Thermodynamics

Previous Year Questions

GATE 1990 – 2023

Devendra Poonia

Q.1. Isothermal mixing of pure gases always results in a decrease in the ……. Hence work has to be done ………the system for separating a mixture of gases into its components.

GATE – 1990

Q.2. A system of unite mass at equilibrium consists of two phases, a and b of extent x and (1-x) respectively. Write down expressions for the pressure and the specific enthalpy of the system as a whole in terms of the properties P^α , P^β ,h^α , h^β.

GATE – 1990

Q.3. The maximum work obtainable from a closed system under isothermal operation is given by ……………….
For one mole of an ideal gas expanding isothermally to twice its volume , this is equal to ……..…..…………

GATE – 1990

Q.4. The minimum work required for steady isothermal compression of a real gas is given by …………
For one mole of an ideal gas that is compressed isothermally from one to two atmosphere , this is equal to ………….

GATE – 1990

Q.5. Solid calcium oxalate dissociates at high temperature into solid calcium carbonate and carbon monoxide,

$$CaC_2O_4 \text{ (S)} = CaCO_3 \text{ (S)} + CO \text{ (g)}$$

The equilibrium pressure of CO between 670 and 700 K is given by

$$P \text{ (atm)} = 14.4 - 9600 / T$$

where T is in K. Assuming ideal behavior, calculate $\Delta G°$, $\Delta H°$ and $\Delta S°$ at 675 K.

GATE – 1990

Q.6. For a gas obeying the van-der-Waal's equation, at the critical temperature,
(A) Both $(\delta p/\delta v)_T$ and $(\delta^2 p/\delta v^2)_T$ are zero.
(B) The first derivative is zero, while the second derivative is non-zero.
(C) The second derivative is zero, while the first derivative is non-zero.
(D) Both the derivatives are non-zero.

GATE – 1991

Q.7. For an ideal gas the slope of the pressure-volume curve, at a given point will be,
(A) Steeper for an isothermal than for an adiabatic process.
(B) Steeper for an adiabatic than for an isothermal process.
(C) Identical for both the processes.
(D) of opposite signs.

GATE – 1991

Q.8. For a system in equilibrium, at a given temperature and pressure:
(A) The entropy must be a minimum
(B) The enthalpy must be a minimum
(C) The internal energy must be a minimum
(D) The Gibbs-free energy must be a minimum

GATE – 1991

Q.9. To obtain the integrated form of Clausius-Clapeyron equation,

$$\ln \frac{p_2}{p_1} = \frac{\Delta H_v}{R}\left[\frac{1}{T_1} - \frac{1}{T_2}\right]$$

from the exact Clapeyron equation, it is assumed that:
(A) The volume of the liquid phase is negligible compared to that of the vapor size.
(B) The vapor phase behaves as ideal gas.
(C) The heat of vaporization is independent of temperature.
(D) All the above are applicable.

GATE – 1991

Q.10. The shape of T-s diagram for Carnot cycle is,
(A) A rectangle
(B) A rhombus
(C) A trapezoid
(D) A circle

GATE – 1991

Q.11. Calculate the fraction of pure ethane that would dehydrogenate at 750 K and 5 atmosphere, if the following reaction goes to equilibrium.
$$C_2H_6 \text{ (g)} \rightleftharpoons C_2H_4 \text{ (g)} + H_2 \text{ (g)};$$
$\Delta G°$ for the reaction at 750 K = 42.576 kJ. Assume ideal gas behavior.

GATE – 1991

Q.12. At 318 K at total pressure of 24.4 kPa, the composition of system ethanol (1) and toluene (2) at equilibrium $x_1 = 0.3$ and $y_1 = 0.634$. The saturation pressure at the given temperature for pure components is, $P_1 = 23.08$ kPa and $P_2 = 10.05$ kPa, respectively. Calculate:

(a) The liquid phase activity coefficients.

(b) The value of $G^{E/RT}$ for the liquid phase.

GATE – 1991

Q.13. Write expressions for,
(A) van't Hoff equation
(B) van-der-Waals equation of state

GATE – 1992

Q.14. During Joule-Thompson expansion of gases,
(A) Enthalpy remains constant
(B) Entropy remains constant
(C) Temperature remains constant
(D) None of the above

GATE – 1992

Q.15. The necessary and sufficient condition for equilibrium between two phases is,
(A) Condition of each component should be same in the two phases
(B) The temperature of each phase should be same
(C) The pressure should be same in the two phases
(D) The chemical potential of each component should be same in the two phases

GATE – 1992

Q.16. For a single component, two-phase mixture the number of independent variable properties are,
(A) Two
(B) One
(C) Zero
(D) Three

GATE – 1992

Q.17. 10^6 Joules of heat are transferred from a reservoir at 327 °C to an engine that operates on the Carnot cycle. The engine rejects heat to a reservoir at 27 °C. Determine the thermal efficiency of the cycle and work done by the engine.

GATE – 1992

Q.18. An inventor claims to have developed a refrigeration unit which maintains the refrigerated space at -3 °C while operating in a room where the temperature is 27 °C, and which has a coefficient of performance of 9.5. How do you evaluate his claim?

GATE – 1992

Q.19. Consider the compression of air from 10^5 Pa at 27°C to 3×10^6 Pa in an ideal two stage compressor with intercooling. Assume that the temperature of the air leaving the intercooler is also 27°C, and that the optimum interstate pressure is used. The compressor is water-jacketed and the polytropic exponent n is 1.30 for both stages. Determine the work of compression per kg of air.

GATE – 1992

Q.20. Ideal gas law is applicable at,
(A) low T, low P
(B) high T, high P
(C) low T, high P
(D) high T, low P

GATE – 1994

Q.21. The second law of thermodynamics states that,
(A) The energy change of a system undergoing any reversible process is zero
(B) It is not possible to transfer heat from a lower temperature to a higher temperature
(C) The total energy of the system and surroundings remain constant
(D) None of the above

GATE – 1994

Q.22. Fill the blanks.
(i) The heat of formation of a compound is defined as the heat of reaction leading to the formation of the compound from it's _____
(ii) The phase rule is given as _____

GATE – 1994

Q.23. True/False
(i)   Pressure is an extensive property
(ii) Work done by a gas during free expansion is zero
(iii) A process is irreversible as long as Δs for the system is greater than zero.
(iv) The mechanical work done by a system is always equal to $\int$ Pdv.

GATE – 1994

Q.24. (I) dH   (A) T ds -P dv

    (II) dG   (B) T ds +vdP

                      (C) –P dV –s dT

                      (D) v dP - sdT

GATE – 1994

Q.25. (I) For any cyclic process   (A) $\Delta U=0$
      (II) For any adiabatic process (B) $Q=0$
                                       (C) $W=0$
                                       (D) ΔU, Q and W are all$=0$

GATE – 1994

Q.26. An experimental determination of a vapor liquid equilibrium state of ether (1) and acetone (2) binary system gave the following result:

$x_1 = 0.3$, T = 40°C,

$y_2 = 0.42$, P = 10^5 Pa.

The saturation vapor pressures of the pure components at 40°C are,

Ether (1) = 1.21 x 10^5 Pa

Acetone (2) = 0.56 x 10^5 Pa

The vapor phase can be assumed to be ideal.

(a) Calculate the liquid phase activities coefficients

(b) What is the value of excess Gibbs free energy G^E/RT for the liquid phase?

GATE – 1994

Q.27. A solid is transformed into vapour without going through the liquid phase at
(A) triple point
(B) boiling point
(C) below triple point
(D) always

GATE – 1995

Q.28. At the inversion point, the Joule-Thompson coefficient is
(A) positive
(B) negative
(C) zero
(D) none of the above

GATE – 1995

Q.29. The kinetic energy of gas molecules is zero at
(A) $0\ {}^{0}C$
(B) $273\ {}^{0}C$
(C) $100\ {}^{0}C$
(D) $-273\ {}^{0}C$

GATE – 1995

Q.30. A closed system is cooled reversely from 100 ^{0}C to 50 ^{0}C. If no work is done on the system.

(A) Its internal energy (U) decreases and its entropy (S) increases
(B) U and S both decrease
(C) U decreases but S is constant
(D) U is constant but S decreases

GATE – 1995

Q.31. Calculate the change in entropy when one gram of ice at 0 ^{0}C is converted into steam at 100 ^{0}C. Latent heat of fusion of ice = 80 cal/s. Latent heat of vaporization = 540 cal/g mean specific heat of water between 0 ^{0}C and 100 ^{0}C = 1.

GATE – 1995

Q.32. The number of degrees of freedom for a mixture of ice and water (liquid) are :
(A) 2
(B) 3
(C) 1
(D) 0

GATE – 1996

Q.33. The equation $dU = TdS - PdV$ is applicable to infinitesimal changes occurring in :
(A) an open system of constant composition
(B) a closed system of constant composition
(C) an open system with changes in composition
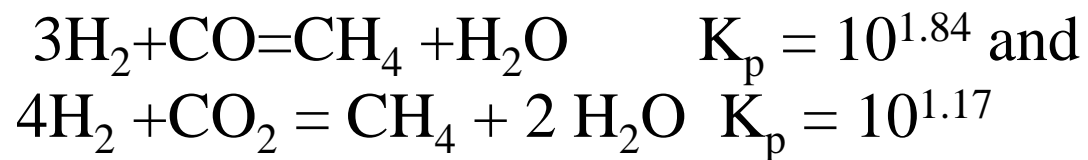(D) a closed system with changes in composition

GATE – 1996

Q.34. The theoretical minimum work required to separate one mole of a liquid mixture at 1 atm, containing 50 mole % each of n-heptane and noctane into pure compounds each at 1 atm is :

(A) -2 RT ln 0.5

(B) -RT ln 0.5

(C) 0.5 RT

(D) 2 RT

GATE – 1996

Q.35. Given

$$3H_2 + CO = CH_4 + H_2O \qquad K_p = 10^{1.84} \text{ and}$$
$$4H_2 + CO_2 = CH_4 + 2H_2O \quad K_p = 10^{1.17}$$

the K_p for the reaction $CO + H_2O = CO_2 + H_2$ is
(A) $10^{3.01}$
(B) $10^{-0.67}$
(C) $10^{-3.01}$
(D) $10^{0.67}$

GATE – 1996

Q.36. The activity coefficients of benzene (A)–cyclohexane (B) mixtures at 40 ^{0}C, are given by RT $\ln g_A = bx_B^2$ and RT $\ln g_B = bx_A^2$. At 40 ^{0}C. A and B form an azeotrope containing 49.4 mol % A at a total pressure of 202.5 mm Hg. If the vapour pressures of pure A and pure B are 182.6 and 183.5 mm Hg respectively, calculate the total pressure of the vapour at temperature 40 ^{0}C in equilibrium with a liquid mixture containing 12.6 mol % A.

GATE – 1996

Q.37. Calculate the change in internal energy of 25 k mol of CO2 gas when it is isothermally expanded from 10132 kPa to 101.32 kPa at 373 K, the corresponding molar volumes being 0.215 m³/kmol and 30.53 m3/k.mol. Assume CO_2 to obey

$$\left[P + \frac{365}{v^2} \right] (v - 0.043) = RT$$

GATE – 1996

Q.38. Identify the extensive and intensive properties from the given list
a.   chemical potential
b.   entropy
c.   fugacity
d.   enthalpy
e.   activity coefficient

GATE – 1996

Q.39. A system undergoes a change from a given initial state to a given final state either by an irreversible process(ΔS_I) or by a reversible process (ΔS_R). Then

(A) ΔS_I is always $> \Delta S_R$

(B) ΔSI is sometimes $> \Delta S_R$

(C) ΔSI is always $< \Delta S_R$

(D) ΔS_I is always $= \Delta S_R$

Where ΔS_I and ΔS_R are the entropy changes of the system for the irreversible and reversible processes, respectively.

GATE – 1997

Q.40. The change in Gibbs free energy for vaporization of a pure substance is –
(A) Positive
(B) negative
(C) Zero
(D) may be positive or negative

GATE – 1997

Q.41. The equilibrium constant, K, for a chemical reaction depends on
(A) temperature only
(B) pressure only
(C) temperature and pressure
(D) ratio of reactants

GATE – 1997

Q.42. One mole feed of a binary mixture of a given composition is flash vapourised at a fixed P and T. If Raoult's law is obeyed, then changing the feed composition would effect.

(A) the product composition but not the fraction vapourized

(B) the product composition as well as the fraction vapourized

(C) the fraction vapourized but not the product composition

(D) neither the product composition nor the fraction vapourized

GATE – 1997

Q.43. The molar excess Gibbs free energy, g^E , for a binary liquid mixture at T and P is given by ($g^E/RT = Ax_1x_2$, where A is a constant. The corresponding equation for $\ln \gamma_1$, where γ_1 is the activity coefficient of component 1, is

(A) Ax_2^2

(B) Ax_1

(C) Ax_2

(D) Ax_1^2

GATE – 1997

Q.44. An equimolar mixture of benzene and toluene is contained in a piston/cylinder arrangement at a temperature T.

What is the maximum pressure below which this mixture will exist as a vapour phase alone?

At the given T, the vapour pressures of benzene and toluene are 1530 and 640 mm Hg, respectively. Assume that Raoult's law is valid.

GATE – 1997

Q.45. Determine the mol fraction of methane, x_1 , dissolved in a light oil at 200 K and 20 bar. Henry's law is valid for the liquid phase, and the gas phase may be assumed to be an ideal solution.
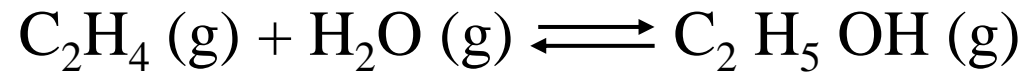
At these conditions,

Henry's law constant for methane in oil = 200 bar

Fugacity coefficient of pure methane gas = 0.90 Mol.

fraction of methane in the gas phase, y_1 = 0.95

GATE – 1997

Q.46. Ethanol is manufactured by the vapour phase hydration of ethylene according to the reaction :

$$C_2H_4 \text{ (g)} + H_2O \text{ (g)} \rightleftharpoons C_2H_5OH \text{ (g)}$$

The reactor operates at 400 K and 2 bar and the feed is a gas mixture of ethylene and steam in the mol ratio 1:3. The equilibrium constant is 0.25.

Estimate the composition (mol%) of the equilibrium mixture. Assume ideal gas behaviour and take $f_1^0 = 1$ bar, where f_1^0 is the standard state fugacity of component 1. **GATE – 1997**

Q.47. A liquid mixture contains 30% o-xylene, 60% p-xylene and 10% m-xylene (all percentages in w/w). Which of the following statements would be true in respect of this mixture ?

