I.6 Thermodynamics

Civil Services 2016–2026: **43** parts, **405** marks · IFoS 2016–2025: **34** parts, **352** marks

Syllabus. Work, heat and internal energy; first law of thermodynamics. Second law of thermodynamics; entropy as a state function, entropy changes in various processes, entropy–reversibility and irreversibility, free energy functions; thermodynamic equation of state; Maxwell relations; temperature, volume and pressure dependence of U, H, A, G, Cp and Cv, α and β; J-T effect and inversion temperature; criteria for equilibrium, relation between equilibrium constant and thermodynamic quantities; Nernst heat theorem, introductory idea of third law of thermodynamics.

Marks	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
CSE	35	45	50	35	40	20	30	40	35	30	45
IFoS	25	50	53	38	23	33	38	28	28	36	

How to use this chapter. Read every question once and mark the ones that repeat. Pick three, write them by hand against the clock (about 7 minutes for 10 marks), then compare with the model answers on vkcscience.com.

2026

CSE 2026 · Q1(c) Two metal blocks in thermal contact [5 marks]

Two blocks of a metal having same mass have same heat capacity 15 J K^{-1} (presumed independent of T), but are at different temperatures 300 K and 400 K, respectively. Calculate the final temperature and entropy change, if the blocks are in thermal contact and reach equilibrium. (Assume two blocks together constitute the isolated system)

CSE 2026 · Q1(d) K_p and ΔG° for $N_2O_4 \rightleftharpoons 2NO_2$ at 300 K [5 marks]

At 300 K temperature and 1 atm pressure, dinitrogen tetraoxide is 20 percent dissociated into nitrogen dioxide. Calculate the equilibrium constant (K_p) and standard free energy change for the reaction at this temperature :

$$N_2O_4(g) \rightleftharpoons 2\,NO_2(g)$$

CSE 2026 · Q2(c) Enthalpy of formation of HI(g) from the gaseous elements at 225°C; ΔG° of ammonia formation at 400 K [20 marks]

(i) At 25 °C, the latent heat of sublimation per mole of iodine is 62.3 kJ mol^{-1} and the standard enthalpy of formation of HI(g) is 24.7 kJ mol^{-1}. Calculate the enthalpy change which occurs when HI(g) is formed from the gaseous elements at 225 °C. The mean molar heat capacities over the temperature range 25 °C to 225 °C are :

$H_2(g)$; $C_{p,m}$ = 29.08 J K^{-1} mol^{-1} $I_2(g)$; $C_{p,m}$ = 33.56 J K^{-1} mol^{-1} HI(g); $C_{p,m}$ = 29.87 J K^{-1} mol^{-1}

(ii) Calculate ΔG° at 400 K temperature for the following reaction :

$$\tfrac{1}{2}N_2(g) + \tfrac{3}{2}H_2(g) \longrightarrow NH_3(g)$$

Assume that ΔS° is independent of temperature.

(Given : $\Delta G^\circ_{298\,K}$ = −16.496 kJ mol^{-1}; $S^\circ_{NH_3}$ = 192.45 J K^{-1} mol^{-1}; $S^\circ_{N_2}$ = 191.61 J K^{-1} mol^{-1}; $S^\circ_{H_2}$ = 130.68 J K^{-1} mol^{-1})

CSE 2026 · Q3(a)(i) Chemical potential from U, H, A and G [10 marks]

(i) Derive the expressions of chemical potential of a component in a mixture system in terms of extensive thermodynamic properties U, H, A and G.

CSE 2026 · Q3(a)(iii) How an acetone–dry ice bath works [5 marks]

(iii) How does acetone-dry ice freezing mixture work?

2025

CSE 2025 · Q1(g) Heat of combustion of naphthalene from bomb calorimetry [5 marks]

0.500 g of benzoic acid was burnt under oxygen. The combustion produced a temperature rise of 1.236 K. The same calorimetric set-up was used to burn 0.300 g of naphthalene and the resulting temperature rise was 1.128 K. The heat of combustion of benzoic acid, $\Delta_c U^{298} = -3227$ kJ mol^{-1}. What is the heat of combustion of naphthalene?

