Chapter 5: Diffusion

- Introduction .
- Definition of diffusion .
- Type of diffusion .
- Conditions of diffusion .
- Mechanisms of diffusion .
- Diffusion laws .
- Diffusion and Materials Processing .
- Applications of diffusion on industry .

Introduction

- Examine the principles and applications of diffusion in materials .
- Discuss, how diffusion is used in the synthesis and processing of advanced materials as well as manufacturing of components using advanced materials .

Definition of diffusion

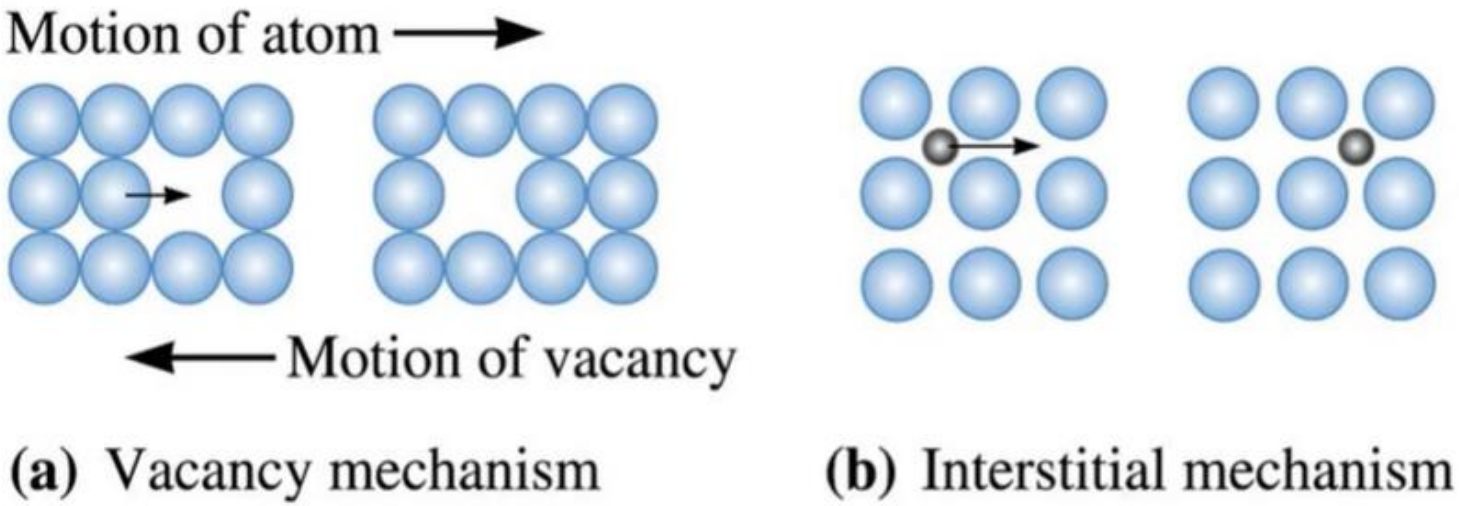
- **Diffusion** – it's a movement of atom from site to site in inside the same material or from material to ether material .

- Type of diffusion are:
  - Self-diffusion – no change in chemical composition only position exchange .
  - Interstitial diffusion change in chemical composition .

- Condition of diffusion are:
  - Empty space
  - Energy

Mechanisms of diffusion

- **Mechanisms for Diffusion are :**
  - **Self-diffusion** - The random movement of atoms within an essentially pure material.
  - **Vacancy diffusion** - Diffusion of atoms when an atom leaves a regular lattice position to fill a vacancy in the crystal.
  - **Interstitial diffusion** - Diffusion of small atoms from one interstitial position to another in the crystal structure.



Diffusion mechanisms in material: **(a)** vacancy or substitutional atom diffusion and **(b)** interstitial diffusion .

