FREE NOTES · NCERT + JEE/NEET LEVEL

Thermodynamics

System aur surroundings, state functions, internal energy, work aur heat, first law, enthalpy, ΔH aur ΔU, heat capacity, calorimetry, reaction enthalpies, Hess's law, Born-Haber idea, entropy, Gibbs energy aur spontaneity, aur equilibrium.

01 Basic terms
02 First law of thermodynamics
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01 Basic terms

- **System** = jo hissa padh rahe; **surroundings** = baaki sab.
- **Open** (matter + energy ka len-den), **closed** (sirf energy), **isolated** (kuch nahi; jaise ideal thermos).
- **State functions** sirf shuruaati aur aakhri state pe depend: U, H, S, G, p, V, T. **Path functions**: q, w.
- **Extensive** (matra pe depend: mass, V, U, H, heat capacity) vs **intensive** (nahi: T, p, density, molar heat capacity).
- Processes: isothermal (T const), adiabatic (q = 0), isobaric (p const), isochoric (V const), reversible (bahut dheere), irreversible.

02 First law of thermodynamics

$$\Delta U = q + w$$

Isolated system ki energy constant. **IUPAC sign:** system heat le to q positive; system **pe** work ho to w positive.

- Isolated: ΔU = 0. Adiabatic: ΔU = w. Isochoric (work nahi): ΔU = q_V.
- Ideal gas me U sirf T pe depend ⇒ isothermal me ΔU = 0 ⇒ q = -w.

03 Expansion ka work

Process	Gas pe kiya gaya work
Constant bahari pressure ke khilaaf (irreversible)	$w = -p_{ext}\,\Delta V$
Free expansion (vacuum me)	$w = 0$
Isothermal reversible	$w = -2.303\ nRT\log(V_2/V_1) = -2.303\ nRT\log(p_1/p_2)$

Expansion ⇒ w negative (system work karta). Reversible expansion me sabse zyada work.

04 Enthalpy; ΔH vs ΔU

$H = U + pV$, $\Delta H = q_p$ (constant pressure pe heat)

$$\Delta H = \Delta U + \Delta n_g RT$$

Δn_g = gaseous products ke moles − gaseous reactants ke moles. $\Delta n_g = 0 \Rightarrow \Delta H = \Delta U$ ($H_2 + Cl_2 \rightarrow 2HCl$).

$\Delta H < 0 \Rightarrow$ **exothermic**; $\Delta H > 0 \Rightarrow$ **endothermic**.

05 Heat capacity & calorimetry

- $q = C\,\Delta T = m\,c\,\Delta T$ (c = specific heat).
- Ideal gas ke liye: $\mathbf{C_p - C_v = R}$.
- **Bomb calorimeter** (constant volume) ΔU naapta; **coffee-cup calorimeter** (constant pressure) ΔH naapta.

06 Enthalpy ke types

Enthalpy of	Matlab
Formation $\Delta_f H°$	Standard state ke elements se 1 mol compound (elements ka $\Delta_f H° = 0$)
Combustion $\Delta_c H°$	1 mol O_2 me poora jale (hamesha negative)
Atomisation	1 mol ko gaseous atoms me todna
Bond enthalpy	Gas phase me 1 mol bond todna
Fusion / vaporisation / sublimation	Phase change; $\Delta_{sub}H = \Delta_{fus}H + \Delta_{vap}H$
Solution, lattice	1 mol ghulna; 1 mol ionic solid banana/todna
Neutralisation	Strong acid + strong base ≈ −57.1 kJ/mol (weak me kam)

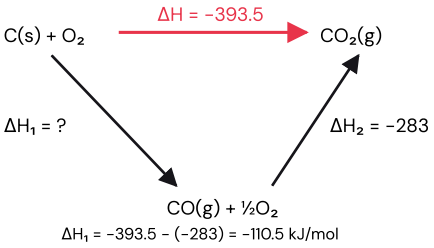
$$\Delta_r H° = \Sigma\,\Delta_f H°(\text{products}) - \Sigma\,\Delta_f H°(\text{reactants})$$

$$\Delta_r H° = \Sigma\,\text{bond enthalpies (reactants)} - \Sigma\,\text{bond enthalpies (products)}$$

07 Hess's law of constant heat summation

H state function hai, isliye reaction ek step me ho ya kai steps me, total enthalpy change same. Equations (aur unke ΔH) ko algebra ki tarah jod-ghata sakte hain.