CSE 2025 · Q1(j) Maximum work of a steam turbine [5 marks]

A steam turbine is operated with an intake temperature of 400 °C, and an exhaust temperature of 150 °C. What is the maximum amount of work the turbine can do for a given heat input '*Q*'? Under what conditions is the maximum work achieved?

CSE 2025 · Q3(d) Water condensed while ice melts and warms [10 marks]

A container with 100 g of ice at 0 °C is placed in a humid room whose temperature is 40 °C. The ice melts as water vapour condenses into the container. Assuming that all the heat transferred to the container comes from the condensation, how much water will have condensed in the container once all the ice is melted and has reached 40 °C?

Given: Heat of fusion of ice = 334 J g^{-1}

Heat of vaporization of water = 2260 J g^{-1}

Heat capacity of water = 4184 J kg^{-1} K^{-1}

CSE 2025 · Q4(d) ΔG°f with the standard state moved to 2 atm [10 marks]

Suppose we redefine the standard state as Pressure, P = 2 atm. Find the new standard ΔG_f° values of each substance:

(i) HCl (g) (ii) N_2O (g)

Explain the results in terms of the relative entropies of reactants and products of each reaction.

Given: Standard free energy of formation at 25 °C:

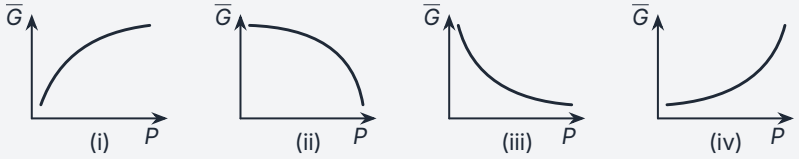
(i) $\Delta G^\circ_{HCl} = -95.3$ kJ mol^{-1} (ii) $\Delta G^\circ_{N_2O} = +103.7$ kJ mol^{-1}

IFoS 2025 · Q1(c) Formation free energy of uranium hydride [8 marks]

The equilibrium pressure of H_2(g) over solid uranium and uranium hydride, UH_3, at 500 K is very low and its value is 139 Pa. Calculate the standard Gibbs energy of formation of UH_3(s) at 500 K and 1 atm.

IFoS 2025 · Q1(d) Pressure dependence of solid Gibbs energy [8 marks]

Select the figure below that illustrates the correct dependence of the molar Gibbs free energy, $\overline{G}$, on pressure P at constant temperature for a single solid component. Explain your choice:



IFoS 2025 · Q3(b)(ii) Entropy change along two paths [10 marks]

(ii) Calculate the change in entropy of n moles of an ideal gas that undergoes quasi-static processes a and b from an initial state (T_0, P_0, V_0) to final state (T_0, P_1, V_1). Then redo the calculation for n moles of gas making the change via process c.

a. Isobaric quasi-static expansion, (T_0, P_0, V_0) to (T_1, P_0, V_1)
b. Isochoric quasi-static heating, (T_1, P_0, V_1) to (T_0, P_1, V_1)
c. Isothermal expansion, (T_0, P_0, V_0) to (T_0, P_1, V_1)

What conclusion can you draw from your answer? 10

IFoS 2025 · Q3(c) Three-state nuclear-spin partition function [10 marks]

A nitrogen nucleus spin can adopt any of three orientations in a magnetic field, and its energies are 0, $\pm\gamma_N\hbar B$, where γ_N is a magnetogyric ratio of the nucleus. Deduce an expression for partition function and mean energy of the nucleus, and sketch the variation of the functions with B. Calculate the relative populations of the spin states at 298 K, when B = 20.0 T. [Given: $\gamma_N\hbar = 2.04 \times 10^{-27}$ J T^{-1}]

2024

CSE 2024 · Q1(c) Normal boiling point of mercury [10 marks]

Use the following data to determine the normal boiling point of mercury. What assumptions must you make in order to do the calculations?

