

# MSE 170 Final review part 1

- Exam date: 12/9/2008 Tues, 8:30-10:20
- Place: Here!
- Closed book, no notes and no collaborations
- Two sheets of letter-sized paper with double-sided notes is allowed
- Exam is comprehensive: material on the exam will be taken from the text book reading, lecture notes, homework, and lab
- Bring a calculator and straight edge/triangle
- The review materials are not comprehensive, there may be questions on the exam on topics not listed here



# Bonding and atomic forces

- The periodic table
- What types of bonding are there?
- How does bonding affect materials properties?



# The Periodic Table

- Columns: Similar **Valence** Structure

columns: Similar Valence Structure

The periodic table is color-coded to show valence electron configurations. Groups 1 and 2 are highlighted in red, indicating they 'give up' 1 and 2 electrons respectively. Groups 13-15 are highlighted in light blue, indicating they 'give up' 3 electrons. Groups 16 and 17 are highlighted in medium blue, indicating they 'accept' 2 and 1 electrons respectively. Group 18 is highlighted in dark blue, indicating they are 'inert gases'. A legend shows three types of boxes: a light blue box for 'Metal', a medium blue box for 'Nonmetal', and a diagonal box for 'Intermediate'.

| IA       | IIA      | IIIB              | IVB       | VB        | VIB       | VII B     | VIII      |           |           | IB       | IIB      | IIIA     | IVA      | VA       | VIA      | VIIA     | 0        |
|----------|----------|-------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|----------|----------|----------|----------|----------|----------|----------|----------|
| 1<br>H   | 2<br>He  |                   |           |           |           |           |           |           |           |          |          | 3<br>B   | 4<br>C   | 5<br>N   | 6<br>O   | 7<br>F   | 8<br>Ne  |
| 3<br>Li  | 4<br>Be  |                   |           |           |           |           |           |           |           |          |          | 13<br>Al | 14<br>Si | 15<br>P  | 16<br>S  | 17<br>Cl | 18<br>Ar |
| 11<br>Na | 12<br>Mg |                   |           |           |           |           |           |           |           |          |          | 31<br>Ga | 32<br>Ge | 33<br>As | 34<br>Se | 35<br>Br | 36<br>Kr |
| 19<br>K  | 20<br>Ca | 21<br>Sc          | 22<br>Ti  | 23<br>V   | 24<br>Cr  | 25<br>Mn  | 26<br>Fe  | 27<br>Co  | 28<br>Ni  | 29<br>Cu | 30<br>Zn | 49<br>In | 50<br>Sn | 51<br>Sb | 52<br>Te | 53<br>I  | 54<br>Xe |
| 37<br>Rb | 38<br>Sr | 39<br>Y           | 40<br>Zr  | 41<br>Nb  | 42<br>Mo  | 43<br>Tc  | 44<br>Ru  | 45<br>Rh  | 46<br>Pd  | 47<br>Ag | 48<br>Cd | 81<br>Tl | 82<br>Pb | 83<br>Bi | 84<br>Po | 85<br>At | 86<br>Rn |
| 55<br>Cs | 56<br>Ba | Rare earth series | 72<br>Hf  | 73<br>Ta  | 74<br>W   | 75<br>Re  | 76<br>Os  | 77<br>Ir  | 78<br>Pt  | 79<br>Au | 80<br>Hg |          |          |          |          |          |          |
| 87<br>Fr | 88<br>Ra | Actinide series   | 104<br>Rf | 105<br>Db | 106<br>Sg | 107<br>Bh | 108<br>Hs | 109<br>Mt | 110<br>Ds |          |          |          |          |          |          |          |          |

Adapted from  
Fig. 2.6,  
*Callister 7e.*

Electropositive elements:  
Readily donate electrons  
to become  $+$  ions.

Electronegative elements:  
Readily acquire electrons  
to become  $-$  ions.



