**2. BASIC CONCEPTS**

**WORKING FLUID:** Fluid which is used thermodynamic analysis.

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| --- | --- |
| **GAS** | **VAPOUR** |
| Tsubstance > Tcritical | Tsubstance < Tcritical |
| Atmospheric Air is mixture of different gases  Eg. O2, N2, H2, He, Ar, etc...  So each Gas will be under same surrounding condition |  |

| **Substance** | **Critical temperature** | | **Critical pressure** | | **Boiling temperature (1 atm)** | | Here All gas Have less than atmospheric temperature so all will be in **GAS** in atmospheric condition.  And Water will be in **VAPOUR** phase. |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **[°F]** | **[°C]** | **[psi], [lb/in2]** | **[bar]** | **[°F]** | **[°C]** |
| Air | -220.94 | -140.52 | 549.08 | 37.858 | - | - |
| Argon | -188 | -122 | 705.6 | 48.7 | -302.5 | -.85.8 |
| Hydrogen (H) | -400 | -240 | 188.2 | 13.0 | -423 | -253 |
| Nitrogen (N) | -232.6 | -147 | 492.4 | 34.0 | -321 | -195 |
| Oxygen (O2) | -181.5 | -118.6 | 732 | 50.5 | -297 | -183 |
| Helium (He) |  | -268 |  | 2.27 |  |  |
| Water | 705 | 374 | 3206.2 | 220.5 | 212 | 100 |

**IDEAL GAS:** No intermolecular forces. (No Molecular Attractive Forces, Repulsive forces and other forces)

(FIntermolecular)Solid >> (FIntermolecular)Liquid >> (FIntermolecular)Gas

**KINETIC THORY OF GAS:**

1) VGAS <<<< VContainer

2) FIntermolecular = 0

3) Collision between molecules are perfectly elastic ==> Zero Kinetic Energy loss/Gain

**GAS BEHAVES AS IDEAL GAS:** Pressure **˅**, Volume **˄**, Temperature **˅** And MFP **˅ (Z = 0)**

At Atmospheric Condition, Patm = 101.325 KPa, Tatm = 25 °C

|  |  |
| --- | --- |
| **Types of Ideal Gas** | |
| **Perfect Ideal Gas** | **Semi Perfect Ideal Gas** |
| Variation of specific heats (KJ/kg K) are not considered. OR specific heats are constant.  Eg. Air Cp = 1.005 KJ/kg K, Cv = 0.718 KJ/kg K | Variation of specific heats (KJ/kg K) Can’t ignore. So that Analysis at each and every temperature. |

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Boyle’s Law** | **Charles’ Law** | **Gay-Lussac Law** |
| For given mass | Pabs ∝ 1/Vgas (@T=C) | Vgas ∝ T (@Pabs=C) | Pabs ∝ T (@Vgas = C) |

**PERFECT/ IDEAL GAS EQUATION:**

|  |  |
| --- | --- |
| Pabsvgas = RT Where, Pabs = Absolute pressure of Gas (Pa)  vgas = Specific Volume of Gas (m3/kg),  T = Absolute Temperature of Gas (K)  R = Characteristic Gas Constant (J/Kg K)  PabsVgas = mRT Where, V= Total Volume of Gas (m3)  m = Mass of the gas (kg)  Pabs = ρgasRT Where, ρgas = Density of Gas (kg/ m3) | If P (Pa), R (J/kg K).  If P (KPa), R (KJ/kg K).  R = 287 J/kg K (for Air) |

**MOLAR ANALYSIS:**

**Mole(n):** Amount of substance. 1 mol = 6.023 \* 1023 Molecules

**Molar Volume (): =** Vgas/n (m3 / Kmol)

**Molar Mass ( ) Molar weight (M):** M =  **=** mgas/n (kg/ Kmol)

**Molar Gas Constant or Universal gas constant ():** (KJ/ Kmol K)

|  |  |  |
| --- | --- | --- |
| Pabs = RT | Pabs = T | Pabs Vgas = nT |

**AVOGADRO’S LAW:** “Equal volume of all gases contains equal number of molecules at the same pressure and same temperature”