Hg(l) $\Delta H_f^\circ = 0$, $S^\circ = 77.4$ J/K mol
Hg(g) $\Delta H_f^\circ = 60.78$ kJ/mol, $S^\circ = 174.7$ J/K mol

CSE 2024 · Q3(c) Change in Helmholtz energy on reversible isothermal compression; Why a tyre gets hot when it is pumped; Pressure of O_2 over NiO at 25 °C; Final temperature after Joule–Thomson expansion [25 marks]

(i) Calculate the change in Helmholtz energy for a reversible isothermal compression of 1 mole of an ideal gas whose volume decreases from 100.0 L to 22.4 L. Assume that temperature is 298 K. *10*

(ii) Why does a tyre get hot when air is pumped into it? Can a tyre be inflated without a rise in temperature? *5*

(iii) Calculate the pressure of O_2 (in atm) over a sample of NiO at 25 °C if ΔG° = 212 kJ/mole for the following reaction: $NiO(s) \rightleftharpoons Ni(s) + \frac{1}{2} O_2(g)$ *5*

(iv) Estimate the final temperature of one mole of gas at 200.00 atm and 19.0 °C as it is forced through a porous plug to a final pressure of 0.95 atm. Given: The Joule-Thomson coefficient (μ_{JT}) of the gas is 0.150 K/atm. *5*

IFoS 2024 · Q1(b) Entropy of water-vapour formation at 373 K [8 marks]

For a reaction $H_2(g) + \frac{1}{2} O_2(g) \longrightarrow H_2O(g)$, calculate standard entropy change of the reaction at 373 K, using data as below:

Given: S°_{298} for $H_2O(g)$ = 188.825 J/K/mol, $O_2(g)$ = 205.138 J/K/mol, $H_2(g)$ = 130.684 J/K/mol

Molar heat capacities at constant pressure of $H_2O(g)$ = 33.58 J/K/mol, $O_2(g)$ = 29.37 J/K/mol, $H_2(g)$ = 28.84 J/K/mol

IFoS 2024 · Q3(b) Heat capacity of an Einstein crystal [10 marks]

Consider an atomic crystal where N atoms are situated at lattice sites. Assume all lattice sites are identical and each atom is vibrating with same frequency, as a three-dimensional harmonic oscillator.
The partition function that satisfies this model is given as:

$$Q = e^{-\beta U_0}\left(\frac{e^{-\beta h\nu/2}}{1-e^{-\beta h\nu}}\right)^{3N}$$

$\nu \rightarrow$ characteristic frequency of vibration of the atoms
$U_0 \rightarrow$ Sublimation energy at 0 K.
$\beta \rightarrow \frac{1}{k_B T}$ where k_B is Boltzmann constant
Calculate the molar heat capacity of this atomic crystal from the given partition function at higher temperature. (Assume constant volume)

IFoS 2024 · Q8(c) Entropy comparison of neon and argon [10 marks]

Among Ne and Ar, under similar conditions, whose standard molar entropy is larger? Explain.
Assume both Ne and Ar are perfect gases.

2023

CSE 2023 · Q2(a) Variation of the Gibbs energy with temperature and pressure [20 marks]

Using the Gibbs equation for a closed system in the absence of non-expansion work at constant composition, answer the following:
(i) Deduce the thermodynamic relations for the variation of G with T, and with P.
(ii) What are the implications of the above relations?
(iii) Draw G versus T graph and identify the phase transition temperatures, if any.
(iv) Explain how the presence of (1) attractive and (2) repulsive molecular interactions affects the molar Gibbs free energy of a gas relative to its normal value.

CSE 2023 · Q2(d) Dissociation equilibrium $A_2(g) \rightleftharpoons 2A(g)$ [10 marks]

Consider the equilibrium reaction $A_2\,(g) \longrightarrow 2\,A\,(g)$, in which A_2 gas is 18.5 % dissociated at 25 °C and 1 bar.
(i) Calculate K_{eq} at 25 °C.
(ii) Calculate K_{eq} at 100 °C.
Given that ΔH° = 57.2 kJ mol^{-1} (at the above temperature range).
(iii) What is the effect of compression on this reaction?