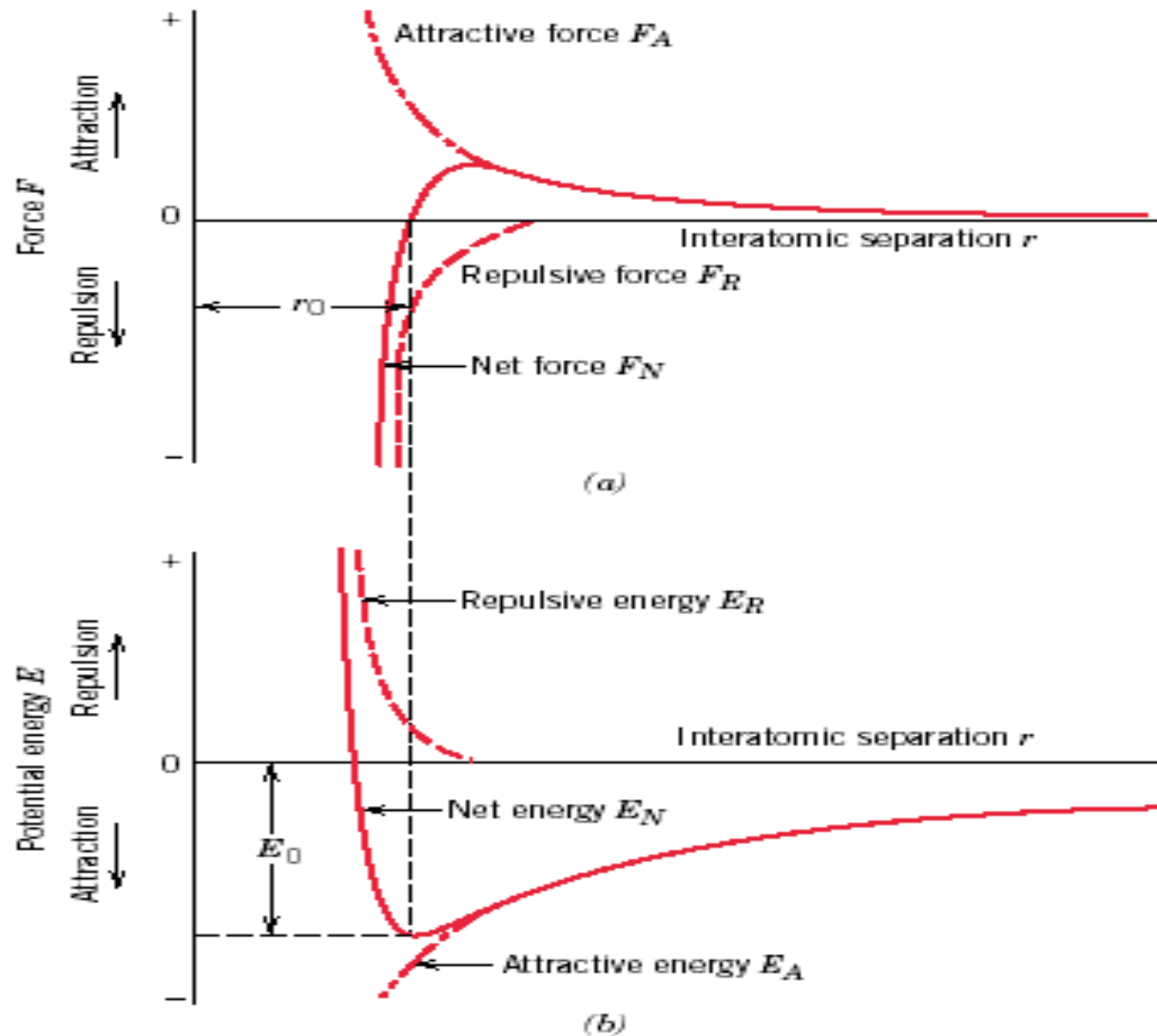
# Bonding and atomic forces (continued)

