EN727005
THERMODYNAMICS FOR CHEMICAL ENGINEERS
อุณหพลศาสตร์สำหรับวิศวกรเคมี

ตอน 2 กฎข้อที่ 2 ของ Thermodynamic

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Heat Engine
cannot have η_{th} = 100%

What is the maximum efficiency then?

The Carnot Efficiency *is the answer*

Reversible and Irreversible Processes

- **Reversible process** : A process that can be reversed without leaving any trace on the surroundings. ➔ both System & Surroundings back to Original state
- **Irreversible Process**: Process that is not Reversible Process.

A system can be restored to its initially state, but for a irreversible process surroundings usually have to do some work on the system.

- Reversible process: ***Ideal***, do not really occur in nature.
- Reversible process: ***Theoretical Limits*** for corresponding irreversible processes.
- Concept of reversible process ➔ ***Second Law Efficiency*** ➔ degree of approximation to the corresponding reversible process.

- **Irreversibility**: Factor that cause a process to be irreversible, i.e.
  - Friction
  - Unrestrained expansion
  - Mixing of two substances
  - Heat transfer
  - Electric resistance
  - Inelastic deformation of solid
  - Chemical reactions

The Carnot Cycle
(proposed by Sadi Carnot in 1824)

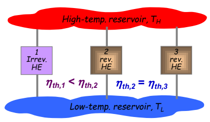
- Carnot processes:
  - All process are reversible.
  - Heat transfer process➔ reversible heat transfer ➔ Isothermal
  - Work in/out process ➔ reversible adiabatic
- The 4 processes of the carnot cycle: (Heat Engine)

1. Reversible Isothermal heat transfer from high temp. reservoir.
2. Reversible adiabatic expansion.
3. Reversible Isothermal heat transfer to low temp. reservoir.
4. Reversible adiabatic compression

If a carnot heat engine is reversed it becomes a carnot heat pump.

The Carnot Principles

1. *The efficiency of an irreversible heat engine is always less than the efficiency of a reversible one operating between the same two reservoirs.*
2. *The efficiency of all reversible heat engines operating between the same two reservoirs are the same.*

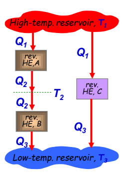


The Thermodynamics Temperature Scale

- 2^{nd} Carnot Principle: if 2 reversible heat engine, A and B, operate between the same T_H and T_L then $\eta_{rev,A} = \eta_{rev,B}$
- So we can conclude that η_{rev} ***is independent of***
  - working fluid employed and its properties
  - the way the cycle is executed
  - type of the reversible engine used
- Because reservoirs are characterized by their *TEMPERATURE* then

$\eta_{th,rev} = g(T_H , T_L)$, ***and from*** $\eta_{th} = 1 - Q_L/Q_H$

then $Q_L/Q_H = f(T_H , T_L)$



- Consider 3-rev HE. A,B and C operate between T_1 and T_3 with intermedeiat T_2
- combine Rev.HE A and B = Rev.HE C
- Then if receive the same Q_1 heat reject must be the same = Q_3

$Q_1/Q_2 = f(T_1 , T_2)$, $Q_2/Q_3 = f(T_2 , T_3)$, $Q_1/Q_3 = f(T_1 , T_3)$

but $Q_1/Q_3 = (Q_1/Q_2)/(Q_2/Q_3)$

then $f(T_1 , T_3) = f(T_1 , T_2)\ f(T_2 , T_3)$

But it must not depend on T_2, the only possible is

$f(T_1 , T_2) = Ø(T_1)/Ø(T_2)$

and $f(T_2 , T_3) = Ø(T_2)/Ø(T_3)$

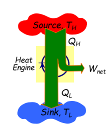
$Q_1/Q_3 = f(T_1 , T_3) = Ø(T_1)/Ø(T_2) \times Ø(T_2)/Ø(T_3)$

$= Ø(T_1)/Ø(T_3)$

$Ø(T)$ = *arbitary, can be many way*

Lord Kelvin propose: $Ø(T) = T$

to define a thermodynamic temperature scale



then $Q_H/Q_L = T_H/T_L$ (5.7)

Kelvin scale = absolute scale .. T = 0 ➔ infinity

10^{th} International Conference on Weights and Measures in 1954: at 1 atm

Triple point of water = 273.16 K (0.01°C over ice point)

magnetude: 1K = 1°C

$T(K) = T(°C) + 273.15$ (5.8)

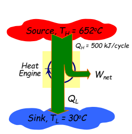
The Carnot Efficiency

Heat Engine: $\eta_{th} = 1 - \frac{Q_L}{Q_H}$ ➔ $\eta_{th,rev} = 1 - \frac{T_L}{T_H}$ (5.9)

Refrigerator $COP_R = \frac{1}{Q_H/Q_L - 1}$ ➔ $COP_{R,rev} = \frac{1}{T_H/T_L - 1}$ (5.10)

Heat Pump $COP_{HP} = \frac{1}{1 - Q_L/Q_H}$ ➔ $COP_{HP,rev} = \frac{1}{1 - T_L/T_H}$ (5.11)

<u>Example 5.5</u> The Carnot heat engine shown, receives 500 kJ of heat per cycle from a high-temperature source at 652°C and rejects heat to a low-temperature sink at 30°C. Determine (a) the thermal efficiency of this Carnot engine and (b) the amount of heat rejected to the sink per cycle.



$\eta_{th,Carnot} = \eta_{th,rev} = 1 - \frac{T_L}{T_H}$

$= 1 - \frac{(30+273)K}{(652+273)K} = 0.672$ *answer*

for a reversible cycle, $Q_H/Q_L = T_H/T_L$

$Q_L = Q_H (T_L/T_H)$

$= (500\ kJ/cycle)/\{(30+273)/652+273)\}$

$= 163.8\ kJ$

Quantity vs Quality

1. Quantity of energy is CONSERVED
   Quality of energy is NOT CONSERVED
2. Wasting energy ≡ Converting it to a less useful form
3. 1-unit of high-quality energy may be more valuable than 3-unit of lower quality energy
4. Energy Crisis ➔ Saving
   quantity ➔ 1^{st} law ....quality ➔ 2^{nd} law
5. Judge things on the basis of their Quantity only is unadequate and may misslead
6. Quantity is easy to measure but Quality is difficult to assess.

Analogy of quantity and quality with life

- มาม่า 1 ชาม VS ข้าวแกง 1 ชาม ราคา/อิ่ม เท่ากัน แต่ ความอร่อย และคุณค่าทางโภชนาการล่ะเท่ากันหรือไม่ (How about KFC)
- เข้าเรียน Thomo. 1 ชม. นศ.แต่ละคนเข้าใจเท่ากันหรือไม่
- ดูหนังสือเตรียมสอบด้วยกัน ทำไมเธอได้คะแนนดีกว่า
- เธอก็ได้เงินจากทางบ้านแต่ละเดือนเท่ากับฉัน ทำไม่เธอถึงมีเงินเหลือเก็บนะ ส่วนฉันปลายเดือนก็กระเป๋าแห้งแล้ว.....
- ขอแลกตังหน่อยซิ.......เหรียญฉันหยอดกระปุกไว้ทั้งปีได้ตั้ง 1,012.25 บาทแน่ะ มีเหรียญสลึงแยะเลยนะ....ให้หมดเลยขอแบงค์ 500 บาท 2 ใบก็พอ

End of

Part 2