CSE 2023 · Q7(e) Reversible isothermal expansion of an ideal gas [10 marks]

An ideal gas (V_i = 0.05 L and P_i = 8 atm) is subjected to reversible isothermal expansion (V_f = 0.40 L and P_f = 1 atm) at 25 °C. Calculate the work done, ΔU, ΔH and ΔS for this process. Is the heat (q) same as ΔH in this process? If not, why?

IFoS 2023 · Q1(d) Derivatives of thermodynamic potentials [8 marks]

Derive the following thermodynamic relations:
(i) $S = -\left(\frac{\partial A}{\partial T}\right)_V$ (ii) $P = -\left(\frac{\partial A}{\partial V}\right)_T$ (iii) $S = -\left(\frac{\partial G}{\partial T}\right)_P$ (iv) $V = \left(\frac{\partial G}{\partial P}\right)_T$

IFoS 2023 · Q3(d) Pressure as a state function [10 marks]

Show that the pressure of a gas obeying the relation

$$\left(P + \frac{a}{V_m^2}\right)(V_m) = RT$$

is a state function.

IFoS 2023 · Q4(a) Translational entropy of nitrogen [10 marks]

Assuming $N_2(g)$ is behaving ideally at 25 °C and 1 bar pressure, calculate the translational contribution to entropy (S°_m) of this gas.

2022

CSE 2022 · Q1(d) ΔG for the formation of ozone in smog [10 marks]

Calculate ΔG at 298 K for the formation of O_3 from O_2 in urban smog, where $[O_2] = 0.21$ atm and $[O_3] = 5 \times 10^{-7}$ atm.
Given; $\Delta G_f^\circ(O_3) = 163$ kJ mol^{-1}, $R = 8.314$ J mol^{-1} K^{-1}, $F = 96485$ C mol^{-1}.

CSE 2022 · Q2(a) Adiabatic expansion of tyre air against a constant external pressure [10 marks]

An automobile tyre contains air at 320×10^3 Pa at 20 °C. The stem valve is removed and the air is allowed to expand adiabatically against a constant external pressure of 100×10^3 Pa until $P = P_{external}$. For air, $C_{V,m} = 5/2\,R$. Calculate the final temperature of the gas in the tyre. Assume ideal gas behaviour.

CSE 2022 · Q3(b) Entropy changes when an ice cube melts in the sea at 0 °C [10 marks]

A 74.6 g ice cube floats in the sea. The temperature and pressure of the system and surroundings are 0 °C and 1 atm. Calculate ΔS_{syst}, ΔS_{surr} and ΔS_{univ} for the melting of ice cube. What can you conclude about the nature of process from the value of ΔS_{univ}? (The molar heat of fusion of water is 6.01 kJ/mol)

IFoS 2022 · Q1(d) Neutral pH at body temperature [8 marks]

What is the pH of pure water at 37 °C?
(Given: $\Delta_r H^0$ (enthalpy of ionization) at 25 °C = 55.82 kJ mol^{-1})

IFoS 2022 · Q3(b) Adiabatic mixing of ice and hot water; Trouton rule [15 marks]

(i) 1 g of ice at $T = 0$ °C and 10 g of water at $T = 100$ °C are mixed in an adiabatic container. What is the temperature within the container when its content reaches equilibrium? Express your answer in K.
For H_2O, the change in enthalpy on melting, $\Delta H_{melt} = 6.01$ kJ/mole and $C_p = 75.3$ J/(mol K). 10

(ii) Which of the following substances would obey Trouton's rule most closely: hydrogen fluoride, toluene, methanol? Explain with reasoning. 5

IFoS 2022 · Q4(b) Rotational partition function [15 marks]

Deduce the expression for rotational partition function of a rigid heteronuclear diatomic rotator.

2021

CSE 2021 · Q1(c) Rubber band: change of length on heating [10 marks]

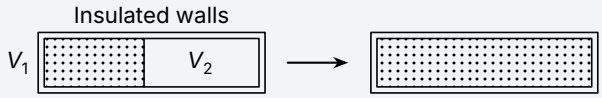
For a rubber band

$$\left(\frac{\partial T}{\partial l}\right)_S = -\frac{T}{C_V}\left(\frac{\partial S}{\partial l}\right)_T$$

What would be the length of the rubber band with an increase in temperature? Explain it.

