/K}$]

- (A) 56 J/K (B) 14 J/K
(C) 16 J/K (D) None of these

Sol.

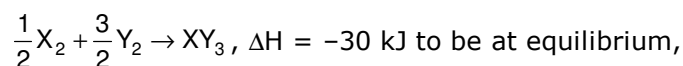
MOTION IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
Nurturing potential through education

28. The enthalpy of tetramerization of X in gas phase ($4X(g) \rightarrow X_4(g)$) is -100 kJ/mol at 300 K. The enthalpy of vaporisation for liquid X and X_4 are respectively 30 kJ/mol and 72 kJ/mol respectively. ΔS for tetramerization of X in liquid phase is -125 J/K mole at 300 K. What is the ΔG at 300 K for tetramerization of x in liquid phase.

- (A) -52 kJ/mol (B) -89.5 kJ/mol
(C) -14.5 kJ/mol (D) None of these

Sol.

30. Standard entropy of X_2 , Y_2 and XY_3 are 60, 40 and 50 $\text{JK}^{-1} \text{mol}^{-1}$, respectively. For the reaction,



to be at equilibrium, the temperature will be

- (A) 1250 K (B) 500 K (C) 750 K (D) 1000 K

Sol.

29. The change in entropy of 2 moles of an ideal gas upon isothermal expansion at 243.6 K from 20 litre until the pressure becomes 1 atm, is :

- (A) 1.385 cal/K (B) -1.2 cal/k
(C) 1.2 cal/K (D) 2.77 cal/K

Sol.

31. When two equal sized pieces of the same metal at different temperatures T_h (hot piece) and T_c (cold piece) are brought into contact into thermal contact and isolate from it's surrounding. The total change in entropy of system is given by

- (A) $C \ln \frac{T_c + T_h}{2T_c}$ (B) $C \ln \frac{T_2}{T_1}$
(C) $C \ln \frac{(T_c + T_h)^2}{2T_h \cdot T_c}$ (D) $C \ln \frac{(T_c + T_h)^2}{4T_h \cdot T_c}$

Sol.

Assertion Reason :

32. Statement-1 : There is no change in enthalpy of an ideal gas during compression at constant temperature.

Statement-II : Enthalpy of an ideal gas is a function of temperature and pressure.

(A) Statement-I is true, statement-II is true and statement-II is correct explanation for statement-I

(B) Statement-I is true, statement-II is true and statement-II is NOT the correct explanation for statement-I

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

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

Sol.

33. Statement-1 : Due to adiabatic free expansion, temperature of a real gas always increases

Statement-II : If a real gas is at inversion temperature then no change in temperature is observed in adiabatic free expansion.

(A) Statement-I is true, statement-II is true and statement-II is correct explanation for statement-I

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

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

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

Sol.

34. Statement-1 : There is no change in enthalpy of an ideal gas during compression at constant temperature

Statement-II : Enthalpy of an ideal gas is a function of temperature and pressure.

(A) Statement-I is true, statement-II is true and statement-II is correct explanation for statement-I

(B) Statement-I is true, statement-II is true and statement-II is NOT the correct explanation for statement-I

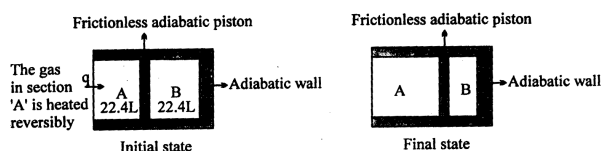
(C) Statement-I is false, statement-II is true.

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

Sol.

COMPREHENSION-I

A cylindrical container of volume 44.8 litres is containing equal no. of moles (in integer no.) of an ideal monoatomic gas in two sections A and B separated by an adiabatic frictionless piston as shown in figure. The initial temperature and pressure of gas in both section is 27.3 K and 1 atm. Now gas in section 'A' is slowly heated till the volume of section B becomes $(1/8)^{\text{th}}$ of initial volume.



Given : $R = 2 \text{ cal/mol-K}$, $C_{v,m}$ of monoatomic gas $= \frac{3}{2}R$,

At 1 atm & 0°C ideal gas occupy 22.4 litre.

35. What will be the final pressure in container B.

- (A) 2 atm (B) 8 atm (C) 16 atm (D) 32 atm

Sol.

37. Change in enthalpy for section A in Kcal.

- (A) 48.3 (B) 80.53 (C) 4.83 (D) 8.05

Sol.

MOTION IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
Nurturing potential through education

36. Final temperature in container A will be

- (A) 1638 K (B) 6988 K (C) 3274 K (D) 51 K

Sol.

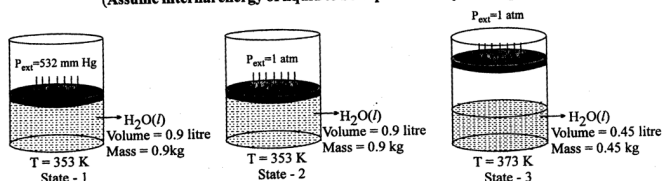
COMPREHENSION - 2

The vapour pressure of $\text{H}_2\text{O}(l)$ at 353 K is 532 mm Hg. The external pressure on $\text{H}_2\text{O}(l)$ taken in a cylinder fitted with frictionless movable piston initially containing 0.9 L (= 0.9 kg) of $\text{H}_2\text{O}(l)$ at 353 K is increased to 1 atm. Temperature remained constant. Now, heat is supplied keeping pressure constant till 0.45 L of $\text{H}_2\text{O}(l)$ (= 0.45 kg) is evaporated to form $\text{H}_2\text{O}(g)$ at 373 K. Carefully observe the diagrams provided and from given data, answer the following questions.

Given: Specific heat of $\text{H}_2\text{O} = 4.2 \text{ J/gm } ^\circ\text{C}$
 ΔH_{vap} at 373 K and 1 atm = +40 kJ/mol
 1 atm = 760 mm Hg

Use
 1 L atm = 100 Joule
 $R = 8 \text{ Joule/mole K}$

(Assume internal energy of liquid to be dependent only on temperature).



38. ΔH when system is taken from state 1 to state 2 (Joule) ?

- (A) zero (B) 0.27 (C) 27 (D) 90

Sol.

39. Total change in ΔU going from state 1 to 3 (kJ) ?

- (A) 75.6 (B) 1075.6 (C) 1001 (D) 74.6

Sol.

40. Total change in enthalpy going from state 1 to state 3 (kJ) ?

- (A) 75.6 (B) 1075.6 (C) 1001 (D) 74.6

Sol.

MOTION IIT-JEE | AIEEE
 CBSE | SAT | NTSE
 OLYMPIADS
 Nurturing potential through education

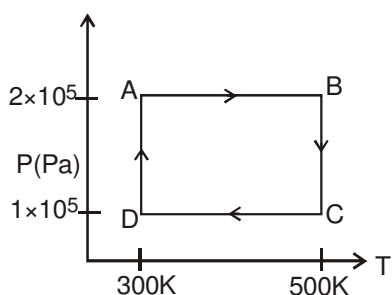
41. What is the work done in going state 1 to state 3 to in Joules.

