Perfect gas

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For the glory of God

· Perfect gas

· A perfect gas is a theoretical gas that is different from a real gas in a way that makes certain calculations easier to handle.

ref. too far between two molecules o······o (10d)

· Its behavior is more simplified compared to a real gas because intermolecular forces are neglected.

↳ It implies that we can use the Ideal-gas law.

· Perfect gas and ideal gas are sometimes used interchangeably;

Gas
- Real gas
- perfect gas
  - Calorically perfect gas : Perfect gas, γ = constant
  - Thermally perfect gas (Thermally Equilibrium and no chemical reaction)
    - Semi-Perfect gas, $\gamma = f(T)$
    - Ideal gas, $\gamma = f(T)$ or $\gamma = f(P)$
    - Imperfect gas, $\gamma = f(T, P)$

specific heat ratio (γ) $\equiv \frac{C_p}{C_v}$

↳ For this gas, the Ideal-gas law isn't valid.

This is useful for modeling. (e.g. γ=const makes easy to calculate an energy)

In thermally Equilibrium, there are no flow of matter or of energy, either within a system or between systems.

→ However, almost all systems found in nature are not in thermodynamic Equilibrium because they're changing.

(Nevertheless, they can be assumed as thermodynamic Equilibrium because of very small size of atoms as compared with macroscopic systems)

· Specific heat ratio, ref. for air, $\gamma = 1.4$

· It can be defined as the ratio : $\gamma = \frac{C_p}{C_v}$

· $C_v = \left(\frac{de}{dT}\right)_v$; Specific heat in constant volume

: C_v is the amount of heat required to raise the temperature by 1°c under constant volume.

· $C_p = \left(\frac{dh}{dT}\right)_p$; Specific heat in constant pressure

: C_p is the amount of heat required to raise the temperature by 1°c under constant pressure.

Perfect gas law

R_u = 8.314 J/kmol·K

· According to the research conducted by Boil-Savart, it was found that; (For perfect/ideal gas)

$\frac{pv}{T} \simeq$ const. ; Here, the constant was defined as R_u, so called as Universal gas constant

$\therefore pv = nR_uT$ ($\because$ the relation is also affected by $n = \frac{\text{mass}}{\text{molecular weight}} = \frac{M}{m}$)

· Then, we have ref. 1 mole = 6.0223×10^3

↳ It will be different as a gas.

$pv = \frac{M}{m}R_uT \Leftrightarrow pv = MRT$; where R is specific gas constant $\left(= \frac{R_u}{m}\right)$

· Also, when we think about the volume, $v = \frac{V}{M}$; Specific volume (= Volume per unit mass)

$$pv = RT$$; It is preferred in thermodynamics.

$$\Leftrightarrow p = \rho R T$$; where $v = \frac{1}{\rho}$ (This relation is preferred in fluid dynamics)

Useful Equations with Perfect (or Ideal) gas

a) Internal Energy

· $e = f(p, T) \longrightarrow e = f(T)$ if perfect gas

$$\therefore C_v \equiv \left(\frac{de}{dT}\right)_v = \left(\frac{de}{dT}\right)_v$$

$$\Leftrightarrow de = C_v \, dT$$

$$\Leftrightarrow \int_{T_{ref}}^{T_{final}} de = \int_{T_{ref}}^{T_f} C_v \, dT \quad \therefore e = C_v T \text{ if } T_{ref} = 0$$

b) Enthalpy

· $h = f(p, T) \longrightarrow h = f(T)$ only if the gas is ideal gas

· Then, $C_p \equiv \left(\frac{dh}{dT}\right)_p = \left(\frac{dh}{dT}\right)_p \quad \therefore h = C_p T$

c) C_p & C_v relationship

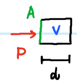
· $\gamma = \frac{C_p}{C_v}$ and typically $C_p > C_v$ (γ is called as specific heat ratio)

· From the definition of Enthalpy, we have

$$h \equiv e + pv = \text{internal Energy} + \text{flow work}$$

→ the work needed to push the fluid into or out to Control Volume

i.e.



Here, Force = Pressure × Area

Work = Force × Distance

along the force direction

Then, Flow work = PAd

$= p \times$ Volume

$\Leftrightarrow$ Flow per unit mass $= \frac{PV}{M} = pv$

; where $v = \frac{V}{M} = \frac{1}{\rho}$

(specific volume)

Since h is the function of T only for ideal gas,

$$\frac{dh}{dT} = \frac{de}{dT} + \frac{d}{dT}(pv)$$; where $pv = RT$

$$\Leftrightarrow C_p = C_v + R$$

$$\Leftrightarrow C_p = \frac{C_p}{\gamma} + R$$; where $\gamma = \frac{C_p}{C_v}$

$$\Leftrightarrow C_p = \frac{\gamma}{\gamma - 1} R \quad \text{or} \quad C_v = \frac{R}{\gamma - 1}$$