CSE 2021 · Q3(c)(ii) Expansion of an ideal gas into a vacuum in an insulated box [10 marks]

(ii) A thermally insulated box is separated into two compartments (volumes V_1 and V_2) by a membrane. One of the compartments contains an ideal gas at temperature T, the other is empty (vacuum). The membrane is suddenly removed, and the gas fills up the compartments and reaches the equilibrium.
What is the final temperature of the gas? Show that the gas expansion process is irreversible. 10



IFoS 2021 · Q1(b) Changing the enthalpy reference [8 marks]

Does the enthalpy of formation of compounds containing a certain element change, if the enthalpy of formation of the element under standard state conditions is set equal to 100 kJ mol^{-1} rather than to zero? If it changes, how will it change for the compound A_nB_m, if the formation enthalpy of element A is set equal to 100 kJ mol^{-1}?

IFoS 2021 · Q3(b) Temperature and decomposition of silver oxide [15 marks]

For the reaction,

$$Ag_2O\ (s) \longrightarrow 2\,Ag\ (s) + \frac{1}{2}\,O_2\ (g),$$

$\Delta_r H^\circ$ = 30.56 kJ mol^{-1} and $\Delta_r S^\circ$ = 6.6 J K^{-1} mol^{-1} at 1 bar. Calculate the temperature at which $\Delta_r G^\circ$ will be zero. What will be the direction of the reaction at this temperature? Also, depict the direction of reaction above and below this temperature and why?

IFoS 2021 · Q4(b) Canonical partition function and heat capacity [10 marks]

Give the classical statistical mechanical definition of the canonical partition function, Q. What is the relationship between thermodynamic Helmholtz free energy, F, and Q? Using these expressions show that heat capacity at constant volume, C_V, is given by

$$C_V = kT\left[\frac{\partial^2}{\partial T^2}(T \ln Q)\right]_V$$

2020

CSE 2020 · Q1(c) C_V in terms of U; $(\partial C_V/\partial V)_T = 0$ for an ideal gas [10 marks]

Express heat capacity at constant volume (C_V) of a substance in terms of its internal energy (U) and show that $\left(\frac{\partial C_V}{\partial V}\right)_{T,n}$ = 0; for ideal gas.

CSE 2020 · Q2(a) Heat absorbed in an isothermal expansion against constant pressure [10 marks]

1.0 mol of a monoatomic ideal gas expands to double of its initial volume against a constant pressure under isothermal condition of 300 K. Calculate the heat involved.

CSE 2020 · Q2(b) Heat engine between 500 K and 300 K: is 450 J from 1000 J possible? [10 marks]

A person claims that a heat engine exchanges heat with reservoirs at 300 and 500 K, produces 450 J of work per 1000 J of heat extracted from the hot reservoir. Is his/her claim feasible? Give reason(s) to support your answer.

CSE 2020 · Q6(d) Maxwell relation $(\partial S/\partial P)_T = -(\partial V/\partial T)_P$ from dG [10 marks]

Using appropriate fundamental equation of thermodynamics, derive the following Maxwell relation :
$(\frac{\partial S}{\partial P})_{T,n} = -(\frac{\partial V}{\partial T})_{P,n}$

IFoS 2020 · Q1(a) Spontaneous crystallisation; two iron blocks in contact [8 marks]

(i) Why is crystallization of solute a spontaneous process?
(ii) Consider a 1·00 kg block of iron at 99 °C placed in contact with a 1·00 kg block of iron at 25 °C. Find the final temperature of the blocks and the amount of heat transferred. For iron, C_p = 444 J/K/kg

IFoS 2020 · Q3(a) q, w and ΔU for the s-II → s-I transition of Li_2SO_4 [15 marks]

Calculate *q*, *w* and Δ*U* at 1·00 bar for the phase transition between two crystalline forms, s-I and s-II of Li_2SO_4

$$Li_2SO_4 \text{ (s-II)} \rightarrow Li_2SO_4 \text{ (s-I)}$$

which takes place at 859 K. The enthalpy change is 27·2 kJ for this reaction. The densities of Li_2SO_4 (s-II) and Li_2SO_4 (s-I) are $2{\cdot}221\times10^3$ kg m^{-3} and $2{\cdot}07\times10^3$ kg m^{-3}, respectively. Given, the molecular weight of Li_2SO_4 = 110 g/mol.