(A) The mixture exhibits an azeotrope at 101.3 kPa

(B) The composition of the mixture, in percent by volume is : o-xylene 30, p-xylene 60 and m-xylene 10

(C) The composition of the mixture in mol percent is : o-xylene 30, p-xylene 60 and m-xylene 10

(D) The mixture contains optical isomers

GATE – 1998

Q.48. A change in state involving a decrease in entropy can be spontaneous only if
(A) it is exothermic
(B) it is isenthalpic
(C) it takes place isothermally
(D) it takes place at constant volume

GATE – 1998

Q.49. A Carnot cycle consists of the following steps :
(A) two isothermals and two isentropics
(B) two isobarics and two isothermals
(C) two isochorics and two isobarics
(D) two isothermals & two isochorics

GATE – 1998

Q.50. It is desired to bring about a certain change in the state of a system by performing work on the system under adiabatic conditions
(A) The amount of work needed is path-dependent
(B) Work alone cannot bring about such a change of state
(C) The amount of work needed is independent of path
(D) More information is needed to conclude anything about the path dependence or otherwise of the work needed

GATE – 1998

Q.51. If the heat of solution of an ideal gas in a liquid is negative, then its solubility at a given partial pressure varies with the temperature as
(A) Solubility increases as temperature increases
(B) Solubility decreases as temperature increases
(C) Solubility is independent of temperature
(D) Solubility increases or decreases with temperature depending on the Gibb's free energy change of solution

GATE – 1998

Q.52. A mixture of A and B conforms closely to Raoult's law. The pure component vapour pressures P_A sat and P_B sat in kPa are given by (t in ^0C)

$$\ln P_A^{sat} = 14.27 - \frac{2945}{t + 224}$$

$$\ln P_B^{sat} = 14.20 - \frac{2973}{t + 209}$$

If the bubble point of a certain mixture of A and B is 76 ^0C at a total pressure of 80 kPa, find the composition of the first vapour that forms.

GATE – 1998

Q.53. The reaction $N_2 + O_2 = 2NO$ takes place in the gas phase at 2700 ^{0}C and 2025 kPa. The reaction mixture initially comprises 15 mole % oxygen, 77 mole % nitrogen and the rest inerts. The standard Gibb's Free Energy change for the reaction is 113.83 kJ/mole at this temperature. Assuming ideal gas behaviour, calculate the partial pressures of all species at equilibrium.

GATE – 1998

Q.54. Which of the following is true for Virial equation of state
(A) Virial coefficients are universal constants
(B) Virial coefficient B represents three body interactions
(C) Virial coefficients are functions of temperature only
(D) For some gases, Virial equations and ideal gas equations are the same.

GATE – 1999

Q.55. A gas mixture of three components is brought in contact with a dispersion of an organic phase in water. The degrees of freedom of the system are
(A) 4   (B) 3   (C) 5   (D) 6

GATE – 1999

Q.56. Saturated solution of benzene in water is in equilibrium with a mixture of air and vapours of benzene and water at room temperature and pressure. Mole fraction of benzene in liquid is x_B and the vapour pressures of benzene and water at these conditions are p_v^n and p_v^w respectively. The partial pressure of benzene in air-vapour mixture is

(A) p_v^B　　　　(B) $x_B\, p_v^B$　　　　(C) $(p_{atm} - p_v^w)\, x_B$　　　　(D) $x_B\, p_{atm}$

GATE – 1999

Q.57. Maxwell's relation corresponding to the identity, $dH = TdS + VdP - \sum \mu_i \, dn_i$

(A) $\left(\dfrac{\delta T}{\delta V}\right)_{S,n_j} = \left(\dfrac{\delta P}{\delta S}\right)_{V,n_j}$ (B) $\left(\dfrac{\delta S}{\delta P}\right)_{T,n_j} = \left(\dfrac{\delta V}{\delta T}\right)_{P,n_j}$

(C) $\left(\dfrac{\delta S}{\delta V}\right)_{T,n_j} = \left(\dfrac{\delta P}{\delta T}\right)_{V,n_j}$ (D) $\left(\dfrac{\delta T}{\delta P}\right)_{S,n_j} = \left(\dfrac{\delta V}{\delta S}\right)_{P,n_j}$

GATE – 1999

Q.58. The vapour pressures of benzene and toluene are 3 and 4/3 atmospheres respectively. A liquid feed of 0.4 moles of benzene and 0.6 moles of toluene is vapourized. Assuming that the products are in equilibrium, the vapour phase mole fraction of benzene is

(A) 0.4   (B) 0.6   (C) 0.8   (D) 0.2

GATE – 1999

Q.59. For the binary system methanol (1) and benzene (2), the recommended values of the Wilson parameters at 68 ^{0}C are $A_{12} = 0.1751$ and $A_{21} = 0.3456$. The vapour pressure of pure species at 68 ^{0}C are $p_1^{sat} = 68.75$ kPa and $p_2^{sat} = 115.89$ kPa. Show that the given system can form an azeotrope at 68 C. Assume that the vapour behaves like an ideal gas.

GATE – 1999

Q.60. In a binary liquid solution of components A and B, if component A exhibits positive deviation from Raoult's law, then components B,
(A) exhibits positive deviation from Raoult's law
(B) exhibits negative deviation from Raoult's law
(C) obeys Raoult's law
(D) may exhibit either positive or negative deviation from Raoult's law

GATE – 2000

Q.61. Assume that benzene is insoluble in water. The normal boiling points of benzene and water are 80.1 ^{0}C and 100 ^{0}C, respectively. At a pressure of 1 atm, the boiling point of a mixture of benzene and water is

(A) 80.1 ^{0}C

(B) less than 80.1 ^{0}C

(C) 100 ^{0}C

(D) greater than 80.1 ^{0}C but less than 100 ^{0}C

GATE – 2000

Q.62. On a P-V diagram of an ideal gas, suppose a reversible adiabatic line intersects a reversible isothermal line at point A. Then at point A, the slope of the reversible adiabatic line $\left(\frac{\delta P}{\delta V}\right)_s$ and the slope of the reversible isothermal line $\left(\frac{\delta P}{\delta V}\right)_T$ are related as

(A) $\left(\dfrac{\delta P}{\delta V}\right)_s = \left(\dfrac{\delta P}{\delta V}\right)_T$

(B) $\left(\dfrac{\delta P}{\delta V}\right)_s = \left\{\left(\dfrac{\delta P}{\delta V}\right)_T\right\}^{\gamma}$

(C) $\left(\dfrac{\delta P}{\delta V}\right)_s = \gamma \left(\dfrac{\delta P}{\delta V}\right)_T$

(D) $\left(\dfrac{\delta P}{\delta V}\right)_s = \dfrac{1}{\gamma} \left(\dfrac{\delta P}{\delta V}\right)_T$
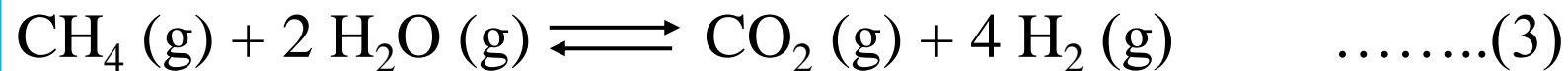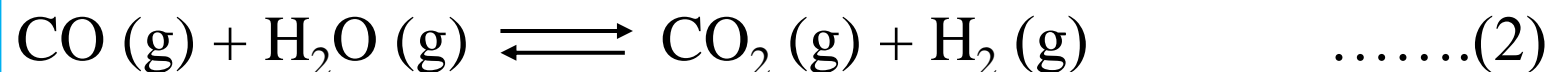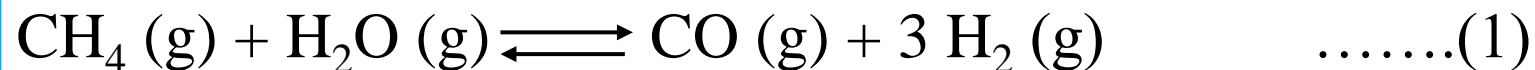
GATE – 2000

Q.63. The thermal efficiency of a reversible heat engine operating between two given thermal reservoirs is 0.4. The device is used either as a refrigerator or as a heat pump between the same reservoirs. Then the coefficient of performance as a refrigerator $(COP)_R$ and the coefficient of performance as a heat pump $(COP)_{HP}$ are
(A) $(COP)_R = (COP)_{HP} = 0.6$
(B) $(COP)_R = 2.5; (COP)_{HP} = 1.5$
(C) $(COP)_R = 1.5; (COP)_{HP} = 2.5$
(D) $(COP)_R = (COP)_{HP} = 2.5$

GATE – 2000

Q.64. At a given temperature, K_1 , K_2 and K_3 are the equilibrium constants for the following reaction 1, 2, 3 respectively :

CH_4 (g) + H_2O (g) $\rightleftharpoons$ CO (g) + 3 H_2 (g) …….(1)

CO (g) + H_2O (g) $\rightleftharpoons$ CO_2 (g) + H_2 (g) …….(2)

CH_4 (g) + 2 H_2O (g) $\rightleftharpoons$ CO_2 (g) + 4 H_2 (g) ……..(3)

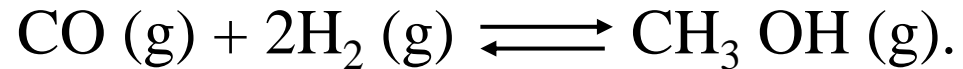Then K_1 , K_2 and K_3 are related as

(A) $K_3 = K_1 \ K_2$

(B) $K_3 = (K_1 \ K_2)^{0.5}$

(C) $K_3 = (K_1 + K_2) / 2$

(D) $K_3 = (K_1 \ K_2)^2$

GATE – 2000

Q.65. Industrial grade methanol can be produced according to the reaction

$$CO\ (g) + 2H_2\ (g) \rightleftharpoons CH_3\ OH\ (g).$$

For this reaction $\Delta G^0_{400} = -1.3484$ kJ. If an equimolal mixture of CO and H_2 is fed to a reactor maintained at 400 K and 10 bar, determine the fraction of CO that is converted into CH_3OH at equilibrium. Assume that the reaction mixture behaves like an ideal gas.

GATE – 2000

Q.66. In a binary mixture the activity coefficient y_1 of component 1, in the entire range of composition, is given by

$$R \ln \gamma_1 = A x_2^2 + B x_2^3$$

where R, A and B are constants. Derive the expression for the activity coefficient of component 2.

GATE – 2000

Q.67. A reasonably general expression for vapour-liquid phase equilibrium at low to moderate pressures is $\phi_i\, y_i\, P = \gamma_i\, x_i\, f_i^0$ Where fi is a vapour fugacity coefficient, γ_i is the liquid activity coefficient, and fi is the fugacity of pure component i. The Ki value ($y_i = K_i\, x_i$) is therefore in general, a function of

(A) temperature only

(B) temperature and pressure only

(C) temperature, pressure, and liquid composition xi only

(D) temperature pressure, liquid composition x_i, and vapour composition y_i

GATE – 2001

Q.68. High pressure steam is expanded adiabatically and reversibly through a well insulated turbine which produces some shaft work. If the enthalpy change and entropy change across the turbine are represented by ΔH and ΔS , respectively, for this process :

(A) ΔH = 0 and ΔS = 0
(B) ΔH ≠ 0 and ΔS = 0
(C) ΔH = 0 and ΔS ≠ 0
(D) ΔH = 0 and ΔS = 0

GATE – 2001

Q.69. The Maxwell relation derived from the differential expression for the Helmholtz free energy (dA) is :

(A) $\left(\dfrac{\partial T}{\partial V}\right)_s = -\left(\dfrac{\partial P}{\partial S}\right)_v$ (B) $\left(\dfrac{\partial T}{\partial P}\right)_T = -\left(\dfrac{\partial V}{\partial T}\right)_P$

(C) $\left(\dfrac{\partial V}{\partial S}\right)_P = \left(\dfrac{\partial T}{\partial P}\right)_s$ (D) $\left(\dfrac{\partial S}{\partial V}\right)_T = \left(\dfrac{\partial P}{\partial T}\right)_v$

GATE – 2001

Q.70. At 100 ^{0}C, water and methylcyclohexane both have vapour pressures of 1.0 atm. Also at 100 ^{0}C, the latent heats of vapourization of these compounds are 40.63 kJ/mol for water and 31.55 kJ/mol for methylcyclohexane. The vapour pressure of water at 150 ^{0}C is 4.69 atm. At 150 ^{0}C, the vapour pressure of methycyclohexane would be expected to be :

(A) significantly less than 4.69 atm

(B) nearly equal to 4.69 atm

(C) significantly more than 4.69 atm

(D) indeterminate due to a lack of data

GATE – 2001

Q.71. Air enters an adiabatic compressor at 300 K. The exit temperature for a compression ratio of 3, assuming air to be an ideal gas ($y = C_p/C_v = 7/5$) and the process to be reversible, is

(A) $300 \, (3^{2/7})$
(B) $300 \, (3^{3/5})$
(C) $300 \, (3^{3/7})$
(D) $300 \, (3^{5/7})$

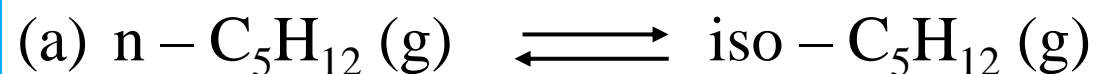**GATE – 2001**

Q.72. 100 m^3 of carbon dioxide initially at 423 K and 50 bar (50 x 10^5 Pa) is to be isothermally compressed in a frictionless piston and cylinder device to a final pressure of 300 bar (300 x 10^5 Pa). Assuming ideal gas behaviour (R = 8.314 x 10^{-2} bar m^3/kmol K).

(a) Write a general expression for the energy balance for the gas within the piston and cylinder device as the system, and define all the terms.

(b) Calculate the volume of the compressed carbon dioxide gas at 300 bar

(c) Calculate the work done to compress the carbon dioxide gas

(d) Calculate the heat flow on compression

GATE – 2001

Q.73. Normal pentane is isomerized to isopentane and neopentane at 500 K and atmospheric pressure. Determine the equilibrium composition (mole %) of the three components. State any assumptions made. Consider the reactions to be :

(a) $n - C_5H_{12}$ (g) $\rightleftharpoons$ iso $- C_5H_{12}$ (g)

(b) $n - C_5H_{12}$ (g) $\rightleftharpoons$ neo $- C_5H_{12}$ (g)

Given Data :

Equilibrium Constant for reaction (a) at 500 K, $K_1 = 3.519$

Equilibrium Constant for reaction (b) at 500 K, $K_2 = 0.682$

GATE – 2001

Q.74. Which of the following conditions are satisfied at the critical point by the P-V-T relation of a real fluid?