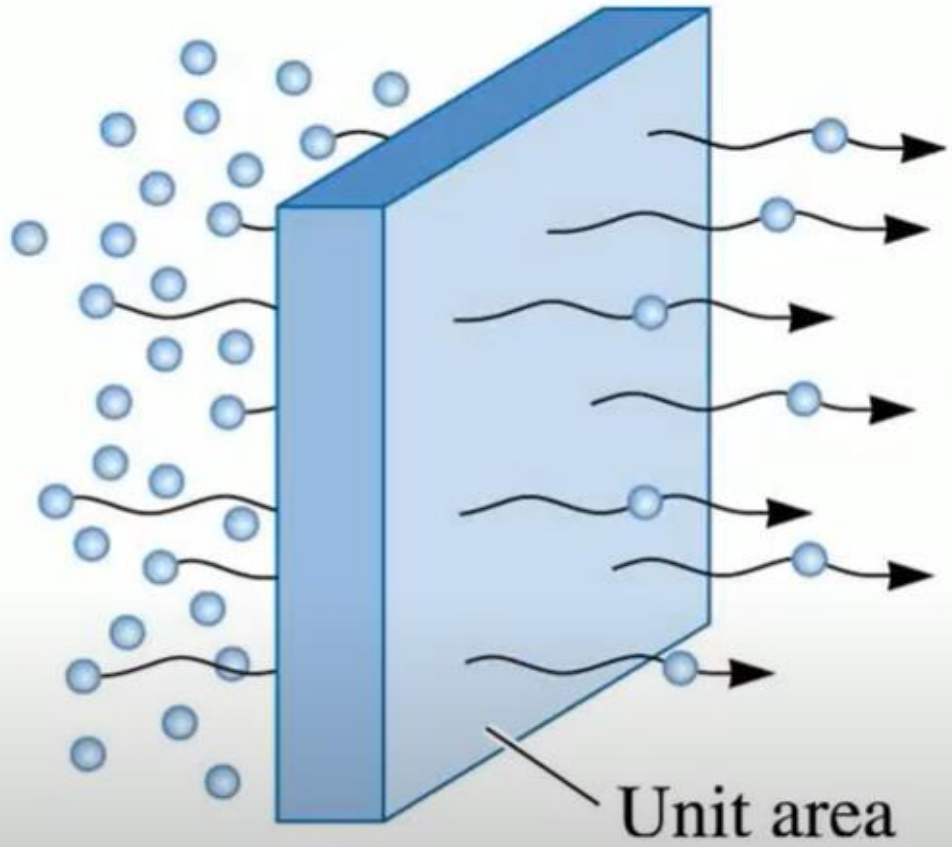
Diffusion laws

- Fick's first law, $J = -D (\Delta C/\Delta)$.
- Fick's Second law $= (Cs-Cx)/(Cs-Co) = erf(X/2\sqrt{Dt})$.