2019

CSE 2019 · Q2(b) Expansion of an ideal gas against a constant pressure of 1 atm [20 marks]

One mole of an ideal gas at 273.15 K undergoes expansion from an initial volume of 2.24 *l* to 22.4 *l* against a constant pressure of 1 atm. Calculate the work done. Also calculate Δ*U*, Δ*H* and Δ*S*.

CSE 2019 · Q8(a) Third law: absolute zero cannot be reached [15 marks]

Use third law of thermodynamics to show that absolute zero of temperature is unattainable.

IFoS 2019 · Q1(d) Nernst heat theorem as the basis of the third law [8 marks]

Deduce Nernst heat theorem and show that this forms the basis of third law of thermodynamics.

IFoS 2019 · Q2(b) Refrigerator at 50% efficiency; K for an ideal-gas reaction [10 marks]

(i) A refrigerator working at 50% of ideal efficiency is operating with its interior at 0 °C in a room at 25 °C. Estimate (I) energy required to freeze 1 kg of water (initially at zero degree Centigrade), and (II) heat discharged into the room during the process (Latent heat of fusion of ice is 334 Jg^{-1}). 4
(ii) Deduce an expression for the equilibrium constant for an ideal gas reaction. 6

IFoS 2019 · Q2(c) Partial molal quantities; method of intercepts [10 marks]

Describe partial molal quantities. Explain Method of Intercepts for determination of partial molal quantities.

IFoS 2019 · Q3(c) Translational partition function of O_2 [10 marks]

(i) Deduce translational partition function. 4

(ii) Calculate the translational partition function for 1 mol of oxygen at 1 atm pressure at 25 °C. Assume the gas to behave ideally (atomic weight of oxygen = 16; N_A = 6·023 × 10^{23} mol^{-1}); k_B = 1·38 × 10^{-23} JK^{-1}; R = 8·314 JK^{-1} mol^{-1}; and h = 6·626 × 10^{-34} Js). 6

2018

CSE 2018 · Q1(b) ΔU for heating one mole of water from 25 to 30°C [10 marks]

Calculate the internal energy, U when 1.00 mol of H_2O goes from 25.0 °C and 1.00 atm to 30.0 °C and 1.00 atm. Densities of water are 0.9970 g/cm^3 at 0 °C and 0.9956 g/cm^3 at 100 °C.

CSE 2018 · Q1(c)(i) $\Delta_r G°$ for the formation of MgO at 0°C [5 marks]

Consider the formation of MgO(s). Assume that ΔH_r° and ΔS_r° are independent of temperature.

$$\mathrm{Mg\,(s)} + \frac{1}{2}\,\mathrm{O_2(g)} \longrightarrow \mathrm{MgO\,(s)} \qquad \Delta H_r^\circ = -602\ \mathrm{kJ/mol}, \quad \Delta S_r^\circ = -108\ \mathrm{J/K/mol}$$

(i) Calculate ΔG_r° for the formation of MgO(s) at 0 °C. Is this reaction spontaneous or non-spontaneous at 0 °C.

CSE 2018 · Q1(c)(ii) Temperature at which the spontaneity switches [5 marks]

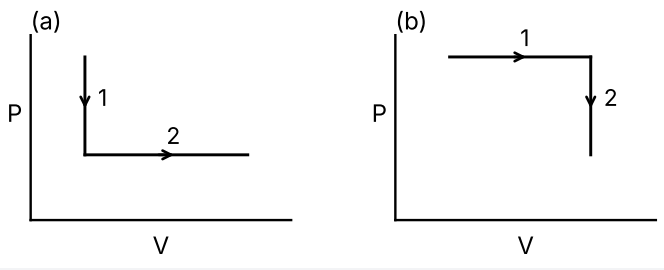
(ii) Is there a temperature at which formation of MgO switches from spontaneous to non-spontaneous or vice-versa? If no, explain why not? If yes, calculate the temperature at which the spontaniety of the reaction switches?