**STP =>** Pstp = 1 atm = 101.325 KPa, Tstp = 0 °C = 273 K, V = 22.4 m3, n = 1Kmol => = 8.314 KJ/Kmol K

**Difference between Characteristic Gas constant and Universal Gas Constant:**

|  |  |  |  |
| --- | --- | --- | --- |
| **Gas** | **Molar Mass (M) (kg/mol)** | **Universal gas constant () (KJ/ Kmol K)** | **Characteristic Gas constant (R) (KJ/ kg K)** |
| Air | 28.9 | 8.314 | 0.287 |
| O2 | 32 | 8.314 | 0.259 |
| N2 | 28 | 8.314 | 0.296 |

**IDEAL GAS EQUATION FOR VARIOUS THERMODYNAMIC PROCESS:**

|  |  |  |
| --- | --- | --- |
| **Reversible Constant Volume/ Isochoric Process:**  Rigid Tank,  Vgas = Constant,  Qsupply / Qrejected,  Eg. Football, Pressure Cooker, Automobile tyre, Automobile car, Both direction Locked Piston cylinder. | Pabs ∝ T (@Vgas = C)  **Gay-Lussac Law** | Isochoric process - Wikipedia |
| **Reversible Constant Pressure/ Isobaric Process:**  Assumptions:  1) Very Slow Process  2) Friction is neglected  3) No effect on gas due to weight of piston. WP = 0  Rigid Tank,  Pgas = Constant,  Qsupply / Qrejected (Expansion/Contraction)  Eg. Piston Cylinder Mechanism with weight less piston, Water heated in atmosphere, | Vgas ∝ T (@Pabs= C) **Charles’ Law** | Isobaric process - Wikipedia |
| **Combination of Constant Volume and Constant Pressure Process:**  Assumptions:  1) Very Slow Process  2) Friction is neglected  3) Effect on gas due to weight of piston. WP ≠ 0.  Two Process happed in index mentioned below when heat is supplied or rejected on one side locked piston:  1) Constant Volume Process  2) Constant Pressure Process | **Process 1:**  Pabs ∝ T (@Vgas = C)  Gay-Lussac Law  **Process 2:**  Vgas ∝ T (@Pabs= C)  Charles’ Law | **Rectangle Triangle diagram.** |
| **Reversible Constant Temperature/ Isothermal Process:**  In order to maintain constant temperature, Heat should be supplied or reject simultaneously.  This is not practically possible because:  1) Simultaneously Qsupply / Qrejected is not possible.  2) Process is very slow process.  Eg. **Boiling Water** In atmosphere, Human Body (37 °C) | Pabs ∝ 1/Vgas (@T = C)  **Boyle’s Law** | Isothermal Process | Definition, Examples, Diagrams**Rectangular Hyperbola** |
| **Reversible Adiabatic Process:**  No heat Transfer (Qsupply / Qrejected = 0)  γ = adiabatic index | **PVγ = Constant**  **TVγ-1 = Constant**  **T = Constant**  (because T ∝ PV) | γ = 1.67 (for mono-atomic Gas Eg. He, Ar)  γ = 1.4 (for die-atomic Gas Eg. H2, O2, N2)  γ = 1.33 (for Poly-atomic Gas Eg. CO2, CH4) |
| **Reversible Polytropic Process:**  Poly = many, Tropic = changes  Qsupply / Qrejected ≠ 0  n = polytropic index | **PVn = Constant**  **TVn-1 = Constant**  **T = Constant**  (because T ∝ PV) | Thermodynamics Definitions |

Adiabatic/ Polytropic index = ln(P1/P2)/ln(V2/V1)