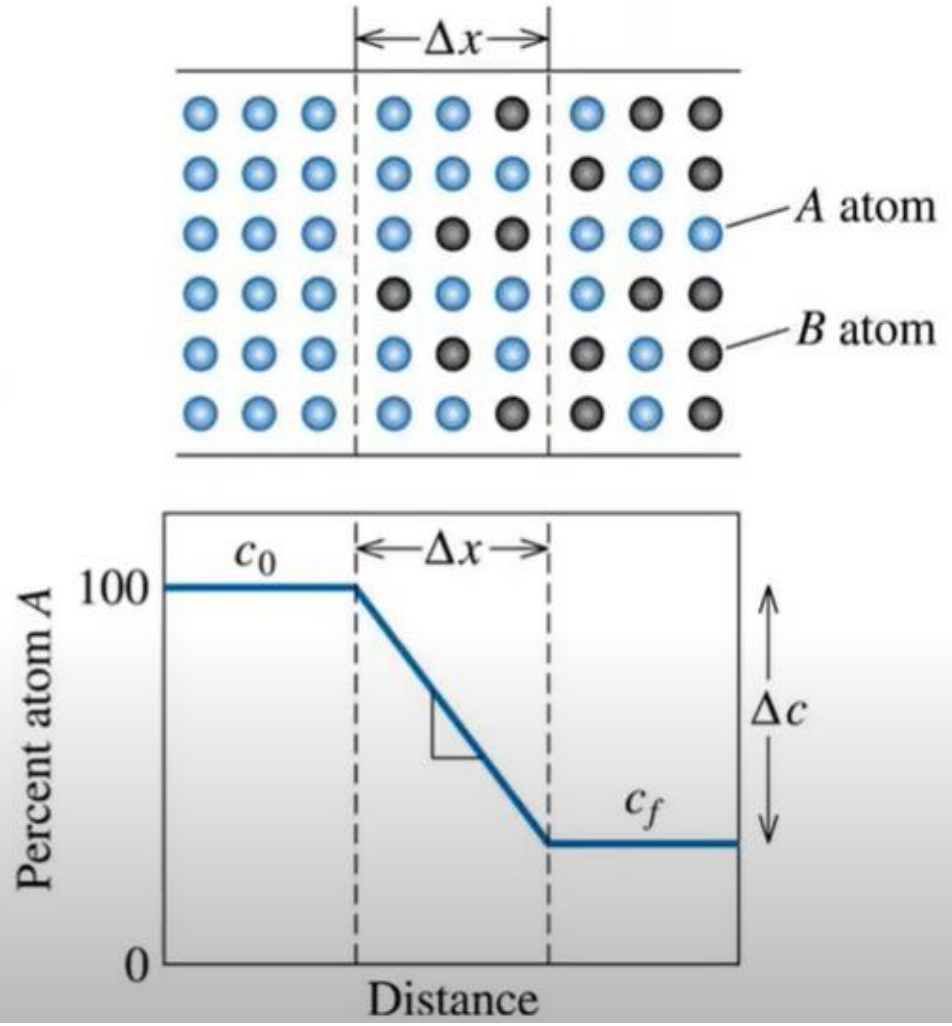
Fick's First Law

- **Fick's first law** - The equation relating the flux of atoms by diffusion to the diffusion coefficient and the concentration gradient.
- **Diffusion coefficient (D)** - A temperature-dependent coefficient related to the rate at which atoms, ions, or other species diffuse.
- **Concentration gradient** - The rate of change of composition with distance in a nonuniform material, typically expressed as atoms/cm3.cm or at%/cm.

- The flux during diffusion is defined as the number of atoms passing through a plane of unit area per unit time.