- Atomic forces & potential vs interatomic distance



# Atomic bonding in solids

- Bonding forces and energies

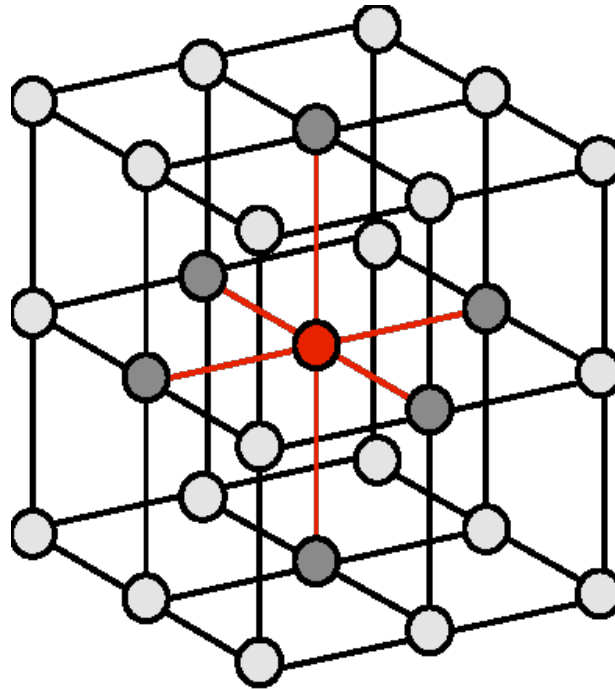


# Crystal structure

- Determine #atoms/unit cell, CN#, APF and density
- Draw and index crystallographic direction and planes
- Close-packed plane and stacking sequence
- Crystal systems

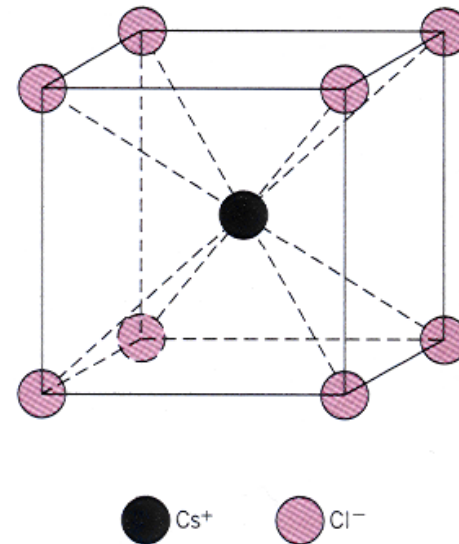


# Crystal Structures



# Crystal structures (*ceramics*)

- Know the types of ceramic structures and identify their unit cells
- Determine coordination number for ceramic structures based on ionic radii and charge