- (A) zero (B) 45 (C) 90 (D) 31.5

Sol.

COMPREHENSION-3

Two moles of helium gas are taken over the cycle ABCDA, as shown in the P-T diagram.



42. Assuming the gas to be ideal the work done by the gas in taking it from A to B is -

- (A) 200 R (B) 300 R (C) 400 R (D) 500 R

Sol.

43. The work done involved in taking it from D to A is
(A) $-414 R$ (B) $+414 R$ (C) $-690 R$ (D) $+690 R$

Sol.

44. The net work done involved in the cycle ABCDA is
(A) zero (B) 276 R (C) 1076 R (D) 1904 R

Sol.

MOTION IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
Nurturing potential through education

Match the column :

45. Match Column-I with Column-II

Column - I

(Ideal Gas)

(A) Reversible isothermal process

(B) Reversible adiabatic process

(C) Irreversible adiabatic process

(D) Irreversible isothermal process

Column-II

(Related equation)

(P) $W = 2.303 nRT \log (P_2/P_1)$

(Q) $W = nC_{v,m} (T_2 - T_1)$

(R) $PV = nRT$

(S) $W = - \int_{V_i}^{V_f} P_{\text{ext.}} dV$

Sol.

46. Match the column - I with column-II

Note that column - I may have more than one matching options in column-II

Column-I

(A) Reversible adiabatic compression

(B) Reversible vaporisation

(C) Free expansion of ideal gas in vacuum

(D) Dissociation of $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$

Sol.

Column-II(P) $\Delta S_{\text{system}} > 0$ (Q) $\Delta S_{\text{system}} < 0$ (R) $\Delta S_{\text{surrounding}} < 0$ (S) $\Delta S_{\text{surrounding}} = 0$ **47. Column I**

(A) For the process

 $\text{A}(\text{l}) \rightarrow \text{A}(\text{s})$, ΔH & ΔV may be(B) $\text{A}_2(\text{s}) + \text{B}_2(\text{g}) \rightleftharpoons \text{C}_2(\text{s}) + \text{D}_2(\text{s})$
 ΔH & ΔG may be

(C) For the given reaction

 $\text{A}_2(\text{g}) \rightleftharpoons \text{B}_2(\text{g}) + \text{C}_2(\text{g})$, $E_{\text{a}(\text{forward})} = 50 \text{ kJ/mol}$ at very high temperature ΔH & ΔG are

(D) For the given reaction

 $\text{A}(\text{g}) \rightleftharpoons \text{B}(\text{g})$, at very low temperature ΔH & ΔG may be

Sol.

Column-II

(P) -ve, +ve

(Q) +ve, -ve

(R) +ve, +ve

(S) -ve, -ve

48. Column - I may have more than one matching options in column-II

Column-I

(A) Reversible condensation of vapour

(B) Irreversible adiabatic compression of an ideal gas

(C) Isothermal free expansion of an ideal gas in vacuum

(D) Reversible adiabatic expansion of an ideal gas

Sol.

Column-II(P) $\Delta S_{\text{system}} > 0$ (Q) $\Delta S_{\text{system}} < 0$ (R) $\Delta S_{\text{surrounding}} < 0$ (S) $\Delta S_{\text{surrounding}} = 0$ **49. Column-I****(Related to process)**

(A) Fusion at melting point

(B) Vapourisation at boiling point

(C) Condensation at triple point

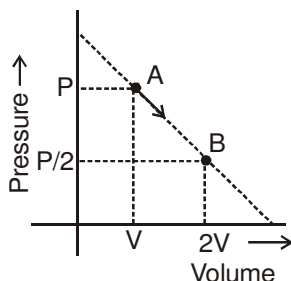
(D) Melting at normal boiling point

Sol.

Column-II**(Related to system)**(P) $\Delta G = 0$ (Q) $\Delta G < 0$ (R) $\Delta S > 0$ (S) $\Delta H \approx \Delta U$

Exercise - II**(One or more than one option correct)**

1. An ideal gas is taken from state A (Pressure P , Volume V) to the state B (Pressure $P/2$, Volume $2V$) along a straight line path in PV diagram as shown in the adjacent figure.



Select the correct statement (s) among the following

(A) The work done by gas in the process A to B exceeds the work that would be done by it if the system were taken from A to B along the isotherm.

(B) In the T-V diagram, the path AB become part of parabola.

(C) In the P-V diagram, the path AB becomes a part of hyperbola.

(D) In going from A to B, the temperature T of the gas first increases to a maximum value then decreases.

Sol.

2. The normal boiling point of a liquid 'A' is 350 K. ΔH_{vap} at normal boiling point is 35 kJ/mole. Pick out the correct statement (s). (Assume ΔH_{vap} to be independent of pressure).

(A) $\Delta S_{\text{vaporisation}} > 100 \text{ J/K mole}$ at 350 K and 0.5 atm

(B) $\Delta S_{\text{vaporisation}} < 100 \text{ J/K mole}$ at 350 K and 0.5 atm

(C) $\Delta S_{\text{vaporisation}} < 100 \text{ J/K mole}$ at 350 K and 2 atm

(D) $\Delta S_{\text{vaporisation}} = 100 \text{ J/K mole}$ at 350 K and 2 atm

Sol.

3. Which of the following statement(s) is/are false :

(A) $\Delta_r S$ for $\frac{1}{2}\text{N}_2(\text{g}) \rightarrow \text{N}(\text{g})$ is positive

(B) ΔG_{system} is always zero for a reversible process in a closed system

(C) ΔG° for an ideal gas is a function of temperature and pressure

(D) entropy of a closed system is always maximized at equilibrium

Sol.

4. Which statement is/are correct :

- (A) Final temperature in reversible adiabatic expansion is lesser than in irreversible adiabatic expansion.
 (B) When heat is supplied to an ideal gas in an isothermal process, kinetic energy of gas will increase
 (C) When an ideal gas is subjected to adiabatic expansion it gets cooled
 (D) Entropy increases in atomisation of dihydrogen

Sol.

- (A) The pressure at B is 2.0 bar
 (B) The temperature at D is 450 K
 (C) $\Delta H_{CD} = 1000 R$ (D) $\Delta U_{BC} = 375 R$

Sol.

5. Which is /are correct statement.

- (A) $W_{\text{adiabatic}} > W_{\text{isothermal}}$ in an ideal gas compression from same initial state to same final volume

- (B) The volume of $\gamma \left(\gamma = \frac{C_p}{C_v} \right)$ remains constant for diatomic gas at all temperature

- (C) Entropy increases when an ideal gas expanded isothermally.

- (D) $\Delta_r H$ & $\Delta_r S$ both are +ve for the decomposition of $\text{MgCO}_3(\text{s})$.

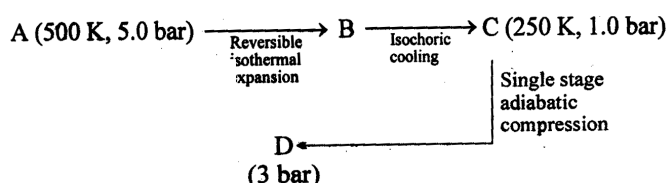
Sol.