(A) $\left(\dfrac{\partial^2 P}{\partial V^2}\right)_T = \left(\dfrac{\partial P}{\partial V}\right)_T = 0$

(B) $\left(\dfrac{\partial^2 P}{\partial V^2}\right)_T > 0 \; ; \quad \left(\dfrac{\partial P}{\partial V}\right)_T = 0$

(C) $\left(\dfrac{\partial^2 P}{\partial V^2}\right)_T < 0 \; ; \quad \left(\dfrac{\partial P}{\partial V}\right)_T = 0$

(D) $\left(\dfrac{\partial^2 P}{\partial V^2}\right)_T > 0 \; ; \quad \left(\dfrac{\partial P}{\partial V}\right)_T > 0$

GATE – 2002

Q.75. The number of degrees of freedom for an azeotropic mixture of ethanol and water in vapour-liquid equilibrium is

(A) 3   (B) 1   (C) 2   (D) 0

GATE – 2002

Q.76. The partial molar enthalpy of a component in an ideal binary gas mixture of composition z, at a temperature T and pressure P, is a function only of
(A) T
(B) T and P
(C) T, P and z
(D) T and z

GATE – 2002

Q.77. Which of the following identities can be most easily used to verify steam table data for superheated steam –

(A) $\left(\dfrac{\partial T}{\partial V}\right)_s = -\left(\dfrac{\partial P}{\partial S}\right)_v$

(B) $\left(\dfrac{\partial T}{\partial P}\right)_s = -\left(\dfrac{\partial V}{\partial S}\right)_P$

(C) $\left(\dfrac{\partial P}{\partial T}\right)_v = -\left(\dfrac{\partial S}{\partial V}\right)_T$

(D) $\left(\dfrac{\partial V}{\partial T}\right)_P = -\left(\dfrac{\partial S}{\partial P}\right)_T$

GATE – 2002

Q.78. Steam undergoes isentropic expansion in a turbine from 5000 kPa and 400 ^{0}C (entropy = 6.65 kJ/kg K) to 150 kPa (entropy of saturated liquid = 1.4336 kJ/kg K, entropy of saturated vapour = 7.2234 kJ/kg K). The exit condition of steam is

(A) superheated vapour

(B) partially condensed vapour with quality of 0.9

(C) saturated vapour

(D) partially condensed vapour with quality of 0.1

GATE – 2002

Q.79. 1 m^3 of an ideal gas at 500 K and 1000 kPa expands reversibly to 5 times its initial volume in an insulated container. If the specific heat capacity (at constant pressure) of the gas is 21 J/mol K, the final temperature will be

(A) 35 K   (B) 174 K   (C) 274 K   (D) 154 K

GATE – 2002

Q.80. The Excess Gibbs free energy for cyclohexanone (1)/ phenol (2) is given by $(G^{E/RT}) = -2.1\ x_1\ x_2$; where, x_1 and x_2 are the mole fractions of components 1 and 2 in the liquid phase. The vapour pressures of components at 417 K are $P_1^{sat} = 75.2$ kPa and $P_2^{sat} = 31.66$ kPa.

(a) Derive the expressions for activity coefficient of each component as a function of composition.

(b) Verify whether the expressions derived in (a) satisfy the Gibbs – Dubem equation.

(c) Determine the equilibrium pressure P and vapour composition for a liquid phase composition $x_1 = 0.8$ and 417 K. Assume vapour phase to be ideal gas.

GATE – 2002

Q.81. Methane gas is compressed in a steady state flow process from 101 kPa and 27 ^{0}C to 500 kPa and 165 ^{0}C. Assume methane to be an ideal gas under all conditions
[R = 8.314 J/mol K; specific heat capacity, C_p/R = 1.7 + 0.009 T(K)]
and surroundings to be at a constant temperature of 27 ^{0}C. If the total entropy change (of the system and surroundings) during the process is 4.5 J/mol K, find
(a) The specific enthalpy and specific entropy changes of methane.
(b) The net shaft work done and heat exchanged with the surroundings, per mole of methane.
(c) The thermodynamic efficiency of the process.

GATE – 2002

Q.82. For estimation of heat capacity of a solid compound, one can use
(A) Clapeyron's equation
(B) Gibb's equation
(C) Kopp's rule
(D) Trouton's rule

GATE – 2003

Q.83. For organic compounds, Group Contribution Method can be used for estimation of
(A) critical properties
(B) specific gravity
(C) specific volume
(D) thermal conductivity

GATE – 2003

Q.84. When dilute aqueous solutions of two salts are mixed, the process is associated with
(A) decrease in temperature
(B) increase in temperature
(C) no change in temperature
(D) change in temperature which is a function of composition

GATE – 2003

Q.85. In Joule's experiments, an insulated container contains 20 kg of water initially at 25 ^{0}C. It is stirred by an agitator, which is made to turn by a slowly failing body weighing 40 kg through a height of 4 m. The process is repeated 500 times. The acceleration due to gravity is 9.8 m s^{-2} . Neglecting the heat capacity of agitator, the temperature of water (in ^{0}C) is

(A) 40.5   (B) 34.4   (C) 26.8   (D) 25

GATE – 2003

Q.86. One mole of Nitrogen at 8 bar and 600 K is contained in a piston-cylinder arrangement. It is brought to 1 bar isothermally against a resisting pressure of 1 bar. The work done (in Joules) by the gas is –

(A) 30554   (B) 10373   (C) 4988.4   (D) 4364.9

GATE – 2003

Q.87. For water at 300 ^{0}C, it has a vapour pressure 8592.7 kPa and fugacity 6738.9 kPa. Under these conditions, one mole of water in liquid phase has a volume 25.28 cm^3 , and that in vapour phase 391.1 cm^3 . Fugacity of water (in kPa) at 9000 kPa will be
(A) 6738.9   (B) 6753.5   (C) 7058.3   (D) 9000

GATE – 2003

Q.88. A solid metallic block weighing 5 kg has an initial temperature of 500 ^{0}C ; 40 kg of water initially at 25 ^{0}C is contained in a perfectly insulated tank. The metallic block is brought into contact with water. Both of them come to equilibrium. Specific heat of block material is 0.4 kJ kg^{-1} K^{-1} . Ignoring the effect of expansion and contraction, and also the heat capacity of tank, the total entropy change in kJ kg^{-1} K^{-1} is

(A) - 1.87   (B) 0.0   (C) 1.26   (D) 3.91

GATE – 2003

Q.89. The following heat engine produces power of 100,000 kW. The heat engine operates between 800 K and 300 K. It has a thermal efficiency equal to 50% of that of the Carnet engine for the same temperatures. The rate at which heat is absorbed from the hot reservoir is
(A) 100,000 kW
(B) 160,000 kW
(C) 200,000 kW
(D) 320,000 kW

GATE – 2003

Q.90. A steam turbine operates with a superheated steam flowing at 1 kg s^{-1} . This steam is supplied at 441 bar and 500 ^{0}C, and discharges at 1.01325 bar and 100 ^{0}C.

Data: 41 bar, 500 ^{0}C   Enthalpy : 3443.9 kJ kg^{-1}
                                 Entropy : 7.0785 kJ kg^{-1} K^{-1}

41 bar, 251.8 ^{0}C   Enthalpy of saturated steam : 2799.9 kJ kg^{-1}
                                 Entropy of saturated steam : 6.0583 kJ kg^{-1} K^{-1}

1.01325 bar, 100 ^{0}C   Enthalpy of saturated vapour : 2676 kJ kg^{-1}
                                 Enthalpy of saturated liquid : 419.1 kJ kg^{-1}
                                 Entropy of saturated vapour : 7.3554 kJ kg^{-1}
                                 Entropy of saturated liquid : 1.3069 kJ kg^{-1}

The maximum power output (in kW) will be

(A) 644.0   (B) 767.9   (C) 871.3   (D) 3024.8

GATE – 2003

Q.91. At 60 ^{0}C, vapour pressure of methanol and water are 84.562 kPa and 19.953 kPa respectively. An aqueous solution of methanol at 60 ^{0}C exerts a pressure of 39.223 kPa; the liquid phase and vapour phase mole fractions of methanol are 0.1686 and 0.5714 respectively. Activity coefficient of methanol is

(A) 1.572   (B) 1.9398   (C) 3.389   (D) 4.238

GATE – 2003

Q.92. One kg of saturated steam at 100 ^{0}C and 1.01325 bar is contained in a rigid walled vessel. It has a volume 1.673 m^3 . It cools to 98 ^{0}C, the saturation pressure is 0.943 bar; one kg of water vapour under these conditions has a volume of 1.789 m ^{3} .

(i) The amount of water vapour condensed (in kg) is

(A) 0.0   (B) 0.065   (C) 0.1   (D) 1.0

(ii) The latent heat of condensation (kJ kg^{-1}) under these conditions is

(A) 40732   (B) 2676   (C) 2263   (D) 540

GATE – 2003

Q.93. For an ideal gas mixture undergoing a reversible gaseous phase chemical reaction, the equilibrium constant
(A) is independent of pressure
(B) increases with pressure
(C) decreases with pressure
(D) increases/decreases with pressure depending on the stoichiometric coefficients of the reaction.

GATE – 2004

Q.94. As pressure approaches zero, the ratio of fugacity to pressure (f/P) for a gas approaches

(A) Zero   (B) Unity   (C) Infinity   (D) an indeterminate value

GATE – 2004

Q.95. A perfectly insulated container of volume V is divided into two equal halves by a partition. One side is under vacuum while the other side has one mole of an ideal gas (with constant heat capacity) at 298 K. If the partition is broken, the final temperature of the gas in the container

(A) will be greater than 298 K

(B) will be 298 K

(C) will be less than 298 K

(D) cannot be determined.

GATE – 2004

Q.96. The number of degrees of freedom for an azeotropic mixture in a two component vapour-liquid equilibria is/are

(A) zero   (B) one   (C) two   (D) three

GATE – 2004

Q.97. A car tyre of volume 0.057 m^3 is inflated to 300 kPa at 300 K. After the car is driven for ten hours, the pressure in the tyre increases to 330 kPa. Assume air is an ideal gas and C$_v$ for air is 21 J/(mol K). The change in the internal energy of air in the tyre in J/mol is

(A) 380   (B) 630   (C) 760   (D) 880

GATE – 2004

Q.98. A gas obeys P (v-b) = RT. The work obtained from reversible isothermal expansion of one mole of this gas from an initial molar volume v_i to a final molar volume v_f is

(A) $RT \ln\left(\dfrac{v_f}{v_I}\right)$

(B) $RT \ln\left(\dfrac{v_f - b}{v_I}\right)$

(C) $RT \ln\left(\dfrac{v_f}{v_I - b}\right)$

(D) $RT \ln\left(\dfrac{v_f - b}{v_I - b}\right)$

GATE – 2004

Q.99. A cyclic engine exchanges heat with two reservoirs maintained at 100 and 300 ^{0}C, respectively. The maximum work (in J) that can be obtained from 1000 J of heat extracted from the hot reservoir is

(A) 349   (B) 651   (C) 667   (D) 1000   **GATE – 2004**

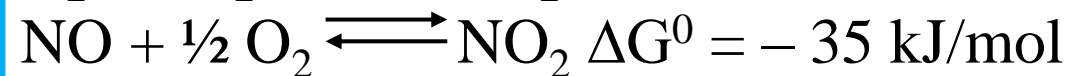Q.100. The vapour pressure of water is given by

$$\ln P^{sat} = A - \frac{5000}{T}$$

where A is a constant, P^{sat} is vapour pressure in atm, and T is temperature in K. The vapour pressure of water in atm at 50 ^{0}C is approximately

(A) 0.07   (B) 0.09   (C) 0.11   (D) 0.13

GATE – 2004

Q.101. At standard conditions,

$N_2 + 2O_2 \rightleftharpoons 2NO_2$ $\Delta G^0 = 100$ kJ/mol

$NO + \frac{1}{2} O_2 \rightleftharpoons NO_2$ $\Delta G^0 = -35$ kJ/mol

The standard free energy of formation of NO in kJ/mol is

(A) 15   (B) 30   (C) 85   (D) 170

GATE – 2004

Q.102. In van der Waals equation of state, what are the criteria applied at the critical point in determine the parameters 'a' and 'b' ?

(a) $\left(\dfrac{\partial P}{\partial V}\right)_T = 0$; $\left(\dfrac{\partial^2 P}{\partial V^2}\right)_T = 0$

(b) $\left(\dfrac{\partial V}{\partial P}\right)_T = 0$; $\left(\dfrac{\partial^2 V}{\partial P^2}\right)_T = 0$

(c) $\left(\dfrac{\partial P}{\partial T}\right)_V = 0$; $\left(\dfrac{\partial^2 P}{\partial T^2}\right)_V = 0$

(d) $\left(\dfrac{\partial V}{\partial T}\right)_P = 0$; $\left(\dfrac{\partial^2 V}{\partial T^2}\right)_P = 0$

GATE – 2005

Q.103. Which one of the following statements in TRUE ?
(A) Heat can be fully converted into work
(B) Work cannot be fully converted into heat
(C) The efficiency of a heat engine increases as the temperature of the heat source is increased while keeping the temperature of the heat sink fixed
(D) A cyclic process can be devised whose sole effect is to transfer heat from a lower temperature to a higher temperature

GATE – 2005

Q.104. A Carnot heat engine cycle is working with an ideal gas. The work performed by the gas during the adiabatic expansion and compression steps, W_1 and W_2 respectively, are related as
(A) $|W_1| > |W_2|$
(B) $|W_1| < |W_2|$
(C) $W_1 = W_2$
(D) $W_1 = -W_2$

GATE – 2005

Q.105. The van Laar activity coefficient model for a binary mixture is given by the form

$$\ln \gamma_1 = \frac{A^*}{\left(1 + \dfrac{A^* \, x_1}{B^* \, x_2}\right)} \qquad \ln \gamma_2 = \frac{B^*}{\left(1 + \dfrac{B^* \, x_2}{A^* \, x_1}\right)}$$

Given $\gamma_1 = 1.40$, $\gamma_2 = 1.25$, $x_1 = 0.25$, $x_2 = 0.75$, determine the constants A* and B*,

(A) A* = 0.5, B* = 0.3

(B) A* = 3, B* = 0.5

(C) A* = 0.333, B* = 0.2

(D) A* = 2, B* = 0.333

GATE – 2005

Q.106. What is the actual power required to drive a reciprocating air compressor which has to compress 34 m^3 of air per minute from 1.013×10^5 N/m^2 to 4.052×10^5 N/m^2 ? Assume that $PV^{1.25}$ is constant, where P is the pressure and V is the volume, and the efficiency of the compressor is 85%.

