VIVEKANANDA COLLEGE

THAKURPUKUR

KOLKATA-700063

NAAC ACCREDITED ‘A’ GRADE

Topic: T-S DIAGRAM

Course Title: Chemistry (Gen)

Paper: CC-2/GE-2

Semester: 2(Gen)

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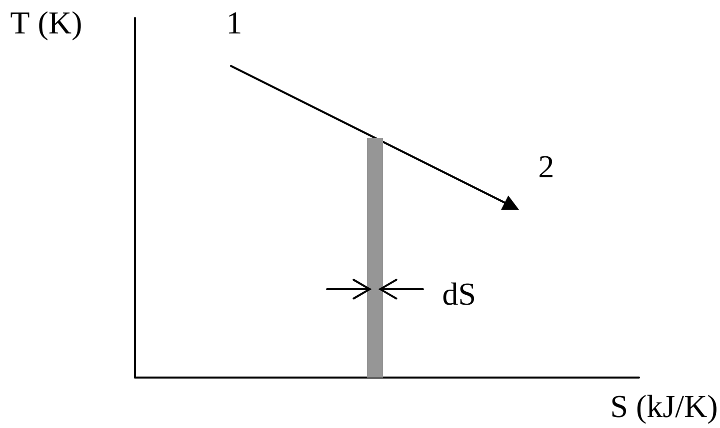
Name of the Department: Chemistry

THE TEMPERATURE-ENTROPY, T-S, DIAGRAM

Clausius' principle for an **internally reversible process**:

$$\delta Q = TdS$$

Any process can be graphed on a T-S (or T-s) diagram (just as with T-v or P-v diagrams). Because of Clausius' Principle, the T-S diagrams for internally reversible processes can be used to calculate heat transfer.

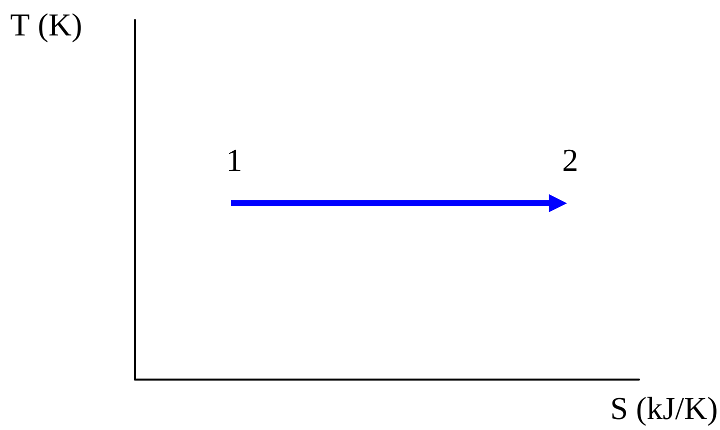


Shaded area = TdS = δQ and the total area under process line for the internally reversible process 1 → 2 is the heat transferred during the process:

$$\int_1^2 TdS = Q_{1\rightarrow 2}$$

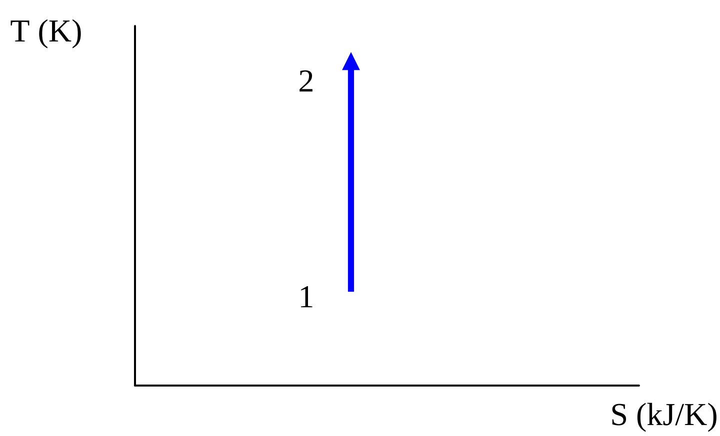
SPECIAL T-S DIAGRAMS

1. For an isothermal internally reversible process:



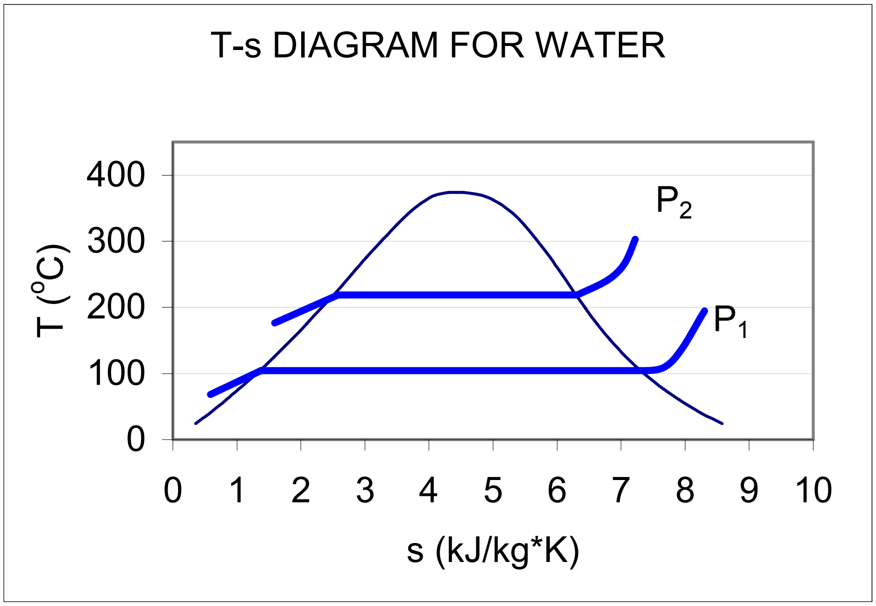
$$Q_{1\rightarrow 2} = T(S_2 - S_1) =$$

2. For an adiabatic and internally reversible process (isentropic):



$$(S_2 - S_1) = 0$$

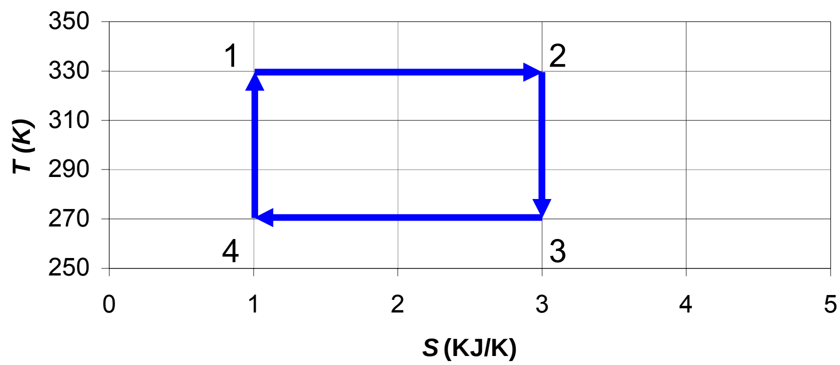
3. For <u>pure substances with liquid vapor phases</u>, the T-s diagram shows similar constant pressure lines as in the P-v and T-v diagrams, indicating vaporization/condensation processes at constant pressure are isothermal and as P increases, s_{fg} decreases:



where $P_2 > P_1$. As with the T-s and P-v diagrams, the critical point (where liquid and vapor phases are indistinguishable) is at the top of the phase curve where the saturated liquid and vapor lines meet. A pure substance is compressed liquid for $s < s_f$, superheated vapor for $s > s_g$, and a saturated liquid-vapor mixture between the saturated liquid and vapor lines.

4. For Carnot cycles:

(a) Carnot Heat Engine – all totally reversible processes



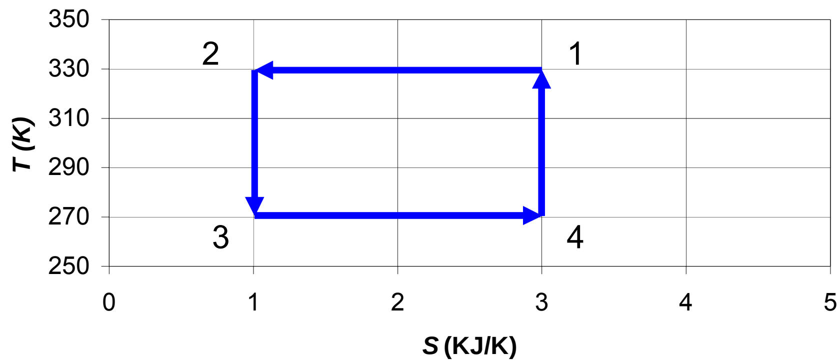
1→2 is <u>isothermal expansion</u>, the heat input process, and Q_H = area under line 1-2 or **$Q_H = T_1(s_2-s_1)$ (will be positive)**
2→3 is <u>isentropic</u> (adiabatic and reversible) expansion, the work output process. $W_{2\to3}$ cannot be inferred from the T-S diagram.
3→4 is <u>isothermal compression</u>, the heat rejection process, and Q_L = area under line 3-4 or **$Q_L = T_3(s_4-s_3)$ (will be negative and $<Q_H$)**
4→1 is <u>isentropic</u> (adiabatic and reversible) compression, the work input process. $W_{4\to1}$ cannot be inferred from the T-S diagram.

For the Carnot heat engine cycle, net heat transfer, Q_{net}, is the area 1-2-3-4 or **$Q_{net} = (T_1-T_4)(s_2-s_1)$ (will be positive),** and by the 1st Law for cycles: **$Q_{net} = W_{net}$**

By Clausius' principle, the entropy generated in a Carnot heat engine cycle is zero, which can be shown using the T-S diagram above and noting that $\Delta S = 0$ for a cycle:

$$S_{gen} = -\sum_k \left(\frac{Q}{T}\right)_k = -\frac{330(2)}{330} - \left(\frac{-270(2)}{270}\right) = 0$$

(b) Carnot Refrigerator – all totally reversible processes



1→2 is <u>isothermal compression</u>, the heat rejection process, and Q_H = area under line 1-2 or **$Q_H = T_1(s_2\text{-}s_1)$ (will be negative)**

2→3 is <u>isentropic</u> (adiabatic and reversible) compression, the work input process. $W_{2\to 3}$ cannot be inferred from the T-S diagram.

3→4 is <u>isothermal expansion</u>, the heat input process, and Q_L = area under line 3-4 or **$Q_L = T_3(s_4\text{-}s_3)$ (will be positive and < Q_H)**

4→1 is <u>isentropic</u> (adiabatic and reversible) expansion, the work output process. $W_{4\to 1}$ cannot be inferred from the T-S diagram.

For the Carnot refrigeration cycle, net heat transfer, Q_{net}, is the area 1-2-3-4 or **$Q_{net} = (T_1\text{-}T_4)(s_2\text{-}s_1)$ (will be negative),** and by the 1st Law for cycles: **$Q_{net} = W_{net}$**

By Clausius' principle, the entropy generated in a Carnot refrigeration cycle is zero, which can be shown using the T-S diagram above and noting that $\Delta S = 0$ for a cycle:

$$S_{gen} = -\sum_k \left(\frac{Q}{T}\right)_k = -\left(\frac{-330(2)}{330}\right) - \left(\frac{270(2)}{270}\right) = 0$$