Generally, 1 ≤ n ≤ γ. Actually, -**∞** ≤ n ≤ **∞**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Slope of Various Processes = dP/dV** | | | | |
| n = 0 | n = 1 | n = γ | n = n | n = ∞ |
| P = Constant | T = Constant | - | - | V = Constant |
| Isobaric | Isothermal | Adiabatic | Polytropic | Isochoric |
| **= 0** | **=** | **= =** | **= =** | **= ∞** |

**THERMODYNAMICS TERMINOLOGY:**

**1.** **System:** Quantity of Matter concentrated or under study.

**2.** **Surroundings:** Outside the system and effect on system is present.

**3.** **Boundary:** Surface which separates system and surroundings.

|  |  |  |  |
| --- | --- | --- | --- |
| **Types of Boundary** | | | |
| Fixed | Moving | Imaginary | Real |

**4.** **Universe:** (System + Surroundings) put together.

**FUNDAMENTAL DEFINATIONS IN THERMODYNAMICS:**

**1.** **State:** Condition of system. (Denotes by point in diagrams)

**2.** **Process:** Change in State.

**3.** **Path:** Line which connects various state points.

**4. Quasi Static Process: (**Quasi = Almost, Static = Fixed) Extremely slow Process.

Each state is in equilibrium condition. dP = dV = 0 (For each successive states)

**5. Reversible Process:**

It’s Idealized or Hypothetical process.

When process is reversed follows same path. (Denotes by Solid/ Continuous line in diagram)

Condition for reversibility: 1) Quasi Static Process 2) Zero Friction loss 3) No effect of surrounding on system.

**1) Integration is possible 2) Area Can be find for work obtain.**

**6.** **Irreversible Process:** Process Which can’t reverse. System and surrounding presently affected.

(Denotes by Dotted/ Discontinuous line in diagram)

Condition for irreversibility: 1) Extremely Fast Process 2) Friction loss is present.

**7. Thermodynamic Cycle:** Series of processes which restores initial condition.

|  |  |
| --- | --- |
| **Thermodynamic Cycle** | |
| **Reversible Thermodynamic Cycle** | **Irreversible Thermodynamic Cycle** |
| All process in cycle must be reversible. | At least one process is Irreversible. |
| **Thermodynamic Cycle** | |
| Work Producing Cycle (Clock wise) | Work Consuming Cycle (Anti-Clock wise) |

**8. Thermodynamic Equilibrium:**

|  |  |  |
| --- | --- | --- |
| **Thermodynamic Equilibrium** | Thermal Equilibrium | Same Temperature throughout the system |
| Mechanical Equilibrium | Same Forces throughout the system |
| Chemical Equilibrium | No Chemical Reaction |

**PROPERTIES:**

|  |  |
| --- | --- |
| **PROPERTIES** | |
| Extensive Property | Intensive Property |
| Depending on Mass and Size | Not Depending on Mass and Size |
| Mass, Volume, kinetic energy, Potential energy | Pressure, Temperature, Density, Viscosity, Thermal Conductivity, Electric Conductivity |
| **1) Intensive Property** = (Extensive Property**/**Extensive Property) **2) All Specific Property are Intensive property** | |

Essential Features of Properties:

1) All Properties are point function. 2) Changes in property does not depend on path. 3) Properties are exact differentials. Eg. dP, dV,…

|  |  |  |
| --- | --- | --- |
| **TYPES OF SYSTEM** | | |
| **Closed System** | **Open System** | **Isolated System** |
| No Mass Transfer Allowed  Energy Transfer Allowed | Mass Transfer Allowed  Energy Transfer Allowed | No Mass Transfer Allowed  No Energy Transfer Allowed  **But Work Transfer is allowed.** |
| Eg. Closed Cointainer, Vessel, Balloons, Piston cylinder when valves are closed | Eg. Turbine, Compressor, Nozzle, Pipe Line. | Eg. Thermos Flask. |

**Controlled Volume:** Region in the space consider for study.

**Controlled Surface:** Separates region from surroundings.