(A) 107.9 kW   (B) 200 kW   (C) 82.6 kW   (D) 91.7 kW

GATE – 2005

Q.107. A frictionless cylinder piston assembly contains an ideal gas. Initially pressure (P_1) = 100 kPa, temperature (T_1) = 500 K and volume (V_1) = 700 x 10^{-6} m^3. This system is supplied with 100 J of heat and pressure is maintained constant at 100 kPa. The enthalpy variation is given by H (J/mol) = 30000 + 50 T; where T is the temperature in K, and the universal gas constant R = 8.314 J/(mole K).

(i) The final volume of the gas (V_2) in m^3 is
(A) 700 x 10^{-6}
(B) 866.32 x 10^{-6}
(C) 934.29 x 10^{-6}
(D) 1000.23 x 10^{-6}

Ideal gas at constant pressure

(ii) The change in internal energy of the gas in J is
(A) 0   (B) 100   (C) 23.43   (D) 83.37

GATE – 2005

Q.108. At a given temperature and pressure, a liquid mixture of benzene and toluene is in equilibrium with its vapor. The available degree(s) of freedom is (are)

(A) zero   (B) 1   (C) 2   (D) 3

GATE – 2006

Q.109. A heat engine operates at 75% of the maximum possible efficiency. The ratio of the heat source temperature (in K) to the heat sink temperature (in K) is 5/3. The fraction of the heat supplied that is converted to work is

(A) 0.2   (B) 0.3   (C) 0.4   (D) 0.6

GATE – 2006

Q.110. For the isentropic expansion of an ideal gas from the initial conditions T_1 , T_1 to the final conditions T_2 , T_2 , which ONE of the following relations is valid ? ($\gamma = C_p/C_v$)

(a) $\left(\dfrac{P_1}{P_2}\right) = \left(\dfrac{T_2}{T_1}\right)^{\gamma}$

(b) $\left(\dfrac{P_1}{P_2}\right) = \left(\dfrac{T_1}{T_2}\right)^{\frac{\gamma}{\gamma-1}}$

(c) $\left(\dfrac{P_1}{P_2}\right) = \left(\dfrac{T_1}{T_2}\right)$

(d) $\left(\dfrac{P_1}{P_2}\right) = \left(\dfrac{T_1}{T_2}\right)^{\frac{\gamma-1}{\gamma}}$

GATE – 2006

Q.111. Match the following :

(a) Heat   (i) State Function
(b) Internal energy   (ii) Path Function
(c) Work
(d) Entropy

(A) (a)-(ii); (b)-(i); (c)-(i); (d)-(i)
(B) (a)-(ii); (b)-(i); (c)-(ii); (d)-(ii)
(C) (a)-(ii); (b)-(ii); (c)-(i); (d)-(i)
(D) (a)-(ii); (b)-(i); (c)-(ii); (d)-(i)

GATE – 2006

Q.112. For a reversible exothermic gas phase reaction, A + B ↔ C, the equilibrium conversion will increase with
(A) increase in pressure and increase in temperature
(B) decrease in pressure and increase in temperature
(C) increase in pressure and decrease in temperature
(D) decrease in pressure and decrease in temperature

GATE – 2006

Q.113. For a binary mixture of A and B at 400 K and 1 atm, which ONE of the following equilibrium states deviates significantly from ideality ?

Given : where

P_A^{sat} = vapor pressure of A, atm

T = temperature, K

P_A = partial pressure of A, atm

x_A = mole fraction of A in liquid

y_A = mole fraction of A in vapor

(A) $x_A = 0.5$; $y_A = 0.25$

(B) $x_A = 0.5$; $P_A = 0.25$

(C) $x_A = 0.5$; $P_A = 0.5$

(D) $x_A = 0.6$; $y_A = 0.3$

GATE – 2006

Q.114. Pure A at 200 ^{0}C is fed to a steady state adiabatic continuous reactor at the rate of 100 kg/hr where it undergoes an exothermic reaction to give its isomer B. The product stream is at temperature 500 ^{0}C. The heat of reaction is 21 kJ/mol of A and the specific heat of the reaction mixture is constant at 35 J/(mol ^{0}C). The conversion in the reactor is

(A) 25%　　　　　(B) 50%　　　　　(C) 75%　　　　　(D) 100%

GATE – 2006

Q.115. The molar density of water vapor at the normal boiling point of water is 33 mol/m^3 . The compressibility factor under these conditions is close to which ONE of the following?
R = 8.314 J/(mol K)
(A) 0.75   (B) 1   (C) 1.25   (D) 1.5

GATE – 2006

Q.116. If T_A and T_B are the boiling points of pure A and pure B respectively and T_{AB} is that of a non-homogeneous immiscible mixture of A and B, then
(A) $T_{AB} < T_A$ and T_B
(B) $T_{AB} > T_A$ and T_B
(C) $T_A > T_{AB} > T_B$
(D) $T_B > T_{AB} > T_A$

GATE – 2007

Q.117. The state of an ideal gas is changed from (T_1, P_1) to (T_2, P_2) in a constant volume process. To calculate the change in enthalpy, Δh, ALL of the following properties/variables are required.

(A) C_V, P_1, P_2

(B) C_P, T_1, T_2

(C) C_P, T_1, T_2, P_1, P_2

(D) C_V, P_1, P_2, T_1, T_2

GATE – 2007

Q.118. The change in entropy of the system, ΔS_{sys} , undergoing a cyclic irreversible process is
(A) greater than 0
(B) less than zero
(C) equal to zero
(D) equal to the $\Delta S_{surroundings}$

GATE – 2007

Q.119. Parameters 'a' and 'b' in the van der Waals and other cubic equations of state represent
(A) a – molecular weight b – molecular polarity
(B) a – molecular size b – molecular attraction
(C) a – molecular size b – molecular speed
(D) a – molecular attraction b – molecular size

GATE – 2007

Q.120. If m_i, $\overline{m}_i$, m_i^R, m_i^E are molar, partial molar, residual and excess properties respectively for a pure species "i", the mixture property M of a binary non-ideal mixture of components 1 and 2, is given by

(A) $x_1 + x_2$

(B) $x_1 m_1^R + x_2 m_2^R$

(C) $x_1 m_1 + x_2 m_2$

(D) $x_1 m_1^E + x_2 m_2$

GATE – 2007

Q.121. For the two paths as shown in the figure, one reversible and one irreversible, the state of the system from a to b,
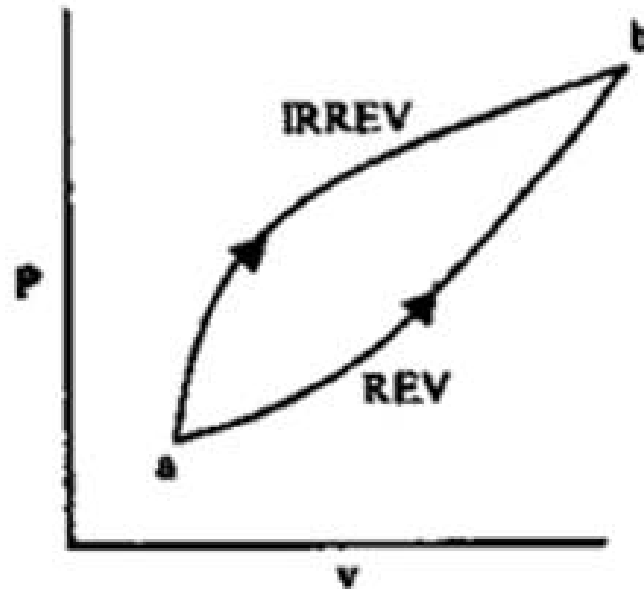
(A) ΔU, Q, W are same   (B) ΔU, is same   (C) Q, W are same   (D) ΔU, Q, are different.

Q.122. For a pure substance, the Maxwell's relation obtained from the fundamental property relation du = Tds − Pdv is

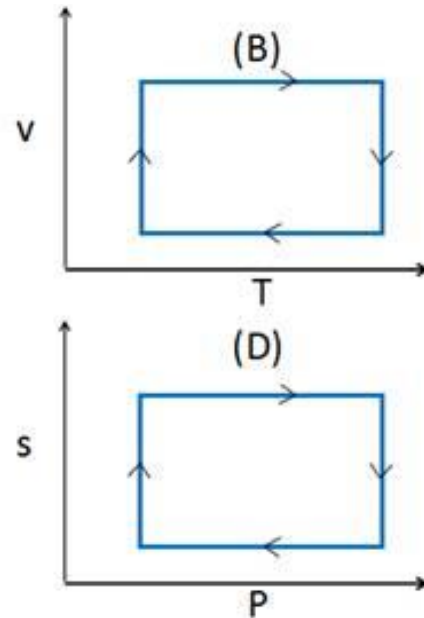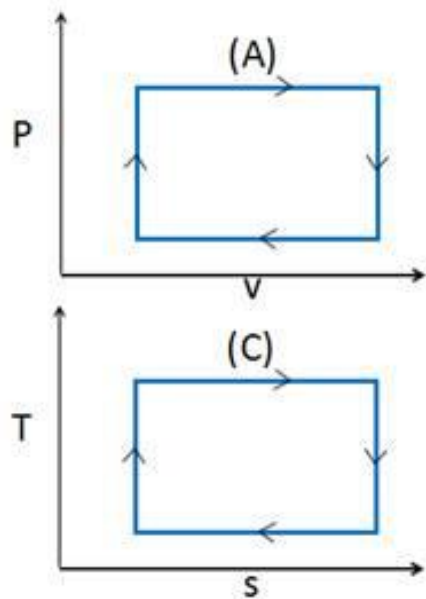(A) $\left(\dfrac{\partial T}{\partial v}\right)_s = -\left(\dfrac{\partial P}{\partial s}\right)_v$

(B) $\left(\dfrac{\partial P}{\partial T}\right)_v = \left(\dfrac{\partial s}{\partial v}\right)_T$

(C) $\left(\dfrac{\partial T}{\partial P}\right)_s = \left(\dfrac{\partial v}{\partial s}\right)_P$

(D) $\left(\dfrac{\partial v}{\partial T}\right)_P = -\left(\dfrac{\partial s}{\partial P}\right)_T$

GATE – 2007

Q.123. Which of the following represents the Carnot cycle (ideal engine) ?

GATE – 2007

Q.124. 2 kg of steam in a piston-cylinder device at 400 kPa and 175 °C undergoes a mechanically reversible, isothermal compression to a final pressure such that the steam becomes just saturated. What is the work, W, required for the process.
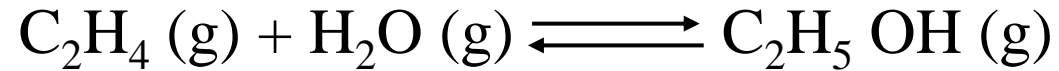
Data :

T = 175 °C, P = 400 kPa – v = 0.503 m^3 /kg, u = 2606 kJ/kg, s = 7.055 kJ/kg-K

T = 175 °C, satd. vapor – v = 0.216 m^3 /kg, u = 2579 kJ/kg, s = 6.622 kJ/kg-K

(A) 0 kJ   (B) 230 kJ   (C) 334 kJ   (D) 388 kJ

GATE – 2007

Q.124. Vapor phase hydration of C_2H_4 to ethanol by the following reaction

$$C_2H_4 \text{ (g)} + H_2O \text{ (g)} \rightleftharpoons C_2H_5 OH \text{ (g)}$$

attains equilibrium at 400 K and 3 bar. The standard Gibbs free energy change of reaction at these conditions is $\Delta g° = 4000$ J/mol. For 2 moles of an equimolar feed of ethylene and steam, the equation in terms of the extent of reaction ε (in mols) at equilibrium is

(A) $\dfrac{\varepsilon(2-\varepsilon)}{(1-\varepsilon)^2} - 0.3 = 0$

(B) $\dfrac{(1-\varepsilon)^2}{\varepsilon(2-\varepsilon)} - 0.9 = 0$

(C) $\dfrac{\varepsilon}{(1-\varepsilon)^2} - 0.3 = 0$

(D) $\dfrac{\varepsilon(2-\varepsilon)}{(1-\varepsilon)^2} - 0.9 = 0$

GATE – 2007

Q.126. A methanol-water vapor liquid system is at equilibrium at 60°C and 60 kPa. The mole fraction of methanol in liquid is 0.5 and in vapor is 0.8. Vapor pressure of methanol and water at 60°C are 85 kPa and 20 kPa respectively. Assuming vapor phase to be an ideal gas mixture, what is the activity coefficient of water in the liquid phase ?
(A) 0.3   (B) 1.2   (C) 1.6   (D) 7.5

GATE – 2007

Q.127. What is the excess Gibbs free energy (g^E , in J/mol) of the liquid mixture ?
(A) 9.7   (B) 388   (C) 422   (D) 3227

GATE – 2007

Q.128. A perfectly insulated cylinder of volume 0.6 m^3 is initially divided into two parts by a thin, frictionless piston, as shown in the figure. The smaller part of volume 0.2 m^3 has ideal gas at 6 bar pressure and 100 °C. The other part is evacuated.

(i) At certain instant of time t, the stopper is removed and the piston moves out freely to the other end. The final temperature is

(A) –140°C   (B) –33°C   (C) 33°C   (D) 100°C

(ii) The cylinder insulation is now removed and the piston is pushed back to restore the system to its initial state. If this is to be achieved only by doing work on the system (no heat addition, only heat removal allowed), what is the minimum work required ?

