# Equation of State (EoS)

- In physics and thermodynamics, an **equation of state** is a relation between state variables. More specifically, an equation of state is a thermodynamic equation describing the state of matter under a given set of physical conditions

. It is a constitutive equation which provides a mathematical relationship between two or more state functions associated with the matter, such as its temperature, pressure, volume, or internal energy. Equations of state are useful in describing the properties of fluids, mixtures of fluids, solids, and even the interior of stars.

# Ideal Gas Equation of State

- An ideal gas is defined as one in which all collisions between atoms or molecules are perfectly elastic and in which there are no intermolecular attractive forces.

- One can visualize it as a collection of perfectly hard spheres which collide but which otherwise do not interact with each other. In such a gas, all the internal energy is in the form of kinetic energy and any change in internal energy is accompanied by a change in temperature.

An ideal gas can be characterized by three state variables: absolute pressure (P), volume (V), and absolute temperature (T). The relationship between them may be deduced from kinetic theory and is called the ideal gas law:

# $PV=nRT=NkT$

n = number of moles

R = universal gas constant = 8.3145 J/mol K

N = number of molecules

k = Boltzmann constant = $1.38066 \times 10^{-23}$ J/K

$k = R/N_A$

$N_A$ = Avogadro's number = $6.0221 \times 10^{23}$ /mol

# Example of EoS for a PVT system – Ideal gas system

- One specific *xyz*-system is the hydrostatic system
- It's a system that exerts uniform hydrostatic pressure to the surrounding - sometimes is referred to as 'fluid system'
- Example – gas, mixture of gases contained in a closed volume. It can be described by three coordinates: *P*, *V*, *T*
- We refer such system as a PVT system

A specific example of a PVT system is the ideal gas system
EoS for ideal gas: $PV = nRT$
This is the specific form of $z=z(x,y)$ taken by the idea gas system.
Different system has different EoS.

# Infinitesimal changes of hydrostatic system (PVT)

- *V*, *T*, *P are the parameters* related by EoS.
- Hence, in general, we know how *V* is related to *P*, *T*, and we state $V = V(P,T)$
- If *V* change by a tiny amount d*V*, so will *T* change by an amount d*T*, and *P* by d*P*.

- Since $V = V(P,T)$, according to the calculus of differential variables, these changes are related via

$$dV = \left(\frac{\partial V}{\partial T}\right)_P dT + \left(\frac{\partial V}{\partial P}\right)_T dP$$

- If EoS is known, we can then work out what is

$$\left(\frac{\partial V}{\partial T}\right)_P, \left(\frac{\partial V}{\partial P}\right)_T$$