CSE 2018 · Q3(a)(i) First law and the cooling of rising clouds [5 marks]

Using the statement of First law of thermodynamics, argue upon the various effects on rising clouds as it goes to higher altitudes.

CSE 2018 · Q3(a)(ii) Reversible work along two different paths [10 marks]

If P_1 = 3.00 atm V_1 = 500 cm^3
P_2 = 1.00 atm V_2 = 2000 cm^3
Calculate the work, $W_{reversible}$ for the processes shown in figure (a) and (b).



CSE 2018 · Q3(b) Two phases in thermal equilibrium have the same temperature [10 marks]

Show that two phases are in thermal equilibrium only if their temperature are same.

CSE 2018 · Q4(b)(i) Why PV is constant in an adiabatic and PV in an isothermal change [5 marks]

Consider the reversible expansion of a perfect gas. Provide the physical interpretation for the fact PV^{γ} = constant for an adiabatic change, whereas PV = constant for an isothermal change.

IFoS 2018 · Q1(c) $(\partial U/\partial V)_T = 0$ implies $(\partial C_v/\partial V)_T = 0$ for an ideal gas [8 marks]

For an ideal gas : $\left(\frac{\partial U}{\partial V}\right)_{T,n} = 0$. Show that $\left(\frac{\partial C_v}{\partial V}\right)_{T,n} = 0$.

IFoS 2018 · Q2(b) Carnot cycle with a real gas; H rises but G falls; signs for adsorption [15 marks]

(i) A non-ideal gas is used in a Carnot engine. Find the values of ΔU, ΔH, ΔS_{univ}, ΔA, ΔG for a cycle. Give reason/s.
(ii) At constant pressure, for fixed amount of a substance, with increase of temperature enthalpy (H) of the substance increases but Gibbs free energy (G) decreases. Give reasons.
(iii) At constant pressure and temperature, adsorption of gas on solid surface occurs spontaneously. What will be the signs of ΔH, ΔS and ΔG of this process? 5+5+5=15

IFoS 2018 · Q3(c) Stirling's approximation error; spacing of the (123) planes [15 marks]

(i) Using Stirling's approximation, we write

$$ln(n!) \cong (n)\,ln(n) - (n).$$

Calculate the % of error when (A) n = 10 and (B) n = 69. Comment on your results.
(ii) Calculate the interplanar distance between two successive 123-Miller planes of an orthorhombic crystal with unit cell lengths a = 0·82 nm, b = 0·94 nm, and c = 0·75 nm. 7+8=15

IFoS 2018 · Q4(a) ΔrS° at 400 K from the temperature dependence of ln K [15 marks]

The equilibrium constant, K_p of a certain gas-phase reaction, varies with temperature (T in K) as $ln\,K_p = -1{\cdot}04 - \frac{1088\,K}{T} + \frac{1{\cdot}51 \times 10^5\,K^2}{T^2}$, in the temperature range of 300 to 500 K.
Calculate the standard entropy change of the reaction ($\Delta_r S°$) at 400 K.
Given : $\Delta_r G° = -RT\,ln\,K_p$ and $\Delta_r S° = -\left[\frac{\partial(\Delta_r G°)}{\partial T}\right]_P$

2017

CSE 2017 · Q1(c) Joule–Thomson coefficient: definition, unit and $-\frac{1}{C_P}(\partial H/\partial P)_T$ [10 marks]

Define Joule-Thomson coefficient (μ_{JT}). What is its unit in SI system? Show that

$$\mu_{JT} = -\frac{1}{C_P}\left(\frac{\partial H}{\partial P}\right)_{T,n}.$$

CSE 2017 · Q3(a)(i) Signs of ΔH and ΔG when hot tea cools [10 marks]

At constant pressure, the temperature of a fixed amount of hot tea in a cup decreases spontaneously to room temperature. What will be the sign of (I) ΔH and (II) ΔG of this process? Give reason(s) in support of your answer.