(A) 3.4 kJ   (B) 107 kJ   (C) 132 kJ   (D) 240 kJ

GATE – 2007

Q.129. For a Carnot refrigerator operating between 40°C and 25°C, the coefficient of performance is

(A) 1 (B) 1.67 (C) 19.88 (D) 39.74

GATE – 2008

Q.130. The work done by one mole of a van der Waals fluid undergoing reversible isothermal expansion from initial volume V_i to final volume V_f is
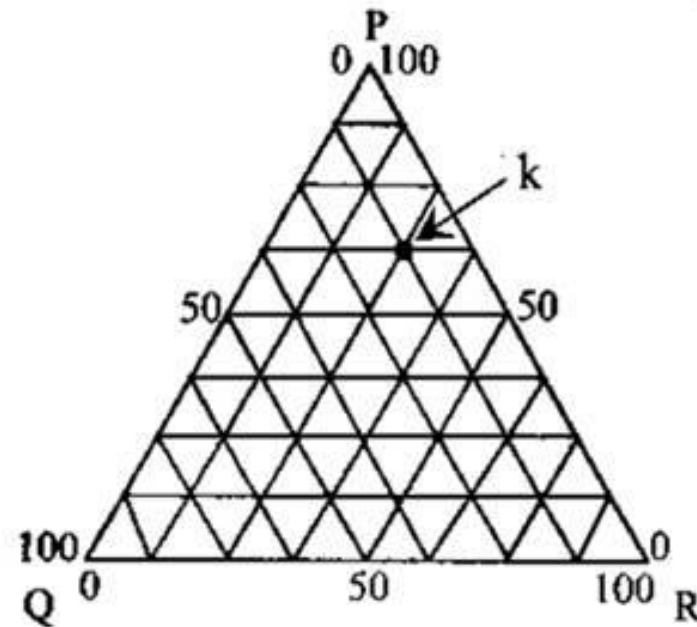
(A) $RT \ln\left(\dfrac{V_f}{V_i}\right)$

(B) $RT \ln\left(\dfrac{V_f - V}{V_i - V}\right)$

(C) $RT \ln\left(\dfrac{V_f - V}{V_i - V}\right) - a\left(\dfrac{1}{V_f} - \dfrac{1}{V_i}\right)$

(D) $RT \ln\left(\dfrac{V_f - V}{V_i - V}\right) + a\left(\dfrac{1}{V_f} - \dfrac{1}{V_i}\right)$

GATE – 2008

Q.131. For a system containing species P, Q and R, composition at point k on the ternary plot is

(A) 62.5% P, 12.5% Q, 25% R

(B) 25% P, 62.5% Q, 12.5% R

(C) 12.5% P, 62.5% Q, 25% R

(D) 12.5% P, 25% Q, 62.5% R

GATE – 2008

Q.132. The molar volume (v) of a binary mixture, of species 1 and 2 having mole fractions x_1 and x_2 respectively is given by $v = 220\, x_1 + 180\, x_2 + x_1\, x_2\, (90\, x_1 + 50\, x_2)$. The partial molar volume of species 2 at $x_2 = 0.3$ is

(A) 183.06   (B) 212.34   (C) 229.54   (D) 256.26

GATE – 2008

Q.133. The standard Gibbs free energy change and enthalpy change at 25°C for the liquid phase reaction

$$CH_3COOH \ (1) + C_2H_5OH \ (1) \longrightarrow CH_2COOC_2H_5 \ (1) + H_2O \ (1)$$
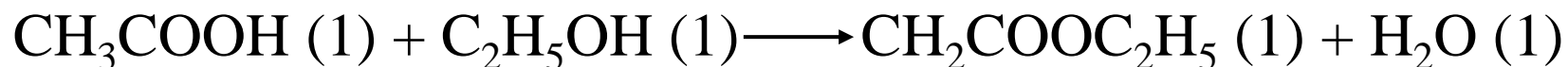
are given as $\Delta G°_{298} = -4650$ J/mol and $\Delta H°_{298} = -3640$ J/mol. If the solution is ideal and enthalpy change is assumed to be constant, the equilibrium constant at 95°C is

(A) 0.65   (B) 4.94   (C) 6.54   (D) 8.65

GATE – 2008

Q.134. A binary mixture containing species 1 and 2 forms an azeotrope at 105.4°C and 1.013 bar. The liquid phase mole fraction of component 1 (x_1) of this azeotrope is 0.62. At 105.4°C, the pure component vapor pressures for species 1 and 2 are 0.878 bar and 0.665 bar, respectively. Assume that the vapour phase is an ideal gas mixture. The van Laar constants, A and B, are given by the expressions :

$$A = \left[1 + \frac{x_2 \ln \gamma_2}{x_1 \ln \gamma_1}\right]^2 \ln \gamma_1 \qquad B = \left[1 + \frac{x_1 \ln \gamma_1}{x_2 \ln \gamma_2}\right]^2 \ln \gamma_2$$

(i). The activity coefficients (γ_1 , γ_2) under these conditions are

(A) (0.88, 0.66)   (B) (1.15, 1.52)   (C) (1.52, 1.15)   (D) (1.52, 0.88)

(ii).The van Laar constants (A, B) are

(A) (0.92, 0.87)   (B) (1.00, 1.21)   (C) (1.12, 1.00)   (D) (1.52, 1.15)

GATE – 2008

Q.135. An ideal gas at temperature T_1 and pressure P_1 is compressed isothermally to pressure P_2 ($> P_1$) in a closed system. Which ONE of the following is TRUE for internal energy (U) and Gibbs free energy (G) of the gas at the two states ?

(A) $U_1 = U_2$, $G_1 > G_2$

(B) $U_1 = U_2$, $G_1 < G_2$

(C) $U_1 > U_2$, $G_1 = G_2$

(D) $U_1 < U_2$, $G_1 = G_2$

GATE – 2009

Q.136. For a binary mixture at constant temperature and pressure, which ONE of the following relations between activity coefficient (γ_i) and mole fraction (x_i) is thermodynamically consistent ?

(A) $\ln \gamma_1 = -1 + 2x_1 - x_1^2$; $\ln \gamma_2 = \dfrac{1}{2} x_1^2$

(B) $\ln \gamma_1 = -1 + 2x_1 - x_1^2$; $\ln \gamma_2 = x_1^2$

(C) $\ln \gamma_1 = -1 + 2x_1 - x_1^2$; $\ln \gamma_2 = -\dfrac{1}{2} x_1^2$

(D) $\ln \gamma_1 = -1 + 2x_1 - x_1^2$; $\ln \gamma_2 = -x_1^2$

GATE – 2009

Q.137. An ideal gas with molar heat capacity $c_p = \frac{5}{2}R$ (where R = 8.314 J/mol.K) is compressed adiabatically from 1 bar and 300 K to pressure P_2 in a closed system. The final temperature after compression is 600 K and the mechanical efficiency of compression is 50%.

(i) The work required for compression (in kJ/mol) is

(A) 3.74   (B) 6.24   (C) 7.48   (D) 12.48

(ii) The final pressure P_2 (in bar) is

(A) $2^{3/4}$ (B) $2^{5/4}$ (C) $2^{3/2}$ (D) $2^{5/2}$

GATE – 2009

Q.138. An equimolar liquid mixture of species 1 and 2 is in equilibrium with its vapour at 400 K. At this temperature, the vapour pressures of the species are $P_1^{sat} = 180$ kPa and $P_2^{sat} = 120$ kPa. Assuming that Raoult's law is valid, the value of y_1 is

(A) 0.30   (B) 0.41   (C) 0.50   (D) 0.60

GATE – 2010

Q.139. A new linear temperature scale, denoted by °S, has been developed, where the freezing point of water is 200 °S and the boiling point is 400 °S. On this scale, 500 °S corresponds, in degrees Celsius, to

(A) 100°C   (B) 125°C   (C) 150°C   (D) 300°C

GATE – 2010

Q.140. A saturated liquid at 1500 kPa and 500 K, with an enthalpy of 750 kJ/kg, is throttled to a liquid-vapour mixture at 150 kPa and 300 K. At the exit conditions, the enthalpy of the saturated liquid is 500 kJ/kg and the enthalpy of the saturated vapour is 2500 kJ/kg. The percentage of the original liquid, which vaporizes, is

(A) 87.5%   (B) 67%   (C) 12.5%   (D) 10%

GATE – 2010

Q.141. At constant T and P, the molar density of a binary mixture is given by $\rho = 1 + x_2$, where x_2 is the mole fraction of component 2. The partial molar volume at infinite dilution for component 1, $\overline{V}_1^\infty$, is

(A) 0.75   (B) 1.0   (C) 2.0   (D) 4.0

GATE – 2010

Q.142. Minimum work (W) required to separate a binary gas mixture at a temperature T_0 and pressure P_0

$$W = -RT_0\left[y_1 \ln\left(\frac{\hat{f}_1}{f_{pure,1}}\right) + y_2 \ln\left(\frac{\hat{f}_2}{f_{pure,2}}\right)\right]$$

is where y_1 and y_2 are mole fractions. $f_{pure.1}$ and $f_{pure.2}$ are fugacities of pure species at T_0 and P_0 and f_1 and f_2 are fugacities of species in the mixture at T_0, P_0 and y_1. If the mixture is ideal then W is

(A) 0   (B) $-RT_0\left[y_1 \ln y_1 + y_2 \ln y_2\right]$

(C) $RT_0\left[y_1 \ln y_1 + y_2 \ln y_2\right]$ (D) RT_0

GATE – 2011

Q.143. The partial molar enthalpies of mixing (in J/mol) for benzene (component 1) and cyclohexane (component 2) at 300 K and 1 bar are given by $\overline{\Delta H}_1 = 3600\, x_2^2$ and $\overline{\Delta H}_2 = 3600\, x_1^2$, where x_1 and x_2 are the mole fractions. When ONE mole of benzene is added to TWO moles of cyclohexane, the enthalpy change (in J) is

(A) 3600   (B) 2400   (C) 2000   (D) 800

GATE – 2011

Q.144. One mole of methane is contained in a leak proof piston – cylinder assembly at 8 bar and 1000 K. The gas undergoes isothermal expansion to 4 bar under reversible conditions. Methane can be considered as an ideal gas under these conditions. The value of universal gas constant is 8.314 J.mol^{-1} K $^{-1}$. The heat transferred (in kJ) during the process is

(A) 11.52   (B) 5.76   (C) 4.15   (D) 2.38

GATE – 2011

Q.145. Two systems are available for compressing 6 m^3 /hr of ambient air to 10 bar. The first one uses a single stage compressor (K_1) and the second one uses a multistage compressor with inter – stage cooling (K_2). Which ONE of the following statements is INCORRECT ?

(A) K_2 will have knockout pots in between the stages
(B) Discharge temperature of K_1 will be higher than that of K_2
(C) K_2 will consume more power than K_1
(D) Cost of K_2 will be more than that of K_1.

GATE – 2011

Q.146. Consider a binary mixture of methyl ethyl ketone (component 1) and toluene (component 2). At 323 K the activity coefficients γ_1 and γ_2 are given by

$$\ln \gamma_1 = x_2^2 (\Psi_1 - \Psi_2 + 4 \Psi_2 x_1),$$

$$\ln \gamma_2 = x_1^2 (\Psi_1 + \Psi_2 - 4 \Psi_2 x_2)$$

where x_1 and x_2 are the mole fractions in the liquid mixture, and Ψ_1 and Ψ_2 are parameters independent of composition. At the same temperature, the infinite dilution activity coefficients γ_1^∞ and γ_2^∞ are given by $\ln \gamma_1^\infty = 0.4$ and $\ln \gamma_1^\infty = 0.2$ The vapour pressure of methyl ethyl ketone and toluene at 323 K are 36.9 and 12.3 kPa respectively. Assuming that the vapour phase is ideal, the equilibrium pressure (in kPa) of a liquid mixture containing 90 mol % toluene is

(A) 19   (B) 18   (C) 16   (D) 15

Q.147. In a throttling process, the pressure of an ideal gas reduces by 50 %. If C_P and C_V are the heat capacities at constant pressure and constant volume, respectively ($\gamma = C_P / C_V$), the specific volume will change by a factor of

(A) 2   (B) $2^{1/\gamma}$ (C) $2^{(\gamma-1)/\gamma}$ (D) 0.5

GATE – 2012

Q.148. If the temperature of saturated water is increased infinitesimally at constant entropy, the resulting state of water will be
(A) Liquid
(B) Liquid – vapor coexistence
(C) Saturated vapor
(D) Solid

GATE – 2012

Q.149. In a parallel flow heat exchanger operating under steady state, hot liquid enters at a temperature $T_{h,in}$ and leaves at a temperature $T_{h,out}$. Cold liquid enters at a temperature $T_{c,in}$ and leaves at a temperature $T_{c,out}$. Neglect any heat loss from the heat exchanger to the surrounding. If $T_{h,in} >> T_{c,in}$, then for a given me interval, which ONE of the following statements is true ?
(A) Entropy gained by the cold stream is GREATER than entropy lost by the hot stream
(B) Entropy gained by the cold stream is EQUAL to the entropy lost by the hot stream
(C) Entropy gained by the cold stream is LESS than the entropy lost by the hot stream
(D) Entropy gained by the cold stream is ZERO

GATE – 2012

Q.150. For an exothermic reversible reaction, which one of the following correctly describes the dependence of the equilibrium constant (K) with temperature (T) and pressure (P) ?
(A) K is independent of T and P
(B) K increases with an increase in T and P
(C) K increases with T and decreases with P
(D) K decreases with an increase in T and is independent of P

GATE – 2012

Q.151. An insulated, evacuated container is connected to a supply line of an ideal gas at pressure Ps , temperature T_s and specific volume v_s . The container is filled with the gas until the pressure in the container reaches P_s . There is no heat transfer between the supply line to the container, and kinetic and potential energies are negligible. If C_P and C_V are the heat capacities at constant pressure and constant volume, respectively ($\gamma = C_P / C_V$), then the final temperature of the gas in the container is

(A) γT_s (B) T_s (C) $(\gamma - 1) T_s$ (D) $(\gamma - 1) T_s / \gamma$

GATE – 2012

Q.152. Consider a binary liquid mixture at constant temperature T and pressure P. If the enthalpy change of mixing, $\Delta H = 5\ x_1\ x_2$ where x_1 and x_2. are the mole fraction of species 1 and 2 respectively and the entropy change of mixing

$$\Delta S = -R\ [x_1\ \ln x_1 + x_2\ \ln x_2\ ] \text{ (with } R = 8.314 \text{ J/mol.K)},$$

then the minimum value of the Gibbs free energy change of mixing at 300 K occurs when

(A) $x_1 = 0$　　　　(B) $x_1 = 0.2$　　　(C) $x_1 = 0.4$　　　　(D) $x_1 = 0.5$

GATE – 2012

Q.153. A gaseous system contains H_2 , I_2 , and HI, which participate in the gas-phase reaction $2\,HI \rightleftharpoons H_2 + I_2$. At a state of reaction equilibrium, the number of thermodynamic degrees of freedom is _____.

GATE – 2013

Q.154. The thermodynamic state of a closed system containing a pure fluid changes from (T_1, P_1) to (T_2, P_2), where T and P denote the temperature and pressure, respectively. Let Q denote the heat absorbed (> 0 if absorbed by the system) and W the work done (> 0 if done by the system). Neglect changes in kinetic and potential energies. Which one of the following is CORRECT ?