7. In isothermal ideal gas compression

- (A) w is +ve (B) ΔH is zero
 (C) ΔS_{gas} is +ve (D) ΔG is +ve

Sol.

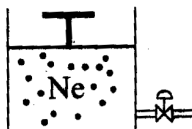
6. Two moles of an ideal gas ($C_{v,m} = 3/2 R$) is subjected to following change of state.



The correct statement is/are :

8. A piston cylinder device initially contains 0.2 m^3 neon (assume ideal) at 200 kPa inside at $T_1^\circ\text{C}$. A valve is now opened and neon is allowed to escape until the volume reduces to half the initial volume.

At the same time heat transfer with outside at $T_2^\circ\text{C}$ ensures a constant temperature inside.



Select correct statement(s) for given process

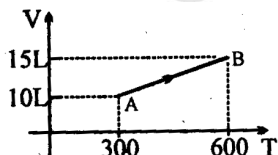
- (A) ΔU must be zero (B) ΔU may not be zero
(C) q may be +ve (D) q may be -ve

Sol.

9. If one mole monoatomic ideal gas was taken through process AB as shown in figure, the select correct option (s).

- (A) $w_{AB} = -1496.52 \text{ J}$
(B) $q_{AB} = 5237.82 \text{ J}$
(C) $\Delta H_{AB} = 3741.3 \text{ J}$
(D) ΔS_{AB} is +ve

Sol.



10. Which of the following statement(s) is/are correct

- (A) Reversible isothermal compression of an ideal gas represents the limiting minimum value of the workdone ($|w|$) by the surrounding on the system.
(B) In an irreversible process, the cyclic integral of work is not zero.
(C) For thermodynamic changes in adiabatic process

$$T^{\left(\frac{C_{P,m}}{R}\right)} \cdot P = \text{constant}$$

- (D) Work done by 1 mole of a real (vander waals) gas

$$W = -RT \ln \frac{V_2 - b}{V_1 - b} - a \left[\frac{V_1 \times V_2}{V_2 - V_1} \right]$$

Sol.

Exercise - III**Subjective Level-I****First law : Heat (q), work (w) and ΔU , ΔH**

1. In which of the following changes at constant pressure is work done by system on surrounding? By the surrounding on system?

Initial state	Final state
(i) $\text{H}_2\text{O}(\text{g})$	$\rightarrow \text{H}_2\text{O}(\text{l})$
(ii) $\text{H}_2\text{O}(\text{s})$	$\rightarrow \text{H}_2\text{O}(\text{g})$
(iii) $\text{H}_2\text{O}(\text{l})$	$\rightarrow \text{H}_2\text{O}(\text{s})$
(iv) $3\text{H}_2(\text{g}) + \text{N}_2(\text{g})$	$\rightarrow 2\text{NH}_3(\text{g})$
(v) $\text{CaCO}_3(\text{s})$	$\rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$

Sol.

2. The gas is cooled and loses 65 J of heat. The gas contracts as it cools and work done on the system equal to 20 J is exchanged with the surroundings. What are q, w and ΔE ?

Sol.

3. The enthalpy change for the reaction of 50 ml of ethylene with 50.0 ml of H_2 at 1.5 atm pressure is $\Delta H = -0.31$ KJ. What is the ΔE .

Sol.

4. The enthalpy of combustion of glucose is -2808 KJ mol^{-1} at 25°C . How many grams of glucose do you need to consume [Assume wt = 62.5 Kg]

(a) to climb a flight of stairs rising through 3M

(b) to climb a mountain of altitude 3000 M?

Assume that 25% of enthalpy can converted to useful work.

Sol.

MOTION IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
Nurturing potential through education

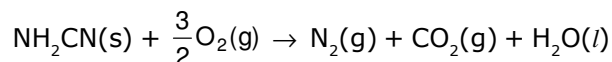
5. What is ΔE when 2.0 mole of liquid water vaporises at 100° ? The heat of vaporisation, ΔH_{vap} of water at 100°C is $40.66 \text{ kJ mol}^{-1}$.

Sol.

6. If 1.0 kcal of heat is added to 1.2 L of O_2 in a cylinder of constant pressure of 1 atm, the volume increases to 1.5 L. Calculate ΔE and ΔH of the process.

Sol.

7. When the following reaction was carried out in a bomb calorimeter, ΔE is found to be -742.7 kJ/mol of $\text{NH}_2\text{CN(s)}$ at 298 K.



Calculate ΔH_{298} for the reaction.

Sol.

8. When 1 mole of ice melt at 0°C and at constant pressure of 1 atm. 1440 calories of heat are absorbed by the system. The molar volumes of ice and water are 0.0196 and 0.0180 litre respectively. Calculate ΔH and ΔE for the reaction.

Sol.

MOTION IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
Nurturing potential through education

9. Water expands when it freezes. Determine amount of work in joules, done when a system consisting of 1.0 L of liquid water freezes under a constant pressure of 1.0 atm and forms 1.1 L of ice.

Sol.

11. One mole of solid Zn is placed in excess of dilute H_4SO_4 at 27°C in a cylinder fitted with a piston. Find the value of ΔE , q and w for the process if the area of piston is 500 cm^2 and it moves out by 50 cm against a pressure of 1 atm during the reaction. The heat given to surrounding is 36.5 KJ.



Sol.

10. Lime is made commercially by decomposition of limestone CaCO_3 . What is the change in internal energy when 1.00 mole of solid CaCO_3 ($V = 34.2\text{ ml}$) absorbs 177.9 kJ of heat and decomposes at 25°C against a pressure of 1.0 atm to give solid CaO . (Volume = 16.9 ml) and CO_2 (g) ($V = 24.4\text{ L}$)

Sol.

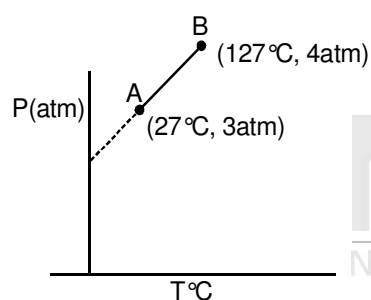
MOTION IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
through education

12. Two mole of ideal diatomic gas ($C_{v,m} = 5/2 R$) at 300 K and 5 atm expanded irreversibly & adiabatically to a final pressure of 2 atm against a constant pressure of 1 atm. Calculate q , w , ΔH & ΔU .

Sol.

13. 4 moles of an ideal gas ($C_{v,m} = 15 \text{ JK}^{-1} \text{ mol}^{-1}$) is subjected to the following process represented on $P - T$ graph from the data given. Find out

(a) The process is isochoric or not



(b) Calculate q , w , ΔU & ΔH for the process.

Sol.

14. Calculate the max. work done by system in an irreversible (single step) adiabatic expansion of 1 mole of a polyatomic gas ($\gamma = 1.33$) from 300 K and pressure 10 atm to 1 atm.

Sol.

15. 1 mole of CO_2 gas at 300 K is expanded under reversible adiabatic condition such that its volume becomes 27 times.

(a) What is the final temperature

(b) What is work done

Given $\gamma = 1.33$ and $C_v = 25.08 \text{ J mol}^{-1} \text{ K}^{-1}$ for CO_2

Sol.