CSE 2017 · Q3(a)(ii) Units of a, b, c and ΔS, ΔH from ΔG=a+bT+cT² [15 marks]

ΔG (J mol^{-1}) for an electrochemical reaction, as a function of temperature, T (K) is given by $\Delta G = a + bT + cT^2$; where a, b and c are constants and independent of T.

(I) What are the units of a, b and c? and

(II) Find the expressions of ΔS and ΔH as a function of T.

CSE 2017 · Q3(b) Partial molar Gibbs energy (chemical potential) [10 marks]

Define partial molar Gibbs free energy. What is its unit in SI system? Is it intensive property? Answer with justification. What factors influence its value?

IFoS 2017 · Q1(d) Work of reversible isothermal expansion of helium [10 marks]

Calculate the work done when 1 mole of He expands isothermally and reversibly from a volume of 1 litre to a volume of 10 litres at 25 °C.

IFoS 2017 · Q2(b) W, ΔE, ΔH and ΔS for reversible vaporisation of water [20 marks]

One mole of water is vapourised reversibly at 100 °C and 1 atm.

$$H_2O\,(l) \rightleftharpoons H_2O\,(g)$$

The heat of vapourisation of water is 9720 cal/mol. Calculate W, ΔE, ΔH and ΔS.

IFoS 2017 · Q2(c) Molecular partition function and its temperature dependence [10 marks]

How is molecular partition function defined? What is the physical significance of this property? Discuss the effect of temperature on the molecular partition function.

IFoS 2017 · Q4(d) Kp and degree of dissociation of PCl_5 [10 marks]

Consider the reaction :

$$PCl_5\,(g) \rightleftharpoons PCl_3\,(g) + Cl_2\,(g)$$

Derive the expression relating K_p and degree of dissociation α.

Given : At 250 °C and 1 atm, K_p for the above reaction is 1·78. Calculate α. 8+2=10

2016

CSE 2016 · Q1(b) Residual entropy of CO and N_2O [10 marks]

What is residual entropy? Why certain substances like CO and N_2O are associated with residual entropy even at 0K?

CSE 2016 · Q2(c) Heat of reaction for $N_2 + 3H_2 \rightarrow 2NH_3$ at 50°C: Kirchhoff's law [10 marks]

The heat of reaction $N_2 + 3\,H_2 \longrightarrow 2\,NH_3$ at 27 °C was found to be −21.97 Kcal. What will be the heat of reaction at 50 °C? The molar heat capacities at constant pressure and at 27 °C for N_2, H_2 and NH_3 are 6.8, 6.77 and 8.86 cal mol^{-1} deg^{-1}.

CSE 2016 · Q3(b) Partial molal property and its significance [15 marks]

Define "Partial molal property". What is its physical significance?

IFoS 2016 · Q1(a)(ii) Residual entropy of CO and N_2O at 0 K [5 marks]

Explain why certain substances like CO and N_2O are associated with residual entropy even at 0 K.

IFoS 2016 · Q1(c) Heat of reaction at 120°C: Kirchhoff's law [10 marks]

The heat of the reaction

$$Fe_2O_3(s) + 3\,H_2(g) \longrightarrow 2\,Fe(s) + 3\,H_2O(l)$$

at 25 °C was found to be −8.4 kcal. What will be the heat of the reaction at 120 °C? The molar heat capacities at constant pressure and at 25 °C for iron oxide, hydrogen, iron and water are 25.0 cal deg^{-1} mol^{-1}, 6.9 cal deg^{-1} mol^{-1}, 6.1 cal deg^{-1} mol^{-1} and 18.0 cal deg^{-1} mol^{-1} respectively.

IFoS 2016 · Q2(b) Partition function as a product of two partition functions [10 marks]

A molecule has only two translational and two vibrational energy levels. Show that the molecular partition function can be written as the product of two partition functions.