(A) Q is path-independent and W is path-dependent

(B) Q is path-dependent and W is path-dependent

(C) (Q – W) is path-independent

(D) (Q + W) is path-independent

GATE – 2013

Q.155. An equation of state is explicit in pressure p and cubic in the specific volume v. At the critical point 'c', the isotherm passing through 'c' satisfies

(A) $\frac{\partial p}{\partial v} < 0, \quad \frac{\partial^2 p}{\partial v^2} = 0$

(B) $\frac{\partial p}{\partial v} > 0, \quad \frac{\partial^2 p}{\partial v^2} < 0$

(C) $\frac{\partial p}{\partial v} = 0, \quad \frac{\partial^2 p}{\partial v^2} > 0$

(D) $\frac{\partial p}{\partial v} = 0, \quad \frac{\partial^2 p}{\partial v^2} = 0$

GATE – 2013

Q.156. The units of the isothermal compressibility are

(A) m^{-3} (B) Pa^{-1} (C) $m^3 Pa^{-1}$ (D) $m^{-3} Pa^{-1}$

GATE – 2013

Q.157. In a process occurring in a closed system F, the heat transferred from F to the surroundings E is 600 J. If the temperature of E is 300 K and that of F is in the range 380 – 400 K, the entropy changes of the surroundings (ΔS_E) and system (ΔS_F), in J/K, are given by

(A) $\Delta S_E = 2, \Delta S_F = -2$

(B) $\Delta S_E = -2, \Delta S_F = 2$

(C) $\Delta S_E = 2, \Delta S_F < -2$

(D) $\Delta S_E = 2, \Delta S_F > -2$

GATE – 2013

Q.158. A binary; liquid mixture is in equilibrium with its vapor at a temperature T = 300K. The liquid mole fraction x_1 of species 1 is 0.4 and the molar excess Gibbs free energy is 200 J/mol. The value of the universal gas constant is 8.314 J/mol-K, and γ_i denotes the liquid-phase activity coefficient of species i. If $\ln(\gamma_1) = 0.09$, then the value of $\ln(\gamma_2)$, up to 2 digits after the decimal point, is _____

GATE – 2013

Q.159. Calculate the heat required (in kJ, up to 1 digit after the decimal point) to raise the temperature of 1 mole of a solid material from 100 °C to 1000 °C. The specific heat (C_p) of the material (in J/mol-K) is expressed as $C_p = 20 + 0.005T$, where T is in K. Assume no phase change. _____.

GATE – 2013

Q.160. From the following list, identify the properties which are equal in both vapour and liquid phases at equilibrium
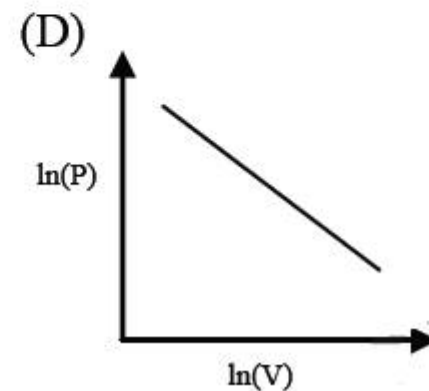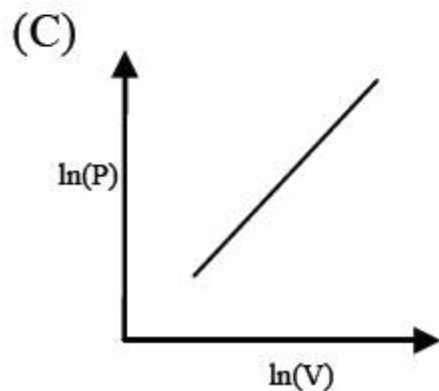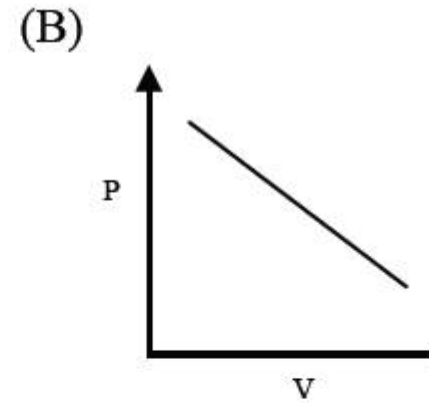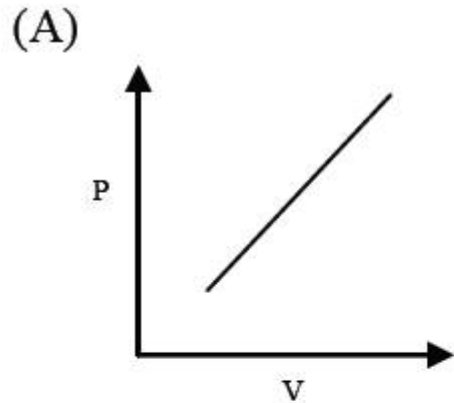
P. Density
Q. Temperature
R. Chemical potential
S. Enthalpy

(A) P and Q only   (B) Q and R only   (C) R and S only   (D) P and S only

GATE – 2014

Q.161. In a closed system, the isentropic expansion of an ideal gas with constant specific heats is represented by

(A)

(B)

(C)

(D)

Q.162. Match the following:

Group 1	Group 2
P. $\left(\dfrac{\partial G}{\partial n_i}\right)_{T,P,n_{j\neq i}}$	I. Arrhenius equation
Q. $\left(\dfrac{\partial G}{\partial n_i}\right)_{S,V,n_{j\neq i}}$	II. Reaction equilibrium constant
R. $\exp\left(\dfrac{-\Delta G^0_{reaction}}{RT}\right)$	III. Chemical potential
S. $\Sigma\left(n_i d\mu_i\right)_{T,P}$	IV. Gibbs-Duhem equation

(A) Q—III, R—I, S—II

(B) Q—III, R—II, S—IV

(C) P—III, R—II, S—IV

(D) P—III, R—IV, S—I

GATE – 2014

Q.163. Which ONE of the following is CORRECT for an ideal gas in a closed system?

(A) $\left(\dfrac{\partial U}{\partial V}\right)_S V = nR\left(\dfrac{\partial U}{\partial S}\right)_V$

(B) $\left(\dfrac{\partial H}{\partial P}\right)_S P = nR\left(\dfrac{\partial H}{\partial S}\right)_P$

(C) $\left(\dfrac{\partial U}{\partial V}\right)_S V = nR\left(\dfrac{\partial H}{\partial S}\right)_P$

(D) $\left(\dfrac{\partial H}{\partial P}\right)_S P = nR\left(\dfrac{\partial U}{\partial S}\right)_V$

GATE – 2014

Q.164. Consider a binary liquid mixture at equilibrium with its vapour at 25 °C. Antoine equation for this system is given as $\log_{10} p_i^{sat} = A - \dfrac{B}{t+C}$.

where t is in C and p in Torr. The Antoine constants (A, B, and C) for the system are given in the following table

Component	A	B	C
1	7.0	1210	230
2	6.5	1206	223

The vapour phase is assumed to be ideal and the activity coefficients (γ_i) for the non-ideal liquid phase are given by

$$\ln(\gamma_1) = x_2^2[2 - 0.6x_1]$$
$$\ln(\gamma_2) = x_1^2[1.7 + 0.6x_2]$$

If the mole fraction of component 1 in liquid phase (x_1) is 0.11, then the mole fraction of component 1 in vapour phase y_1) is

(A) 0.50   (B) 0.60   (C) 0.70   (D) 0.80

GATE – 2014

Q.165. For a pure liquid, the rate of change of vapour pressure with temperature is 0.1 bar/K in the temperature range of 300 to 350 K. If the boiling point of the liquid at 2 bar is 320 K, the temperature (in K) at which it will boil at 1 bar (up to one decimal place) is _____ .

GATE – 2015

Q.166. Three identical closed systems of a pure gas are taken from an initial temperature and pressure (T_1, P_1) to a final state (T_2, P_2) each by a different path. Which of the following is ALWAYS TRUE for the three systems? (Δ represents the change between the initial and final states, U, S, G, Q and W are internal energy, entropy, Gibbs free energy, heat added and work done, respectively.)
(A) ΔU, ΔS, Q are same
(B) W, ΔU, ΔG are same
(C) ΔS, W, Q are same
(D) ΔG, ΔU, ΔS are same

GATE – 2015

Q.167. For a gas phase cracking reaction A → B + C at 300ºC, the Gibbs free energy of the reaction at this temperature is $\Delta G^º$ = -2750 J/mol. The pressure is 1 bar and the gas phase can be assumed to be ideal. The universal gas constant R = 8.314 J/mol.K. The fractional molar conversion of A at equilibrium is :

(A) 0.44   (B) 0.50   (C) 0.64   (D) 0.80

GATE – 2015

Q.168. If v, u, s and g represent respectively the molar volume, molar internal energy, molar entropy and molar Gibbs free energy, then match the entries in the le and right columns below and choose the correct option.

P. $- (\partial u/\partial v)_s$ 　　　　　　　　 I. Temperature
Q. $(\partial g/\partial P)_T$ 　　　　　　　　 II. Pressure
R. $- (\partial g/\partial T)_P$ 　　　　　　　 III. v
S. $(\partial u/\partial s)_v$ 　　　　　　　　 IV. S

(A) P-II, Q-III, R-IV, S-I 　　　　　　　 (B) P-II, Q-IV, R-III, S-I
(C) P-I, Q-IV, R-II, S-III 　　　　　　　 (D) P-III, Q-II, R-IV, S-I

GATE – 2015

Q.169. An ideal gas is initially at a pressure of 0.1 MPa and a total volume of 2 m³ . It is first compressed to 1 MPa by a reversible adiabatic process and then cooled at constant pressure to a final volume of 0.2 m³ . The total work done (in kJ) on the gas for the entire process (up to one decimal place) is _____

Data: R = 8.314 J/mol.K; heat capacity at constant pressure (C_P) = 2.5R

GATE – 2015

Q.170. Given that molar residual Gibbs free energy, g^R , and molar residual volume, v^R , are related as $$\frac{g^R}{RT} = \int_0^P \left(\frac{V^R}{RT}\right) dP$$, find g^R at T = 27 °C and P = 0.2 MPa. The gas may be assumed to follow the virial equation of state, $z = 1 + BP/RT$, where $B = -10^{-4}$ m^3/mol at the given conditions (R = 8.314 J/mol.K). The value of g^R in J/mol is:

(A) 0.008   (B) –2.4   (C) 20   (D) –20

GATE – 2015

Q.171. A binary mixture of components (1) and (2) forms an azeotrope at 130ºC and x_1 = 0.3. The liquid phase non-ideality is described by $\ln \gamma_1 = Ax_2^2$ and $\ln \gamma_2 = Ax_1^2$, where γ_1 , γ_2 are the activity coefficients, and x_1 , x_2 are the liquid phase mole fractions. For both components, the fugacity coefficients are 0.9 at the azeotropic composition. Saturated vapor pressures at 130 ºC are P_1^{sat} = 70 bar and P_2^{sat} = 30 bar. The total pressure in bars for the above azeotropic system (up to two decimal places) is _____. **GATE – 2015**

Q.172. The partial molar enthalpy (in kJ/mol) of species 1 in a binary mixture is given by $\bar{h}_1 = 2 - 60x_2^2 + 100x_1x_2^2$, where x_1 and x_2 are the mole fractions of species 1 and 2, respectively. The partial molar enthalpy (in kJ/mol, rounded off to the first decimal place) of species 1 at infinite dilution is _____.

GATE – 2016

Q.173. An ideal gas is adiabatically and irreversibly compressed from 3 bar and 300 K to 6 bar in a closed system. The work repaired for the irreversible compression is 1.5 times the work that is required for reversible compression from the same initial temperature and pressure to the same final pressure. The molar heat capacity of the gas at constant volume is 30 J mol^{-1} K^{-1} (assumed to be independent of temperature), universal gas constant, R is 8.314 J mol^{-1} K^{-1} , ratio of molar heat capacities is 1.277. The temperature (in K, rounded off to the first decimal place) of the gas at the final state in the irreversible compression case is _____ .

GATE – 2016

Q.174. A gas obeying the Clausius equation of state is isothermally compressed from 5 MPa to 15 MPa in a closed system at 400 K. The Clausius equation of state is

$$P = \frac{RT}{\upsilon - b(T)}$$

where P is the pressure, T is the temperature, υ is the molar volume and R is the universal gas constant. The parameter b in the above equation varies with temperature as $b(T) = b_0 + b_1 T$ with $b_0 = 4 \times 10^{-5}$ $m^3 mol^{-1}$ and $b_1 = 1.35 \times 10^{-7}$ $m^3 mol^{-1}$ K^{-1}. The effect of pressure on the molar enthalpy (h) at a constant temperature is given by

$$\left(\frac{\partial h}{\partial P}\right)_T = \upsilon - T\left(\frac{\partial \upsilon}{\partial T}\right)_P$$

Let h_i and h_f denote the initial and final molar enthalpies, respectively. The change in the molar enthalpy $h_f - h_i$ (in J mol^{-1}, rounded off to the first decimal place) for this process is _____.

GATE – 2016

Q.175. A binary system at a constant pressure with species '1' and '2' is described by the two-suffix Margules equation, $\frac{g^E}{RT} = 3x_1x_2$, where g E is the molar excess Gibbs free energy, R in the universal gas constant, T is the temperature and x_1 , x_2 are the mole fractions of species 1 and 2, respectively. At a temperature T, $\frac{g_1}{RT} = 1$ and $\frac{g_2}{RT} = 2$, where g_1 and g_2 are the molar Gibbs free energies of pure species 1 and 2, respectively. At the same temperature, g represents the molar Gibbs free energy of the mixture. For a binary mixture with 40 mole % of species 1, the value (rounded off to the second decimal place) of $\frac{g}{RT}$ is

_____.

GATE – 2016

Q.176. The volumetric properties of two gases M and N are described by the generalized compressibility chart which expresses the compressibility factor (Z) as a function of reduced pressure and reduced temperature only. The operating pressure (P) and temperature (T) of two gases M and N along with their critical properties (P_C, T_C) are given in the table below

Gas	P (bar)	T (K)	P_C (bar)	T_C (K)
M	25	300	75	150
N	75	1000	225	500

Z_M and Z_N are the compressibility factor of the gases M and N under the given operating conditions, respectively. The relation between Z_M and Z_N is,

(A) $Z_M = 8Z_N$ (B) $Z_M = 3Z_N$ (B) $Z_M = Z_N$ (D) $Z_M = 0.333Z_N$ **GATE – 2017**

Q.177. Water is heated at atmospheric pressure from 40 ^{0}C to 80 ^{0}C using two different processes. In process I, the heating is done by a source at 80 ^{0}C. In process II, the water is first heated from 40 ^{0}C to 60 ^{0}C by a source at 60 ^{0}C and then from 60 ^{0}C to 80 ^{0}C by another source at 80 ^{0}C. Identify the correct statement.
(A) Enthalpy change of water in process I is greater than enthalpy change in process II.
(B) Enthalpy change of water in process II is greater than enthalpy change in process I.
(C) Process I is closer to reversibility
(D) Process II is closer to reversibility

GATE – 2017

Q.178. The pressure of a liquid is increased isothermally. The molar volume of the liquid decreases from 50.45×10^{-6} m^3/mol to 48×10^{-6} m^3/mol during this process. The isothermal compressibility of the liquid is 10^{-9} Pa^{-1}, which; can be assumed to be independent of pressure. The change in the molar Gibbs free energy of the liquid rounded to nearest integer, is _____ J/mol

GATE – 2017

Q.179. A sparingly soluble gas (solute) is in equilibrium with a solvent at 10 bar. The mole fraction of the solvent in the gas phase is 0.01. At the operating temperature and pressure, the fugacity coefficient of the solute in the gas phase and the Henry's law constant are 0.92 and 1000 bar, respectively. Assume that the liquid phase obeys Henry's law. The MOLE PERCENTAGE of the solute in the liquid phase rounded to 2 decimal places, is _____ .