16. Three moles of a ideal gas at 200K and 2.0 atm pressure undergo reversible adiabatic compression until the temperature becomes 250 K for the gas C_v is $27.5 \text{ JK}^{-1} \text{ mol}^{-1}$ in this temperature range. Calculate q , w , ΔU , ΔH and final V and final P .

Sol.

17. A sample of a fluorocarbon was allowed to expand to expand reversibly and adiabatically to twice its volume. In the expansion the temperature dropped from 298.15 K to 248.44 K. Assume the gas behaves perfectly Estimate the value of $C_{v,m}$.

Sol.

18. Find the work done when one mole of the gas is expanded reversibly and isothermally from 5 atm to 1 atm at 25°C

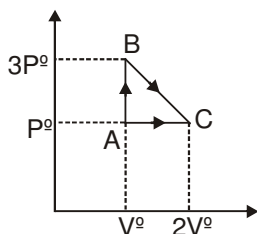
Sol.

MOTION IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
Nurturing potential through education

19. One mole of ideal monoatomic gas is carried through the reversible cyclic process as shown in figure.

Calculate .

- (a) work done by the gas.
 (b) The heat changed by the gas in path CA and AB.
 (c) Net heat absorbed by the gas in the path BC.

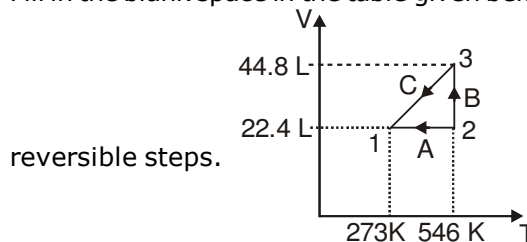


- (d) The max. temperature attained by the gas during the cycle.

Sol.

20. One mole of an ideal monoatomic gas is carried through the reversible cycle of the given figure consisting of step A, B and C and involving state 1, 2 and 3.

Fill in the blank space in the table given below assuming



reversible steps.

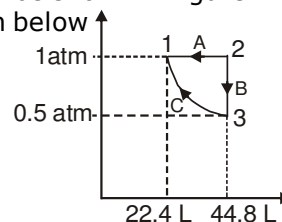
Table-1			
State	P	V	T
1			
2			
3			

Step	Name of process	q	w	ΔE	ΔH
A					
B					
C					

Sol.

MOTION IIT-JEE | AIEEE
 CBSE | SAT | NTSE
 OLYMPIADS
 Nurturing potential through education

21. One mole of an ideal monoatomic gas is put through reversible path as shown in figure. Fill in the blank in the table given below



State	P	V	T
1			
2			
3			

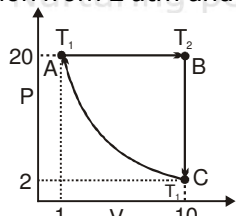
Step	Name of process	q	w	E	H
A					
B					
C					
	cyclic				

Sol.

22. One mole of a perfect monoatomic gas is put through a cycle consisting of the following three reversible steps.

(CA) Isothermal compression from 2 atm and 10 litres to 20 atm and 1 litre

(AB) Isobaric expansion to return the gas to the original volume of 10 litres



with T going from T_1 to T_2 .

(BC) Cooling at constant volume to bring the gas to original pressure and temperature. The steps are shown schematically in the figure shown.

(a) Calculate T_1 and T_2

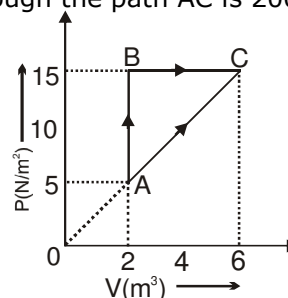
(b) Calculate ΔE , q and w in calories, for each step and for the cycle.

Sol.

23. The given figure shows a change of state A to state C by two paths ABC and AC for an ideal gas. Calculate the :

(a) Path along which work done is least.

(b) Internal energy at C if the internal energy of gas at A is 10 J and amount of heat supplied to change its state to C through the path AC is 200 J.



(c) Amount of heat supplied to the gas to go from A to B, if internal energy change of gas is 10 J.

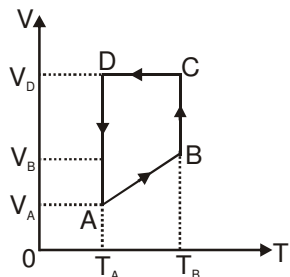
Sol.

Sol.

24. A monoatomic ideal gas of two moles is taken through a reversible cyclic process starting from A as shown in figure. The volume ratios are $\frac{V_B}{V_A} = 2$ and

$\frac{V_D}{V_A} = 4$. If the temperature T_A at A is 27°C , calculate
 (a) The temperature of the gas at point B.
 (b) Heat absorbed or released by the gas in each

process.



(c) The total work done by the gas during complete cycle.

Kirchoff's Rule : Variation of Enthalpy with Temperature

25. The standard enthalpy of formation of water liquid is -285.76 kJ at 298 K . Calculate the value of $\Delta_f H^\circ$ at 373 K . The molar heat capacities at constant pressure (C_p) in the given temperature range of $\text{H}_2(\text{g})$, $\text{O}_2(\text{g})$ and $\text{H}_2\text{O}(\text{l})$ are respectively 38.83 , 29.16 and $75.312 \text{ JK}^{-1} \text{ mol}^{-1}$.

Sol.

26. Methane (considered to be an ideal gas) initially at 25°C and 1 bar pressure is heated at constant pressure until the volume has doubled. The variation of the molar heat capacity with absolute temperature is given by

$$C_p = 22.34 + 48.1 \times 10^{-3} T$$

where C_p in $\text{JK}^{-1} \text{mol}^{-1}$. Calculate molar (a) ΔH (b) ΔU .

Sol.

Second & third law & Entropy change in thermodynamic processes

27. One mole of NaCl (s) on melting absorbed 30.5 KJ of heat and its entropy is increased by 28.8 JK^{-1} . What is the melting point of sodium chloride ?

Sol.

MOTION IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
Nurturing potential through education

28. Oxygen is heated from 300 to 600 at a constant pressure of 1 bar. What is the increase in molar entropy ? The molar heat capacity in $\text{JK}^{-1} \text{mol}^{-1}$ for the O_2 is

$$C_p = 25.5 + 13.6 \times 10^{-3} T - 42.5 \times 10^{-7} T^2$$

Sol.

30. Calculate the entropy of a substance at 600 K using the following data.

(i) Heat capacity of solid from 0 K to normal melting point 200 K $C_{p,m}(s) = 0.035 T$ JK⁻¹ mol⁻¹

(ii) Enthalpy of fusion = 7.5 kJ mol⁻¹,

(iii) Enthalpy of vaporisation = 30 kJ mol⁻¹.

(iii) Heat capacity of liquid from 200 K to normal boiling point 300 K $C_{p,m}(l) = 60 + 0.016 T$ JK⁻¹ mol⁻¹

(iv) Heat capacity of gas from 300 K to 600 K at 1 atm $C_{p,m}(g) = 50.0$ JK⁻¹ mol⁻¹.

Sol.