Born-Haber cycle Hess's law se lattice enthalpy nikalta: sublimation + ionisation + dissociation + electron gain + lattice = $\Delta_f H$.



Hess's law se CO ka $\Delta_f H$

08 Entropy, Gibbs energy & spontaneity

- **Entropy S** = bikhraav/randomness ka naap. Gas > liquid > solid. $\Delta S = q_{rev}/T$. Phase change: $\Delta S = \Delta H/T$.
- **Second law:** spontaneous process me $\Delta S_{total} > 0$. **Third law:** 0 K pe perfect crystal ki S zero.

$$\Delta G = \Delta H - T\Delta S$$

ΔG < 0 spontaneous; ΔG = 0 equilibrium; ΔG > 0 non-spontaneous. $\Delta G^\circ = -RT \ln K = -2.303\ RT \log K$. ΔG = useful work bhi.

ΔH	ΔS	Spontaneous?
−	+	Hamesha
+	−	Kabhi nahi
−	−	Kam T pe
+	+	Zyada T pe (T > ΔH/ΔS)

09 JEE Extra + Tricks

JEE LEVEL

- Sign convention (IUPAC): $\Delta U = q + w$; system **pe** kaam positive. Free expansion: $w = 0$; ideal gas isothermal: $\Delta U = \Delta H = 0$.
- $\Delta H = \Delta U + \Delta n_g RT$ (Δn_g = products − reactants ke gaseous moles).
- Spontaneity: $\Delta G = \Delta H - T\Delta S$. $\Delta H -, \Delta S + \Rightarrow$ hamesha; $\Delta H +, \Delta S - \Rightarrow$ kabhi nahi; baaki T pe nirbhar ($T = \Delta H/\Delta S$ switch).
- $\Delta G^\circ = -RT \ln K = -2.303RT \log K$; $\Delta G^\circ = -nFE^\circ$.
- Bond enthalpy method: $\Delta H = \Sigma$(toote bonds) − Σ(bane bonds).
- Extensive: U, H, S, G, V, mass. Intensive: T, P, density, molar properties.

10 Solved numericals

Q1. Gas 701 J heat leti aur 394 J work karti. ΔU?

q = +701, w = −394 ⇒ ΔU = **+307 J**.

Q2. $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ ke liye 298 K pe ΔU = −87.8 kJ. ΔH?

$\Delta n_g = 2 - 4 = -2$ ⇒ $\Delta H = -87.8 + (-2)(8.314 \times 10^{-3})(298)$ = **−92.8 kJ**.

Q3. 300 K pe 2 mol ideal gas 10 L se 20 L isothermally aur reversibly phailti. Work?

$w = -2.303 \times 2 \times 8.314 \times 300 \times \log 2$ = **−3458 J**.

Q4. ΔH = 30 kJ/mol, ΔS = 100 J/(K mol). Kis T ke upar spontaneous?

T > ΔH/ΔS = 30000/100 = **300 K**.

11 Mistakes & practice

- Purana sign convention lagana (w = +pΔV). NCERT me $w = -p_{ext}\Delta V$.
- Δn_g me liquids/solids gin lena.
- ΔG = ΔH − TΔS me kJ (ΔH) aur J (ΔS) mila dena.
- Kehna ki har exothermic reaction spontaneous.

1. Kya heat state function hai?
2. Ideal gas ke isothermal expansion me ΔU?
3. $O_2(g)$ ka $\Delta_f H°$?
4. Barf pighalne pe ΔS ka sign?
5. ΔG° aur K ka rishta?

ANSWERS

1) Nahi (path function) · 2) 0 · 3) 0 · 4) Positive · 5) $\Delta G° = -2.303\ RT \log K$

12 Quick revision: exam se 5 minute pehle

FIRST LAW

- ΔU = q + w.
- $w = -p_{ext}\Delta V$.
- Reversible: $-2.303\ nRT \log(V_2/V_1)$.

ENTHALPY

- $\Delta H = \Delta U + \Delta n_g RT$.
- $C_p - C_v = R$.
- Hess: equations jodo.

ENTROPY

- Gas > liquid > solid.
- $\Delta S = q_{rev}/T$.
- 0 K pe perfect crystal S = 0.

GIBBS

- $\Delta G = \Delta H - T\Delta S$.
- $\Delta G < 0$ spontaneous.
- $\Delta G^\circ = -2.303RT \log K$.

Koi doubt? padhaiadda.netlify.app pe AI Doubt Solver se poocho, ya is chapter ka mock test do.