GATE – 2017

Q.180. The vapour pressure of a pure substance at a temperature T is 30 bar. The actual and ideal gas values of g/RT for the saturated vapour at this temperature T and 30 bar are 7.0 and 7.7, respectively. Here g is the molar Gibbs free energy; and R is the universal gas constant. The fugacity of the saturated liquid at these conditions, rounded to 1 decimal place, is _____bar.

GATE – 2017

Q.181. Consider the following properties

(P) temperature

(Q) specific gravity

(R) chemical potential

(S) volume

The option which lists ALL the intensive properties is

(A) P   (B) P and Q   (C) P, Q and R   (D) P, Q, R and S

GATE – 2018

Q.182. G denotes the Gibbs free energy of a binary mixture, n_T denotes the total number of moles present in the system, μ_i is the chemical potential of the ith component ($\mu_1 \neq 0$ and $\mu_1 > \mu_2$) and x_i is the mole fraction of the i component. The correct variation of G/n_T (in J/mol) at constant temperature and pressure is given by

(A)

(B)

(C)

(D)
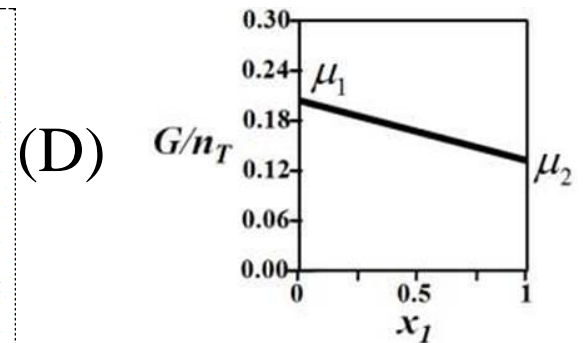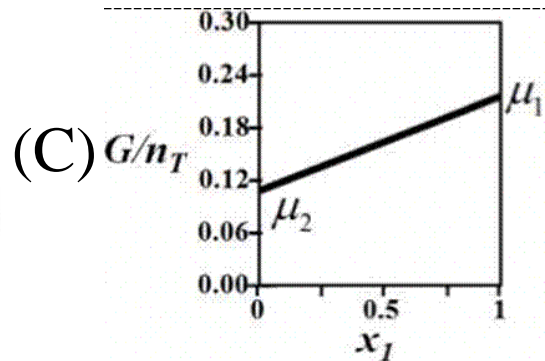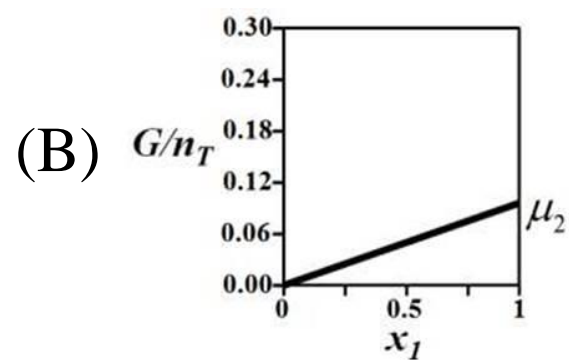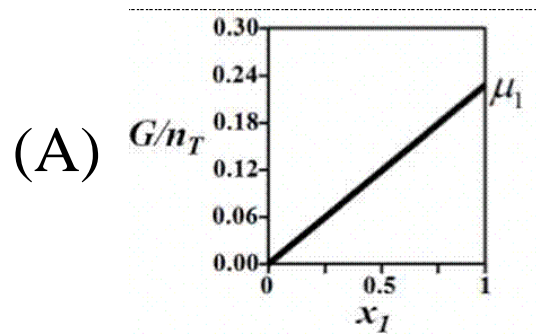
GATE – 2018

Q.183. Under isothermal condition, a vertical tube of length L = 100 m contains a gas of molecular weight equal to 60. The pressure and temperature at the top of the tube are 100 kPa and 25 ^{0}C respectively. Consider the universal gas constant and acceleration due to gravity as 8.314 J mol^{-1} K^{-1} and 9.81 m s^{-2} respectively. If the gas is ideal, the pressure (in kPa) at the bottom of the tube will be _____ (rounded off to third place)

GATE – 2018

Q. 184. In a closed piston-cylinder system, methane was observed to obey the following equation of state

$$P\ (V - nb) = nRT$$

where b = 0.029 m^3/mol. The temperature and volume are 500°C and 5 m^3 respectively for 100 moles of methane. At this state of the system, the isobaric rate of change of temperature with volume (in ^{o}C/m^3) is _____ (rounded off to second decimal place).

GATE – 2018

Q. 185.

Consider a rigid, perfectly insulated, container partitioned into two unequal parts by a thin membrane (see figure). One part contains one mole of an ideal gas at pressure P_i and temperature T_i while the other part is evacuated. The membrane ruptures, the gas fills the entire volume and the equilibrium pressure is $P_f = P_i/4$. If C_p (molar specific heat capacity at constant pressure), C_v (molar specific heat capacity at constant volume) and R (universal gas constant) have the same units as molar entropy, the change in molar entropy $(S_f - S_i)$ is

P_i, T_i Vacuum
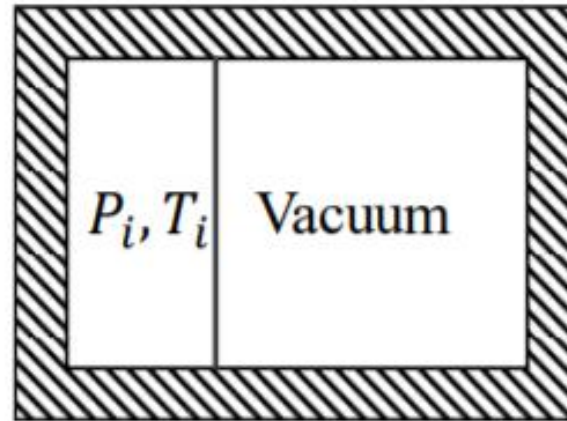
(A) $C_p\ln2 + R\ln4$
(B) $-C_v\ln2 + R\ln4$
(C) $R\ln4$
(D) $C_p\ln2$

GATE – 2019

Q. 186.

For a single component system, vapor (subscript g) and liquid (subscript f) coexist in mechanical, thermal and phase equilibrium when

(A) $u_g = u_f$ (equality of specific internal energy)
(B) $h_g = h_f$ (equality of specific enthalpy)
(C) $s_g = s_f$ (equality of specific entropy)
(D) $g_g = g_f$ (equality of specific Gibbs free energy)

GATE – 2019

Q. 187.

For a binary nonideal A-B mixture exhibiting a minimum boiling azeotrope, the activity coefficients, γ_i (i = A, B), must satisfy

(A) $\gamma_A > 1, \gamma_B > 1$
(B) $\gamma_A < 1, \gamma_B > 1$
(C) $\gamma_A = 1, \gamma_B = 1$
(D) $\gamma_A < 1, \gamma_B < 1$

GATE – 2019

Q. 188.

Consider a sealed rigid bottle containing CO_2 and H_2O at 10 bar and ambient temperature. Assume that the gas phase in the bottle is pure CO_2 and follows the ideal gas law. The liquid phase in the bottle contains CO_2 dissolved in H_2O and is an ideal solution. The Henry's constant at the system pressure and temperature is $\mathcal{H}_{CO_2} = 1000$ bar. The equilibrium mole fraction of CO_2 dissolved in H_2O is _____ (rounded off to three decimal places).

GATE – 2019

Q. 189.

Carbon monoxide (CO) reacts with hydrogen sulphide (H_2S) at a constant temperature of 800 K and a constant pressure of 2 bar as:

$$CO + H_2S \leftrightharpoons COS + H_2$$
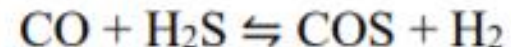
The Gibbs free energy of the reaction $\Delta g°_{rxn} = 22972.3$ J/mol and universal gas constant $R = 8.314$ J/(mol K). Both the reactants and products can be assumed to be ideal gases. If initially only 4 mol of H_2S and 1 mol of CO are present, the extent of the reaction (in mol) at equilibrium is _____ (rounded off to two decimal places).

GATE – 2019

Q. 190.

For a given binary system at constant temperature and pressure, the molar volume (in m^3/mol) is given by: $v = 30x_A + 20x_B + x_A x_B (15x_A - 7x_B)$, where x_A and x_B are the mole fractions of components A and B, respectively. The volume change of mixing Δv_{mix} (in m^3/mol) at $x_A = 0.5$ is _____ (rounded off to one decimal place).

GATE – 2019

Q. 191.

Consider a vessel containing steam at 180 °C. The initial steam quality is 0.5 and the initial volume of the vessel is 1 m³. The vessel loses heat at a constant rate $\dot{q}$ under isobaric conditions so that the quality of steam reduces to 0.1 after 10 hours. The thermodynamic properties of water at 180 °C are (subscript g: vapor phase; subscript f: liquid phase):

specific volume: $v_g = 0.19405$ m³/kg, $v_f = 0.001127$ m³/kg;
specific internal energy: $u_g = 2583.7$ kJ/kg, $u_f = 762.08$ kJ/kg;
specific enthalpy: $h_g = 2778.2$ kJ/kg, $h_f = 763.21$ kJ/kg.

The rate of heat loss $\dot{q}$ (in kJ/hour) is_____ (rounded off to the nearest integer).

GATE – 2019

Q. 192.

A fractionator recovers 95 mol % *n*-propane as the distillate from an equimolar mixture of *n*-propane and *n*-butane. The condensate is a saturated liquid at 55 °C. The Antoine equation is of the form, $\ln\left(P^{sat}\ [\text{in bar}]\right) = A - \dfrac{B}{T\ [\text{in K}] + C}$, and the constants are provided below:

	A	B	C
n-propane	9.1058	1872.46	−25.16
n-butane	9.0580	2154.90	−34.42

Assuming Raoult's law, the condenser pressure (in bar) is _____ (rounded off to one decimal place).

GATE – 2019

Q. 193. Mole fraction and activity coefficient of component 1 in a binary liquid mixture are x_1 and γ_1 respectively. G^E is excess molar Gibbs energy of the mixture. R is universal gas constant and T is absolute temperature of the mixture. Which one of the following is always true?

(A) $\lim\limits_{x_1 \to 1} \dfrac{G^E}{RT} = 0$

(B) $\lim\limits_{x_1 \to 1} \dfrac{G^E}{RT} = 0.5$

(C) $\lim\limits_{x_1 \to 1} \gamma_1 = 0$

(C) $\lim\limits_{x_1 \to 1} \gamma_1 = 0.5$

GATE – 2020

Q. 194.

Consider two Carnot engines C_1 and C_2 as shown in the figure.
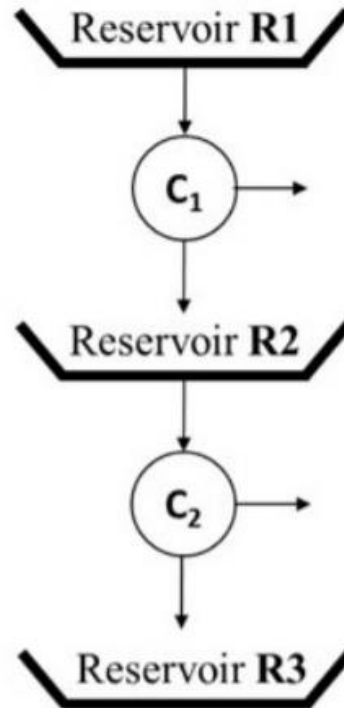
The efficiencies of the engines C_1 and C_2 are 0.40 and 0.35, respectively. If the temperature of Reservoir **R1** is 800 K, then the temperature (in K) of Reservoir **R3** is _____ (round off to nearest integer).

GATE – 2020

Q. 195.

A pure gas obeys the equation of state given by

$$\frac{PV}{RT} = 1 + \frac{BP}{RT}$$

where P is the pressure, T is the absolute temperature, V is the molar volume of the gas, R is the universal gas constant, and B is a parameter independent of T and P. The residual molar Gibbs energy, G^R, of the gas is given by the relation

$$\frac{G^R}{RT} = \int_0^P (Z-1)\frac{dP}{P}$$

where Z is the compressibility factor and the integral is evaluated at constant T. If the value of B is 1×10^{-4} m^3 mol^{-1}, the residual molar enthalpy (in J mol^{-1}) of the gas at 1000 kPa and 300 K is

(A)   100

(B)   300

(C)   2494

(D)   30000

GATE – 2020

Q. 196.

Consider one mole of an ideal gas in a closed system. It undergoes a change in state from **L** to **N** through two different non-isothermal processes, as shown in the P-V diagram (where P is the pressure and V is the molar volume of the gas). Process **I** is carried out in a single step, namely **LN**, whereas process **II** is carried out in two steps, namely **LM** and **MN**. All the steps are reversible.
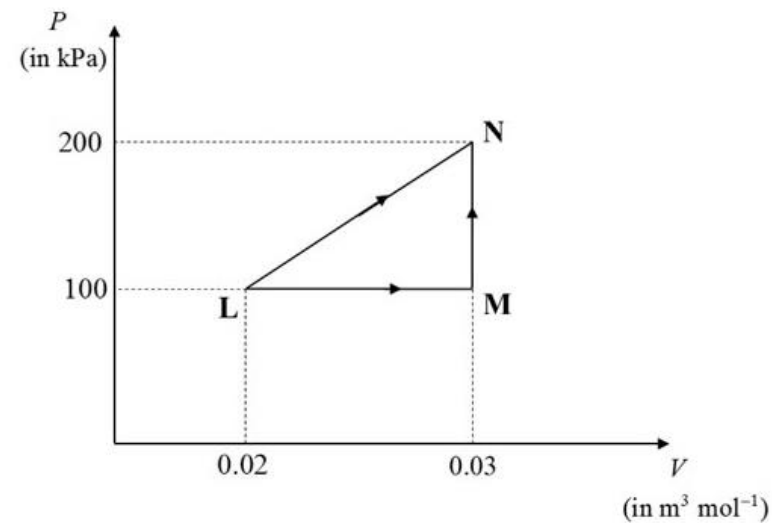
The net heat flowing into the system for process **I** is Q_I and that for process **II** is Q_{II}. The value of $Q_I - Q_{II}$ (in J) is

(A) 250

(B) 500

(C) 1000

(D) 1500

GATE – 2020

Q. 197. The van der Waals equation of state is given by

$$P_r = \frac{8T_r}{3v_r - 1} - \frac{3}{v_r^2}$$

where P_r, T_r and v_r represent reduced pressure, reduced temperature and reduced molar volume, respectively. The compressibility factor at critical point (z_c) is 3/8.