29. A heat engine absorbs 760 kJ heat from a source at 380 K. It rejects (i) 650 kJ, (ii) 560 kJ, (iii) 504 kJ of heat to sink at 280 K. State which of these represent a reversible, an irreversible and an impossible cycle.

Sol.

MOTION IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
Nurturing potential through education

Gibb's Function

31. Calculate the free energy change at 298 K for the reaction ;

$\text{Br}_2(l) + \text{Cl}_2(g) \rightarrow 2\text{BrCl}(g)$. For the reaction $\Delta H^\circ = 29.3$ kJ & the entropies of $\text{Br}_2(l)$, $\text{Cl}_2(g)$ & $\text{BrCl}(g)$ at the 298 K are 152.3, 223.0, 239.7 J mol⁻¹ K⁻¹ respectively.
Sol.

32. Using the data given below, establish that the vaporization of $\text{CCl}_4(l)$ 298 K to produce $\text{CCl}_4(g)$ at 1atm pressure does not occur spontaneously.

Given : $\text{CCl}_4(l, 1\text{atm}) \rightarrow \text{CCl}_4(g, 1\text{atm})$;

$$\Delta S^\circ = 94.98 \text{ JK}^{-1} \text{ mol}^{-1}$$

$$\Delta H_f^\circ (\text{CCl}_4, g) = -106.7 \text{ kJ mol}^{-1}$$

$$\& \Delta H_f^\circ (\text{CCl}_4, l) = -139.3 \text{ kJ mol}^{-1}$$

Sol.

33. Animals operate under conditions of constant pressure and most of the processes that maintain life are electrical (in a broad sense). How much energy is available for sustaining this type of muscular and nervous activity from the combustion of 1 mol of glucose molecules under standard conditions at 37°C (blood temperature)? The entropy change is +182.4 JK⁻¹ for the reaction as stated.

$$\Delta H_{\text{combustion}}[\text{glucose}] = -2808 \text{ KJ}$$

Sol.



(i) Calculate $\Delta_r H_{298}^\circ$ (ii) Calculate $\Delta_r G_{298}^\circ$

(iii) Calculate $\Delta_r S_{298}^\circ$ (iv) Calculate $\Delta_r E_{298}^\circ$

(v) Calculate $S_{298}^\circ [\text{H}_2\text{O}(\text{g})]$

Sol.

34. At 298 K, $\Delta H_{\text{combustion}}^\circ (\text{sucrose}) = -5737 \text{ kJ/mol}$,

$\Delta G_{\text{combustion}}^\circ (\text{sucrose}) = -6333 \text{ kJ/mol}$.

Estimate additional non-PV work that is obtained by raising temperature to 310 K.

Assume $\Delta_r C_p = 0$ for this temperature change

Sol.

MOTION IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
Nurturing potential through education

35. From the given table answer the following questions

	$\text{CO}(\text{g})$	$\text{CO}_2(\text{g})$	$\text{H}_2\text{O}(\text{g})$	$\text{H}_2(\text{g})$
ΔH_{298}° (-KCal/mole)	-26.42	-94.05	-57.8	0
ΔG_{298}° (-KCal/mole)	-32.79	-94.24	-54.64	0
S_{298}° (-Cal/Kmole)	47.3	51.1	?	31.2

Exercise - IV**Subjective Level-II**

1. Calculate workdone in adiabatic compression of one mole of an ideal gas (monoatomic) from an initial pressure of 1 atm to final pressure of 2 atm. Initial temperature = 300 K.

- (a) If process is carried out reversibly
(b) If process is carried out irreversible against 2 atm external pressure.

Compute the final volume reached by gas in two cases and describe the work graphically.

2. 0.5 mole each of two ideal gases A ($C_v = \frac{3}{2}R$) and B ($C_v = \frac{5}{2}R$) are taken in a container and expanded

reversibly and adiabatically from $V = 1$ L to $V = 4$ L starting from initial temperature $T = 300$ K.

Find ΔH for the process in (cal/mol).

3. 20.0 dm³ of an ideal gas (diatomic $C_{v,m} = 5R/2$) at 673 K and 0.7 MPa expands until pressure of the gas is 0.2 MPa. Calculate q , w , ΔU and ΔH for the process if the expansion is :

- (i) Isothermal and reversible
(ii) Adiabatic and reversible
(iii) Isothermal and adiabatic
(iv) Against 0.2 MPa and adiabatic
(v) Against 0.2 MPa and isothermal.

4. One mole of a ideal monoatomic gas ($C_{v,m} = 1.5 R$) is subjected to the following sequence of steps :

- (a) The gas is heated reversibly at constant pressure of 101.325 kPa from 298 K to 373 K.
(b) Next, the gas is expanded reversibly and isothermally to double its volume.
(c) Finally, the gas is cooled reversibly and adiabatically to 308 K.

Calculate q , w , ΔU and ΔH for the overall process.

5. 2 mole of an ideal gas undergoes isothermal compression along three different paths

- (i) reversible compression from $P_i = 2$ bar and $V_i = 4$ L to $P_f = 20$ bar
(ii) a single stage compression against a constant external pressure of 20 bar, and
(iii) a two stage compression consisting initially of compression against a constant external pressure of 10 bar until $P_{\text{gas}} = P_{\text{ext}}$, followed by compression against a constant pressure of 20 bar until $P_{\text{gas}} = P_{\text{ext}}$.

Calculate the work (in bar. L) for each of these processes and for which of the irreversible processes is the magnitude of the work greater ? [Given : $R = 0.08$ bar.L/mole.K]

6. Calculate the heat of vaporisation of water per gm at 25°C and 1 atm.

Given $\Delta H_f^0[\text{H}_2\text{O}(l)] = -285.57$ kJ/mol

$\Delta H_f^0[\text{H}_2\text{O}(g)] = -241.6$ kJ/mol

Comment why $\Delta H_{\text{vap}}(25^\circ\text{C}) > \Delta H_{\text{vap}}(100^\circ\text{C})$

7. Given: $\Delta_{\text{vap}} H$ at 373 K = 40.639 kJ mol⁻¹,

$C_p(\text{H}_2\text{O}, l) = 75.312$ J K⁻¹ mol⁻¹,

$C_p(\text{H}_2\text{O}, g) = 33.305$ J K⁻¹ mol⁻¹.

Pressure over 1000 ml of a liquid is gradually increases from 1 bar to 1001 bar under adiabatic conditions. If the final volume of the liquid is 990 ml, calculate ΔU and ΔH of the process, assuming linear variation of volume with pressure.

8. (a) An ideal gas undergoes a single stage expansion against a constant opposing pressure from (P_1, V_1, T) to (P_2, V_2, T) . What is the largest mass m which mass m which can be lifted through a height h in this expansion?

(b) The system in (a) restored to initial state by a single compression. What is the smallest mass 'm' which must fall through the height h to restore the system?

(c) What is the net mass lowered through height h in the cycle transformation in (a) and (b) ?