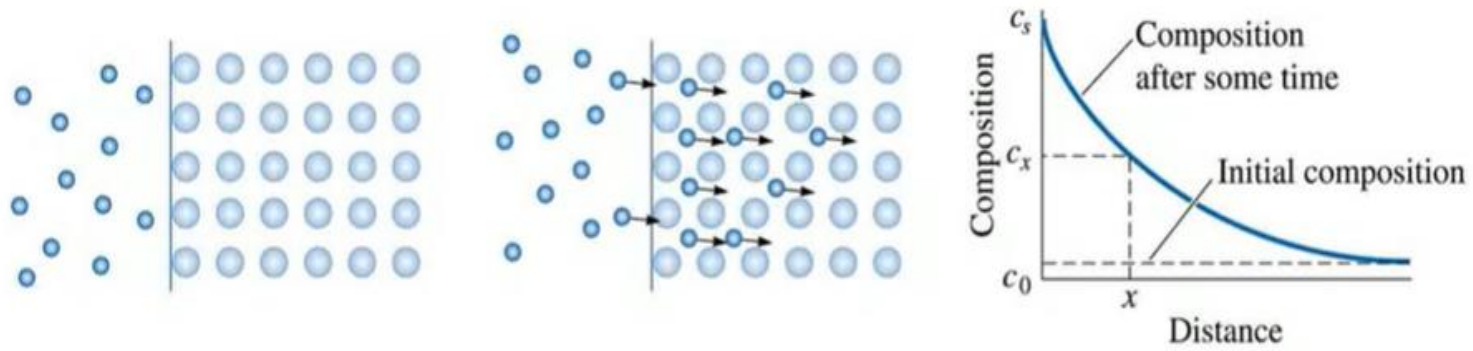


- Illustration of the concentration gradient



Fick's Second Law

- **Fick's second law** - The partial differential equation that describes the rate at which atoms are redistributed in a material by diffusion.
- Fick's Second law $= (Cs-Cx)/(Cs-Co) = \text{erf}(X/2\sqrt{Dt})$
- **Interdiffusion** - Diffusion of different atoms in opposite directions.
- **Kirkendall effect** - Physical movement of an interface due to unequal rates of diffusion of the atoms within the material.
- **Purple plague** - Formation of voids in gold-aluminum welds due to unequal rates of diffusion of the two atoms; eventually failure of the weld can occur.

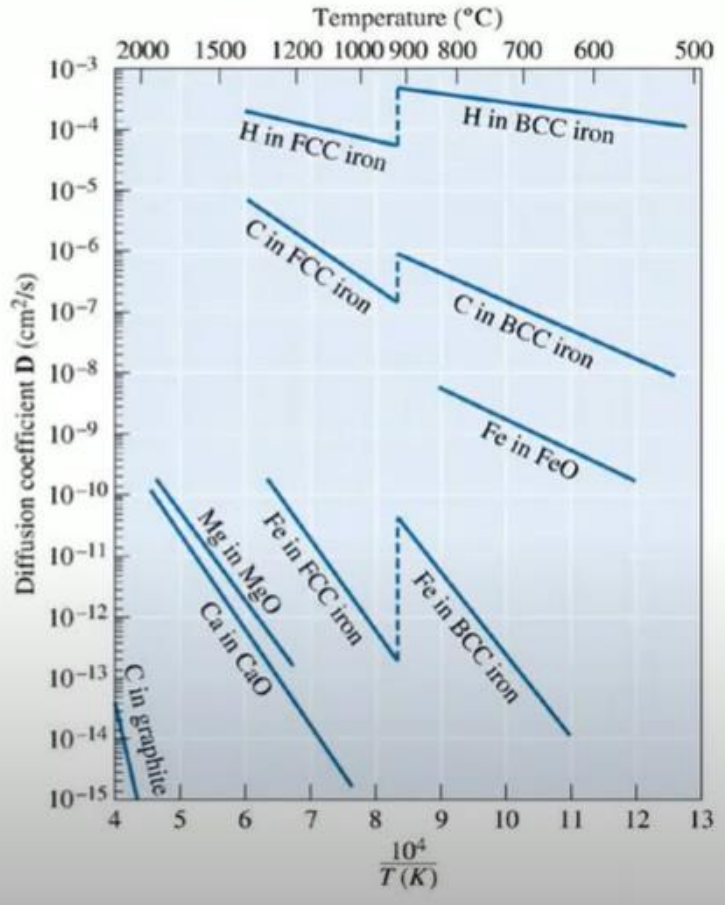


- Diffusion of atoms into the surface of a material illustrating the use of Fick's second law .

Factors Affecting Diffusion

- Temperature and the Diffusion Coefficient (D) .
- Types of Diffusion - volume diffusion, grain boundary diffusion, Surface diffusion .
- Time .
- Dependence on Bonding and Crystal Structure .
- Dependence on Concentration of Diffusing Species and Composition of Matrix .

- The diffusion coefficient *D* as a function of reciprocal temperature for some metals and ceramics. In the Arrhenius plot, *D* represents the rate of the diffusion process. A steep slope denotes a high activation energy .



- The activation energy for self-diffusion increases as the melting point of the metal increases .