If $v_r = 3$ and $T_r = 4/3$, then the compressibility factor based on the van der Waals equation of state is _____ (round off to 2 decimal places).

GATE – 2021

Q.198. The molar heat capacity at constant pressure C_p (in J mol^{-1} K^{-1}) for n-pentane as a function of temperature (T in K) is given by

$$\frac{C_p}{R} = 2.46 + 45.4 \times 10^{-3} T - 14.1 \times 10^{-6} T^2$$

Take R= 8.314 J mol^{-1}K^{-1}.

At 1000 K, the rate of change of molar entropy of n-pentane with respect to temperature at constant pressure is _____ J^{-1}mol^{-1} K^{-2} (round off to 2 decimal places).

GATE – 2021

Q.199. The combustion of carbon monoxide is carried out in a closed, rigid and insulated vessel. 1 mol of CO, 0.5 mol of O_2 and 2 mol of N_2 are taken initially at 1 bar and 298 K, and the combustion is carried out to completion.

The standard molar internal energy change of reaction (Δu^0_R) for the combustion of carbon monoxide at 298 K = - 282 kJ mol^{-1}. At constant pressure, the molar heat capacities of N_2 and CO_2 are 33.314 J mol^{-1} K^{-1} and 58.314 J mol^{-1} K^{-1}, respectively. Assume the heat capacities to be independent of temperature, and the gases are ideal. Take R = 8.314 J mol^{-1} K^{-1} .

The final pressure in the vessel at the completion of the reaction is _____ bar (round off to 1 decimal place).

GATE – 2021

Q.200. A gaseous mixture at 1 bar and 300 K consists of 20 mol % CO_2 and 80 mol% inert gas.

Assume the gases to be ideal. Take R = 8.314 J mol^{-1} K^{-1}

The magnitude of minimum work required to separate 100 mol of this mixture at 1 bar and 300 K into pure CO_2 and inert gas at the same temperature and pressure is _____ kJ (round off to nearest integer).

GATE – 2021

Q.201. A binary liquid mixture consists of two species 1 and 2. Let γ and x represent the activity coefficient and the mole fraction of the species, respectively. Using a molar excess Gibbs free energy model, In γ_1 vs. x_1 and In γ_2 vs. x_1 are plotted. A tangent drawn to the $\ln\gamma_1$ vs. x_1 curve at a mole fraction of $x_1 = 0.2$ has a slope = -1.728.

The slope of the tangent drawn to the In γ_2 vs. x_1 curve at the same mole fraction is _____ (correct to 3 decimal places).

GATE – 2021

Q.202. The following homogeneous liquid phase reactions are at equilibrium.
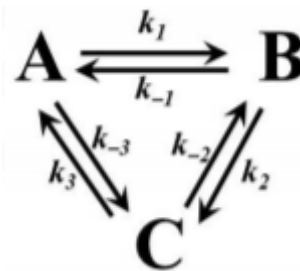
The values of rate constants are given by:

$k_1 = 0.1$ s^{-1}, $k_{-1} = 0.2$ s^{-1}, $k_2 = 1$ s^{-1} , $k_{-2} = 10$ s^{-1}, $k_3 = 10$ s^{-1}.

The value of rate constant k_{-3} is _____ s^{-1} (round off to 1 decimal place).

GATE – 2021

Q.203. For a single component system at vapor-liquid equilibrium, the extensive variables A, V, S and N denote the Helmholtz free energy, volume, entropy, and number of moles, respectively, in a given phase. If superscripts (v) and (l) denote the vapor and liquid phase, respectively, the relation that is NOT CORRECT is

(A) $\left(\dfrac{\partial A^{(l)}}{\partial V^{(l)}}\right)_{T,N^{(l)}} = \left(\dfrac{\partial A^{(v)}}{\partial V^{(v)}}\right)_{T,N^{(v)}}$

(B) $\left(\dfrac{\partial A^{(l)}}{\partial N^{(l)}}\right)_{T,V^{(l)}} = \left(\dfrac{\partial A^{(v)}}{\partial N^{(v)}}\right)_{T,V^{(v)}}$

(C) $\left(\dfrac{A + PV}{N}\right)^{(l)} = \left(\dfrac{A + PV}{N}\right)^{(v)}$

(D) $\left(\dfrac{A + TS}{N}\right)^{(l)} = \left(\dfrac{A + TS}{N}\right)^{(v)}$

Q.204. 5 moles of liquid benzene, 8 moles of liquid toluene and 7 moles of liquid xylene are mixed at 25 °C and 1 bar. Assuming the formation of an ideal solution and using the universal gas constant $R = 8.314$ J mol^{-1} K^{-1}, the total entropy change is _____ J K^{-1} (rounded off to one decimal place).

GATE – 2022

Q.205. N moles of an ideal gas undergo a two-step process as shown in the figure. Let P, V and T denote the pressure, volume and temperature of the gas, respectively. The gas, initially at state-1 (P_1, V_1, T_1), undergoes an isochoric (constant volume) process to reach state-A, and then undergoes an isobaric (constant pressure) expansion to reach state-2 (P_1, V_1, T_1). For an ideal gas, $C_P - C_v = NR$, where C_p and C_v are the heat capacities at constant pressure and constant volume, respectively, and assumed to be temperature independent. The heat gained by the gas in the two-step process is given by
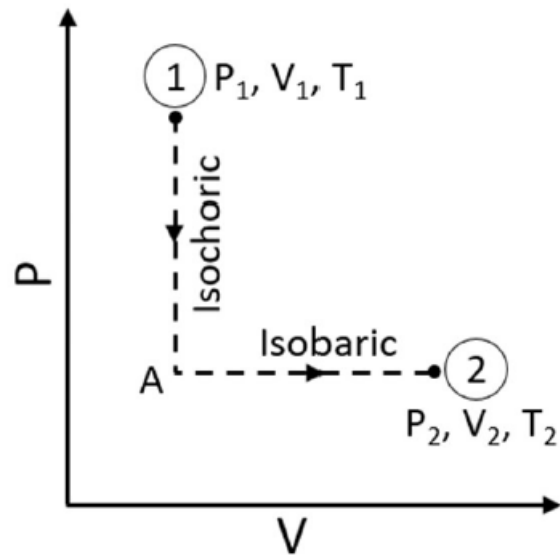
(A) $P_2(V_2 - V_1) + C_V(T_2 - T_1)$

(B) $P_2(V_2 - V_1) + C_P(T_2 - T_1)$

(C) $C_P(T_2 - T_1) + C_V(T_2 - T_1)$

(D) $P_2 V_2 - P_1 V_1$

GATE – 2022

Q.206. A substance at 4 °C has a thermal expansion coefficient $\beta = \frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_P = 0 \text{ K}^{-1}$

an isothermal compressibility, $\kappa_T = -\frac{1}{v}\left(\frac{\partial v}{\partial P}\right)_T = 5 \times 10^{-4} \text{ Pa}^{-1}$

and a molar volume $v = 18 \times 10^{-6} \text{ m}^3 \text{ mol}^{-1}$.

If s is the molar entropy, then at 4 °C, the quantity $\left[v\left(\frac{\partial s}{\partial v}\right)_T\right]$ evaluated for the substance is _____ J mol^{-1} K^{-1}

(rounded off to the nearest integer).

GATE – 2022

Q.207. The molar excess Gibbs free energy (g^E) of a liquid mixture of A and B is given by

$$\frac{g^E}{RT} = x_A x_B [C_1 + C_2(x_A - x_B)]$$

where x_A and x_B are the mole fraction of A and B, respectively, the universal gas constant, $R = 8.314$ J K^{-1} mol^{-1}, T is the temperature in K, and C_1, C_2 are temperature-dependent parameters. At 300 K, $C_1 = 0.45$ and $C_2 = -0.018$. If γ_A and γ_B are the activity coefficients of A and B, respectively, the value of

$$\int_0^1 \ln\left(\frac{\gamma_A}{\gamma_B}\right) dx_A$$

at 300 K and 1 bar is _____ (rounded off to the nearest integer).

GATE – 2022

Q.208. For a pure substance, the following data at saturated conditions are given:

ln P^{sat} (bar)	T (K)
0.693	350
1.386	370

Assume that the vapor phase behaves ideally, the molar volume of the liquid is negligible, and the latent heat of vaporization is constant over the given temperature range. The universal gas constant, $R = 8.314$ J K^{-1} mol^{-1}. From the above data, the estimated latent heat of vaporization at 360 K is _____ kJ/mol (rounded off to one decimal place).

GATE – 2022

Q.209. John and Jane independently performed a thermodynamic experiment, in which **X** and **Y** represent the initial and final thermodynamic states of the system, respectively. John performed the experiment under reversible conditions, for which the change in entropy of the system was $\mathbf{\Delta S_{rev}}$. Jane performed the experiment under irreversible conditions, for which the change in entropy of the system was $\mathbf{\Delta S_{irr}}$.

Which one of the following relationships is CORRECT?
(A) $\mathbf{\Delta S_{rev}} = \mathbf{\Delta S_{irr}}$
(B) $\mathbf{\Delta S_{rev}} > \mathbf{\Delta S_{irr}}$
(C) $\mathbf{\Delta S_{rev}} < \mathbf{\Delta S_{irr}}$
(D) $\mathbf{\Delta S_{rev}} = \mathbf{2\Delta S_{irr}}$

GATE – 2023

Q.210. The enthalpy (H, in J. mol^{-1}) of a binary liquid system at constant temperature and pressure is given as

$$H = 40x_1 + 60x_2 + x_1x_2(4x_1 + 2x_2)$$

where x_1 and x_2 represent the mole fractions of species 1 and 2 in the liquid, respectively. Which one of the following is the CORRECT value of the partial molar enthalpy of species 1 at infinite dilution, H_1^∞ (in J. mol^{-1}) ?

(A) 100

(B) 42

(C) 64

(D) 40

GATE – 2023

THERMODYNAMICS

Que. No.	Answer	Que. No.	Answer	Que. No.	Answer	Que. No.	Answer
1.	subjective	14.	A	27.	C	40.	C
2.	subjective	15.	C	28.	C	41.	A
3.	0.693RT	16.	B	29.	D	42.	C
4.	subjective	17.	500 kJ	30.	B	43.	A
5.	subjective	18.	False	31.	2.052	44.	902.49mm
6.	A	19.	360.39	32.	A	45.	0.0855
7.	A	20.	D	33.	B	46.	Subjective
8.	D	21.	C	34.	B	47.	C
9.	D	22.	subjective	35.	D	48.	A
10.	A	23.	F,F,F, F	36.	192.94mm	49.	A
11.	0.408	24.	B,D	37.	42139.2 kJ	50.	C
12.	Subjective	25.	A,B	38.	subjective	51.	B
13.	Subjective	26.	subjective	39.	D	52.	0.925

THERMODYNAMICS

Answer Key

Que. No.	Answer	Que. No.	Answer	Que. No.	Answer	Que. No.	Answer
53.	2025	66.	Subjective	79.	B	92.	B, C
54.	C	67.	C	80.	56.94 kPa	93.	D
55.	A	68.	B	81.	2.37,6397.5	94.	B
56.	B	69.	D	82.	C	95.	C
57.	D	70.	A	83.	A	96.	B
58.	B	71.	A	84.	D	97.	B
59.	Subjective	72.	Subjective	85.	B	98.	D
60.	A	73.	0.676, 0.1	86.	B	99.	A
61.	B	74.	A	87.	B	100.	D
62.	C	75.	B	88.	C	101.	C
63.	C	76.	A	89.	D	102.	A
64.	A	77.	D	90.	C	103.	C
65.	0.4385	78.	B	91.	A	104.	D

THERMODYNAMICS   Answer Key

Que. No.	Answer	Que. No.	Answer	Que. No.	Answer	Que. No.	Answer
105.	B	118.	A	131	A	144	B
106.	A	119.	D	132	B	145	C
107.	B, D	120	A	133	B	146	C
108.	A	121	B	134	B , C	147	B
109.	B	122	A	135	D	148	A
110.	B	123	C	136	C	149	A
111.	D	124	C, D	137	D	150	D
112.	C	125	A	138	D	151	A
113.	C	126	B	139	C	152	D
114.	B	127	C	140	C	153	3
115.	B	128	C, D	141	A	154	C
116.	A	129	C	142	B	155	D
117.	B	130	D	143	C	156	B

THERMODYNAMICS

Answer Key

Que. No.	Answer	Que. No.	Answer	Que. No.	Answer	Que. No.	Answer
157.	D	170.	D	183.	102.3 KPa	196.	B
158.	0.073	171.	27.548 bar	184.	368	197.	0.83
159.	21.7 kJ	172.	-58 kJ/mol	185.	C	198.	0.27
160.	B	173.	373 k	186.	D	199.	8.9
161.	D	174.	400 J/ mol	187.	A	200.	124
162.	C	175.	1.647	188.	0.01	201.	0.432
163.	D	176.	C	189.	0.288	202.	0.5
164.	0.6978	177.	D	190.	1 m^3	203.	D
165.	310 K	178.	2450	191.	825.9 kJ/h	204.	178.7 to 180.7
166.	D	179.	0.91	192.	18 bar	205.	A
167.	D	180.	14.8 kPa	193.	A	206.	0 to 0
168.	A	181.	C	194.	312 K	207.	0 to 0
169.	-756.9 kJ	182.	C	195.	A	208.	36.3 to 38.3

THERMODYNAMICS

Que. No.	Answer	Que. No.	Answer	Que. No.	Answer	Que. No.	Answer
209.	A						
210.	B						

Thank you