9. The vapour pressure of $\text{H}_2\text{O}(l)$ at 353 K is 532 mm Hg. The external pressure on $\text{H}_2\text{O}(l)$ taken in a cylinder fitted with frictionless movable piston initially containing 0.9 L (= 0.9 kg) of $\text{H}_2\text{O}(l)$ at 353 K is increased to 1 atm. Temperature remained constant. Now, heat is supplied keeping pressure constant till 0.45 L of $\text{H}_2\text{O}(l)$ (= 0.45 kg) is evaporated to form $\text{H}_2\text{O}(g)$ at 373 K. Carefully observe the diagrams provided and from given data, answer the following questions.

(a) ΔH when system is taken from state 1 to state 2 (Joule) ?

(b) Total change in ΔU going from state 1 to 3 (kJ) ?

(c) Total change in enthalpy going from state 1 to state 3 (kJ) ?

Given : Specific heat of $\text{H}_2\text{O} = 4.2 \text{ J/gm } ^\circ\text{C}$

ΔH_{vap} at 373 K and 1 atm = +40 kJ/mol

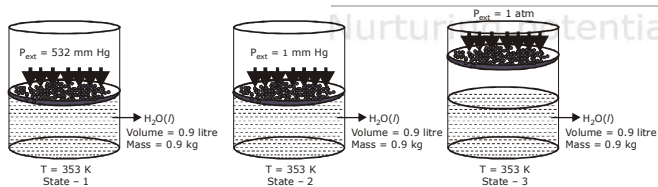
1 atm = 760 mm Hg

Use

1 L atm = 100 Joule

$R = 8 \text{ Joule/mole K}$

(Assume internal energy of liquid to be dependent only on temperature).



10. Derive a mathematical expression for the work done on the surrounding when a gas that has the equation of state $PV = nRT - \frac{n^2a}{V}$ expands reversibly from V_i to V_f at constant temperature.

11. Calculate ΔS_f° at 298 K of ; (i) $\text{NaCl}(s)$, (ii) $\text{NH}_4\text{Cl}(s)$ & diamond. The values of S° of Na, Cl_2 , NaCl , NH_4Cl , N_2 , H_2 , diamond & graphite are 51, 223, 72, 95, 192, 131, 2.43 & 5.69 $\text{JK}^{-1} \text{mol}^{-1}$ respectively.

12. One mole of an ideal gas is expanded isothermally at 298 K until its volume is tripled. Find the values of ΔS_{gas} and ΔS_{total} under the following conditions.

(i) Expansion is carried out reversibly.

(ii) Expansion is carried out irreversibly where 836.8 J of heat is less absorbed than in (i)

(iii) Expansion is free.

13. The enthalpy change for vapourization of liquid 'A' at 200 K and 1 atm is 22 kJ/mol. Find out $\Delta S_{\text{vapourisation}}$ for liquid 'A' at 200 K ? The normal Boiling point of liquid 'A' is 300 K.

$A(l) [200 \text{ K}, 1 \text{ atm}] \rightarrow A(g) [200 \text{ K}, 1 \text{ atm}]$

Given : $C_{p,m}(A, g) = 30 \text{ J/mol-K}$, $C_{p,m}(A, l) = 40 \text{ J/mol-K}$

Use : $\ln(3/2) = 0.405$

14. Pressure of 10 moles of an ideal gas is changed from 2 atm to 1 atm against constant external pressure without change in temperature. If surrounding temperature (300 K) and pressure (1 atm) always remains constant then calculate total entropy change ($\Delta S_{\text{system}} + \Delta S_{\text{surrounding}}$) for given process.

[Use : $\ln 2 = 0.70$ and $R = 8.0 \text{ J/mol-K}$]

15. Compute, $\Delta_r G$ for the reaction

$\text{H}_2\text{O}(l, 1 \text{ atm}, 323 \text{ K}) \rightarrow \text{H}_2\text{O}(g, 1 \text{ atm}, 323 \text{ K})$

Given that, $\Delta_{\text{vap}} H$ at 373 K = 40.639 kJ mol⁻¹, $C_p(\text{H}_2\text{O}, l) = 75.312 \text{ J K}^{-1} \text{mol}^{-1}$,

$C_p(\text{H}_2\text{O}, g) = 33.305 \text{ J K}^{-1} \text{mol}^{-1}$.

Exercise - V

JEE-Problems

1. Among the following, the state function(s) is (are)

- (A) Internal energy
(B) Irreversible expansion work
(C) Reversible expansion (D) Molar enthalpy

Sol.

[JEE 2009]

2. **Statement-I** : There is a natural asymmetry between converting work to heat and converting heat to work.

Statement-II : No process is possible in which the sole result is the absorption of heat from a reservoir and its complete conversion into work.

- (A) **Statement-I** is True, **Statement-II** is True, **Statement-II** is a correct explanation for **Statement-I**
(B) **Statement-I** is True, **Statement-II** is True, **Statement-II** is NOT a correct explanation for **Statement-I**
(C) **Statement-I** is True, **Statement-II** is False
(D) **Statement-I** is False, **Statement-II** is True

Sol.

[JEE 2008]

3. For the process $\text{H}_2\text{O}(l)$ (1 bar, 373 K) \rightarrow $\text{H}_2\text{O}(g)$ (1 bar, 373 K), the correct set of thermodynamic parameters is

- (A) $\Delta G = 0$, $\Delta S = +ve$ (B) $\Delta G = 0$, $\Delta S = -ve$
(C) $\Delta G = +ve$, $\Delta S = 0$ (D) $\Delta G = -ve$, $\Delta S = +ve$

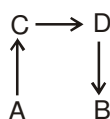
Sol.

[JEE 2007]

4. A process $A \rightarrow B$ is difficult to occur directly instead it takes place in the three successive steps.

$$\Delta S (A \rightarrow C) = 50 \text{ e.u.}$$

$$\Delta S (C \rightarrow D) = 30 \text{ e.u.}$$



$\Delta S (B \rightarrow D) = 20 \text{ e.u.}$ where e.u. is entropy unit.

Then the entropy change for the process $\Delta S (A \rightarrow B)$ is:

- (A) +100 e.u. (B) -60 e.u.
(C) -100 e.u. (D) +60 e.u.

Sol.

[JEE 2006]

5. The molar heat capacity of a monoatomic gas for which the ratio of pressure and volume is one.

- (A) $4/2 R$ (B) $3/2 R$ (C) $5/2 R$ (D) zero

Sol.

[JEE 2006]

MOTION IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
Nurturing potential through education

6. One mole of monoatomic ideal gas expands adiabatically at initial temp. T against a constant external pressure of 1 atm from one litre to two litre. Find out the final temp. ($R = 0.0821 \text{ litre. atm K}^{-1} \text{ mol}^{-1}$):

- (A) T (B) $\frac{T}{(2)^{5/3-1}}$ (C) $T - \frac{2}{3 \times 0.0821}$ (D) $T + \frac{2}{3 \times 0.0821}$

Sol.

[JEE 2005]

7. Two mole of an ideal gas is expanded isothermally and reversibly from 1 litre to 10 litre at 300 K. The enthalpy change (in kJ) for the process is

- (A) 11.4 kJ (B) -11.4 kJ (C) 0 kJ (D) 4.8 kJ

Sol.

[JEE 2004]

Sol.

