Isothermal Process (constant T)

$$Q = -W = RT \ln \frac{V_2^{ig}}{V_1^{ig}} = RT \ln \frac{P_1}{P_2}$$

Isobaric Process (constant P)

$$dU^{ig} = C_V^{ig} dT \text{ and } W = -R(T_2 - T_1)$$

$$Q = \Delta H^{ig} = \int C_P^{ig} dT \quad (const\ P)$$

THERMODYNAMIC PROCESSES

Isochoric Process (constant V)

V: constant, dV = 0, so W=0

By Eqs. $\Delta U^{ig} = \int C_V^{ig} dT$ and $dQ = C_V^{ig} dT + RT \frac{dV^{ig}}{V^{ig}}$,

$$Q = \Delta U^{ig} = \int C_V^{ig} dT \quad (const \ V^{ig})$$

THERMODYNAMIC PROCESSES

Adiabatic Process (constant Q); Constant Heat Capacities

Q: constant, dQ = 0, (there is no heat transfer),

$$\frac{dT}{T} = -\frac{R}{C_V^{ig}} \frac{dV^{ig}}{V^{ig}}$$

integration of the equation (ideal gas and constant heat capacity) yields:

$$\frac{T_2}{T_1} = \left(\frac{V_1^{ig}}{V_2^{ig}}\right)^{R/C_V^{ig}}$$

Similarly, for equation $C_P^{ig} dT - RT \frac{dP}{P} = 0$ leads to

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{R/C_P^{ig}}$$

THERMODYNAMIC PROCESSES

Adiabatic Process (constant Q); Constant Heat Capacities

The first law for an adiabatic process in a closed system combined with Eq. $dU^{ig} = C_V^{ig} dT$ yields:

$$dW = dU^{ig} = C_V^{ig} dT, \text{ For constant } C_V^{ig}, W = \Delta U^{ig} = C_V^{ig} \Delta T$$

$$W = C_V^{ig} \Delta T = \frac{R \Delta T}{\gamma - 1}$$

Because $RT_1 = P_1 V_1^{ig}$ and $RT_2 = P_2 V_2^{ig}$, this expression may be written:

$$W = \frac{RT_2 - RT_1}{\gamma - 1} = \frac{P_2 V_2^{ig} - P_1 V_1^{ig}}{\gamma - 1}$$

THERMODYNAMIC PROCESSES

Adiabatic Process (constant Q); Constant Heat Capacities

However, T_2 and V_2^{ig} are usually unknown. Elimination of V_2^{ig} from Eq. (**) by Eq. ($P(V^{ig})^\gamma =$ **const**), valid only for mechanically reversible processes, leads to the expression:

$$W = \frac{P_1 V_1^{ig}}{\gamma - 1}\left[\left(\frac{P_2}{P_1}\right)^{(\gamma-1)/\gamma} - 1\right] = \frac{RT_1}{\gamma - 1}\left[\left(\frac{P_2}{P_1}\right)^{(\gamma-1)/\gamma} - 1\right]$$

This equation is valid only for the ideal-gas state, for constant heat capacities, and for adiabatic, mechanically reversible, closed-system processes.

Text Book: : J. M. Smith, H. C. Van Ness, M. M. Abbott, M. T. Swihart. "INTRODUCTION TO CHEMICAL ENGINEERING THERMODYNAMICS", EIGHTH EDITION. 2018

VIRIAL EQUATIONS OF STATE

Volumetric data for fluids are useful for many purposes. PVT data are necessarily required for calculations. Expression of the functional relation $f(P, V, T) = 0$ by equations is much more compact and convenient. The virial equations of state for gases are uniquely suited to this purpose.

Product PV may be given for an isotherm by a power series in P:

$PV = a + bP + c\,P^2 + \ldots\ldots$

Lets define; $b \equiv aB'$, $c \equiv aC'$, etc., then,

$PV = a\,(1 + B'P + C'P2 + D'P3 + \ldots)$

where B', C', etc., are constants for a given temperature and a given substance.