[JEE 2004]

9. One mol of non-ideal gas undergoes change of state (2.0 atm, 3.0 L, 95 K) to (4.0 atm, 5.0 L, 245 K) with a change in internal energy (ΔU) = 30.0 L-atm. The change in enthalpy (ΔH) of the process in L-atm

- (A) 40.0 (B) 42.3 (C) 44.0

(D) not defined, because pressure is not constant

[JEE 2002]

Sol.

MOTION IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
Nurturing potential through education

8. The enthalpy of vapourization of a liquid is 30 kJ mol⁻¹ and entropy of vapourization is 75 J mol⁻¹ K. The boiling point of the liquid at 1 atm is

- (A) 250 K (B) 400 K (C) 450 K (D) 600 K

10. Which of the following statement is false ?

- (A) Work is a state function
- (B) Temperature is a state function
- (C) Change of state is completely defined when initial and final states are specified.
- (D) Work appears at the boundary of the system

Sol. [JEE 2001]

11. For the reaction.



In one litre vessel at 500 K the initial pressure is 70 atm and after the reaction it becomes 40 atm at constant volume of one litre. Calculate change in internal energy. All the above gases show significant deviation from ideal behaviour. (1 L atm = 0.1 kJ)

Sol. [JEE 2006]

13. Two moles of a perfect gas undergoes the following processes : [JEE 2002]

- (a) a reversible isobaric expansion from (1.0 atm, 20.0 L) to (1.0 atm, 40.0 L) ;
- (b) a reversible isochoric change of state from (1.0 atm, 40.0 L) to (0.5 atm, 40.0 L) ;
- (c) a reversible isothermal compression from (0.5 atm, 40.0 L) to (1.0 atm, 20.0 L) ;
- (i) Sketch with labels each of the processes on the same P-V diagram.
- (ii) Calculate the total work (w) and the total heat change (q) involved in the above processes.
- (iii) What will be the values of ΔU , ΔH and ΔS for the overall process ?

Sol.

12. One mole of a liquid (1 bar, 100 ml) is taken in an adiabatic container and the pressure increases steeply to 100 bar. Then at a constant pressure of 100 bar, volume decreases by 1 ml. Find ΔU and ΔH

Sol. [JEE 2004]

MOTION IIT-JEE | AIEEE
CBSE | SAT | NTSE
OLYMPIADS
Nurturing potential through education

14. Show that the reaction $\text{CO(g)} + \frac{1}{2}\text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)}$ at 300 K is spontaneous and exothermic, when the standard entropy is $-0.094 \text{ kJ mol}^{-1}\text{K}^{-1}$. The standard Gibbs free energies of formation for CO_2 and CO are -394.4 and $-137.2 \text{ kJ mol}^{-1}$, respectively.

Sol.

[JEE 2001]

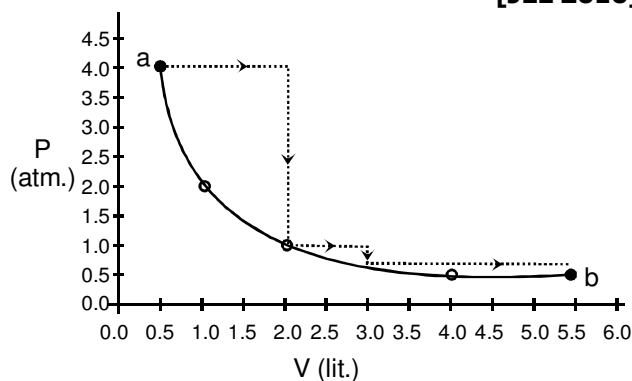
15. A sample of argon gas at 1 atm pressure and 27° expands reversibly and adiabatically from 1.25 dm^3 to 2.50 dm^3 . Calculate the enthalpy change in this process. $C_{v,m}$ for argon is $12.48 \text{ JK}^{-1} \text{ mol}^{-1}$.

Sol.

[JEE 2000]

16. One mole of an ideal gas is taken from a to b along two paths denoted by the solid and the dashed lines as shown in the graph below. If the work done along the solid line path is w_s and that along the dotted line path is w_d , then integer closest to the ratio w_d/w_s is

[JEE 2010]



Sol.

17. Match the transformations in **Column-I** with appropriate options in **Column-II**. [JEE 2011]

Column-I	Column-II
(A) $\text{CO}_2\text{(s)} \rightarrow \text{CO}_2\text{(g)}$	(P) Phase transition
(B) $\text{CaCO}_3\text{(s)} \rightarrow \text{CaO(s)} + \text{CO}_2\text{(g)}$	(Q) allotropic change
(C) $2\text{H}^\bullet \rightarrow \text{H}_2\text{(g)}$	(R) ΔH is positive
(D) $\text{P}_{(\text{white, solid})} \rightarrow \text{P}_{(\text{red, solid})}$	(S) ΔS is positive
	(T) ΔS is negative

Sol.

ANSWER-KEY

Exercise-I

- | | | | | | | | |
|--|-------|-------|-------|--|-------|-------|-------|
| 1. C | 2. D | 3. D | 4. B | 5. C | 6. B | 7. C | 8. A |
| 9. B | 10. C | 11. D | 12. C | 13. A | 14. C | 15. C | 16. D |
| 17. A | 18. A | 19. B | 20. C | 21. A | 22. C | 23. D | 24. C |
| 25. A | 26. C | 27. C | 28. C | 29. D | 30. C | 31. D | 32. D |
| 33. D | 34. D | 35. D | 36. A | 37. B | 38. C | 39. C | 40. B |
| 41. B | 42. C | 43. B | 44. B | 45. (A) \rightarrow P,R,S, (B) \rightarrow Q,R,S, (C) \rightarrow Q,R,S, (D) \rightarrow R,S | | | |
| 46. (A) \rightarrow S, (B) \rightarrow P,R (C) \rightarrow P,S, (D) \rightarrow P, R | | | | 47. (A) \rightarrow P,S, (B) \rightarrow P,R,S, (C) \rightarrow Q, (D) \rightarrow R,S | | | |
| 48. (A) \rightarrow Q, (B) \rightarrow P,S, (C) \rightarrow P,S, (D) \rightarrow S | | | | 49. (A) \rightarrow P,S,R (B) \rightarrow R, (C) \rightarrow P, (D) \rightarrow Q,R,S | | | |

Exercise-II

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

Exercise-III

- | | | |
|--|--|--|
| 1. (i) w, (ii) $-w$, (iii) $-w$, (iv) w, (v) $-w$ | 2. $q = -65 \text{ J}$; $w = 20 \text{ J}$; $\Delta E = -45 \text{ J}$ | |
| 3. -0.3024 kJ | 4. (a) 0.47 gm , (b) 0.47 kg | 5. $\Delta E = 75.11 \text{ kJ}$ |
| 6. $\Delta E = 0.993 \text{ kcal}$, $\Delta H = 1 \text{ kcal}$ | 7. -741.5 kJ | 8. $\Delta H \cong \Delta E = 1440 \text{ calories}$ |
| 9. -10 J | 10. $q = 177.9 \text{ kJ}$, $w = -2.5 \text{ kJ}$; $\Delta E = 175.4 \text{ kJ}$ | |
| 11. $\Delta E = -39.03 \text{ KJ/mole}$; $q = -36.5 \text{ kJ}$; $w = -2.53 \text{ kJ}$ | 12. $\Delta U = w = -1247.1$; $\Delta H = -1745.94 \text{ J}$ | |
| 13. (i) yes (ii) $w = 0$; $q = \Delta E = 6000 \text{ J}$; $\Delta H = 9325.6 \text{ J}$ | 14. -1.683 kJ | |
| 15. $T_2 = 100 \text{ K}$; $w = 5.016 \text{ KJ}$ | 16. $q = 0$; $w = \Delta U = 4.12 \text{ KJ}$; $\Delta H = 5.37 \text{ KJ}$; $V_f = 11.8 \text{ dm}^3$; $P = 5.21 \text{ atm}$ | |
| 17. $C_{V,m} = 31.6 \text{ JK}^{-1}\text{mol}^{-1}$ | 18. $w = -3.988 \text{ kJ}$ | |

$$19. w = -P_0 V_0 ; q_{CA} = -\frac{5}{2} P^\circ V^\circ ; q_{AB} = 3P^\circ V^\circ ; q_{BC} = \frac{1}{2} P^\circ V^\circ T_{\max} = \frac{25}{8} \left(\frac{P^\circ V^\circ}{R} \right)$$

Table - 1

State	P	V	T
1	1 atm	22.4	273
2	2 atm	22.4	546
3	1 atm	44.8	546

20.

Step	Name of process	q	w	ΔE	ΔH
A	Isochoric	$3/2 R(273)$	0	$3/2 R(273)$	$5/2 R(273)$
B	Isothermal	$546 R \ln 2$	$-546 R \ln 2$	0	0
C	Isobaric	$-5/2 R(273)$	$R(273)$	$-3/2 R(273)$	$-5/2 R(273)$

21.

State	P	V	T
1	1 atm	22.4	273
2	1	44.8	546
3	0.5	44.8	273

Step	Name of process	q	w	ΔE	ΔH
A	Isobaric	$5/2 R(273)$	$-R(273)$	$3/2 R(273)$	$5/2 R(273)$
B	Isochoric	$-3/2 R(273)$	0	$-3/2 R(273)$	$-5/2 R(273)$
C	Isothermal	$-273 R \ln 2$	$273 R \ln 2$	0	0
	Cyclic	$R(273) - 273 R \ln 2$	$-R(273) - R \ln 2$	0	0

22. (a) $T_1 = 243.60 \text{ K}$; $T_2 = 2436.0 \text{ K}$, (b) $\Delta E = 0$; $q = -w = +3262.88 \text{ cal}$

23. (a) AC, (b) 170 J, (c) 10 J

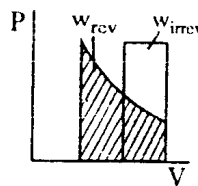
24. (a) 600 K, (b) $q_{AB} = 3000 \text{ cal}$; $q_{BC} = 1663 \text{ cal}$; $q_{CD} = -1800 \text{ cal}$; $q_{DA} = -1663 \text{ cal}$; Total $q = 1200 \text{ cal}$,
(c) $w = -1200 \text{ cal}$ 25. $\Delta H_{373}^\circ (\text{H}_2\text{O}(l)) = -284.11 \text{ kJ}$ 26. (a) $13.064 \text{ kJ mol}^{-1}$, (b) $10.587 \text{ kJ mol}^{-1}$ 27. $T = 1059 \text{ K}$ 28. $21.18 \text{ JK}^{-1} \text{ mol}^{-1}$

29. (i) irreversible, (ii) reversible, (iii) impossible (Where Faith Counts the Success)

30. $205.08 \text{ JK}^{-1} \text{ mol}^{-1}$ 31. -1721.8 J 32. $\Delta G^\circ = 4.3 \text{ kJ mol}^{-1}$ 33. -2864.5 KJ 34. 24 kJ/mol 35. (i) -9.83 Kcal/mole , (ii) -6.81 Kcal/mole , (iii) -10.13 Cal/Kmole , (iv) -9.83 Kcal/mole
(v) $+45.13 \text{ Cal/Kmole}$ 

Exercise-IV

1. (a) $T_2 = 395.8$; $V_2 = 16.24$ L; $w_{rev} = 1194.72$ J,
 (b) $V_2' = 17.24$ L; $T_2' = 420$ K, $w_{irrev} = 1496.52$ J



2. -900 calories
3. (i) $q = -w = 17.54$ kJ, $\Delta U = 0$ and $\Delta H = 0$; (ii) $q = 0$, $w = \Delta U = -10.536$ kJ and $\Delta H = -14.75$ kJ
 (iii) $q = 0$, $w = 0$, $\Delta U = 0$ and $\Delta H = 0$ (iv) $q = 0$; $\Delta U = w = -7.14$ KJ; $\Delta H = -9.996$ KJ,
 (v) $q = -w = 10.0$ KJ, $\Delta U = \Delta H = 0$
4. (a) $q = \Delta H = 1558.88$, $\Delta U = 935.33$; $w = -P(\Delta U) = -623.55$ J mol $^{-1}$
 (b) $w = -2149.7$; ΔU & $\Delta H = 0$, $q = -w$
 (c) $q = 0$, $w = -810.62$, $\Delta H = -1351.03$ J mol $^{-1}$
 for overall process $q = 3708.59$; $w = -3583.88$, $\Delta U = 124.71$; $\Delta H = 207.85$
5. (i) 18.424 bar. L; (ii) 72 bar. L; (iii) 40 bar L.
 Magnitude of work is maximum in single stage compression
6. $\Delta H_{vap}(25^\circ\text{C}) = 43.97$ kJ/mol = 2.433 kJ/gm, $\Delta H_{vap}(100^\circ\text{C}) = 40.62$ KJ/mol (given)
7. $\Delta U = 501$ J; $\Delta H = 99.5$ KJ
8. (a) $m = \frac{nRT}{gh} \left(1 - \frac{P_2}{P_1} \right)$, (b) $m' = \frac{nRT}{gh} \left(\frac{P_1}{P_2} - 1 \right)$ (c) $m' - m = \frac{nRT}{gh} \left(\frac{(P_1 - P_2)^2}{P_1 P_2} \right)$
9. (a) 27 Joule, (b) 1001 kJ, (c) 1075.627 kJ
10. $w = -nRT \ln \frac{V_f}{V_i} - n^2 a \left(\frac{1}{V_f} - \frac{1}{V_i} \right)$

Exercise-V

(Where Faith Counts the Success)

1. A,D 2. A 3. A 4. D 5. A 6. C 7. C
8. B 9. C 10. A 11. -557 kJ/mol
12. $\Delta U = 0.1$ litre atm, $\Delta H = 9.9$ litre atm 13. (ii) $-w = q = 620.77$ J, (iii) $\Delta H = 0$, $\Delta U = 0$, $\Delta S = 0$
14. $\Delta H^\circ = -285.4$ kJ/mol, $\Delta G^\circ = -257.2$ kJ/mol 15. $\Delta H \approx -115$ J 16. 0002
17. A-PRS, B-RS, C-T, D-QR