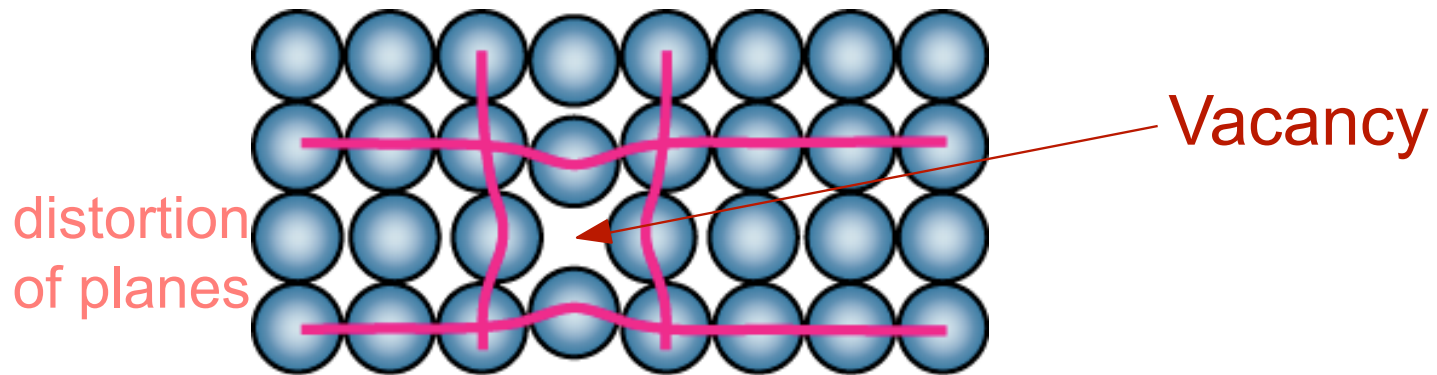
# Defects

- Distinguish point, linear (dislocation 1D), interfacial(2D), volume(3D) defects
- Draw and describe edge and screw dislocations
- Burgers circuits and vectors
- Understand equilibrium of vacancies and effect of T

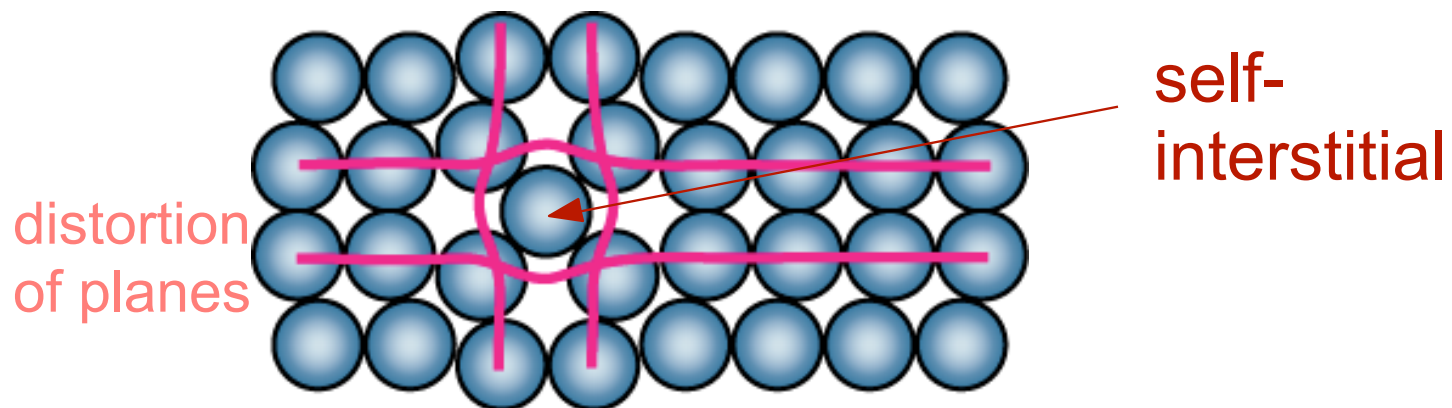


# Point Defects

- **Vacancies:**  
-vacant atomic sites in a structure.



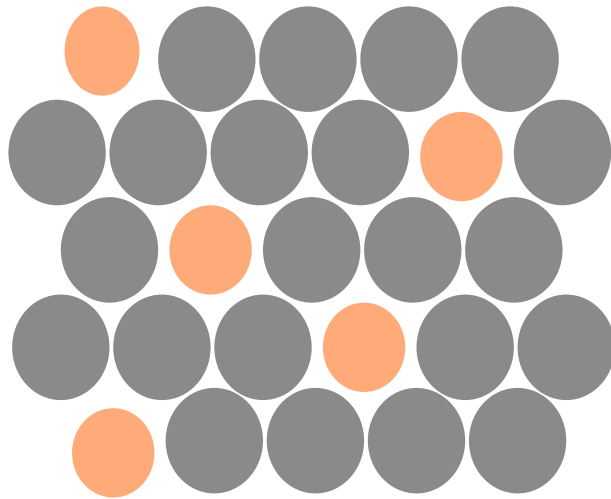
- **Self-Interstitials:**  
-"extra" atoms positioned between atomic sites.



# Point Defects in Alloys

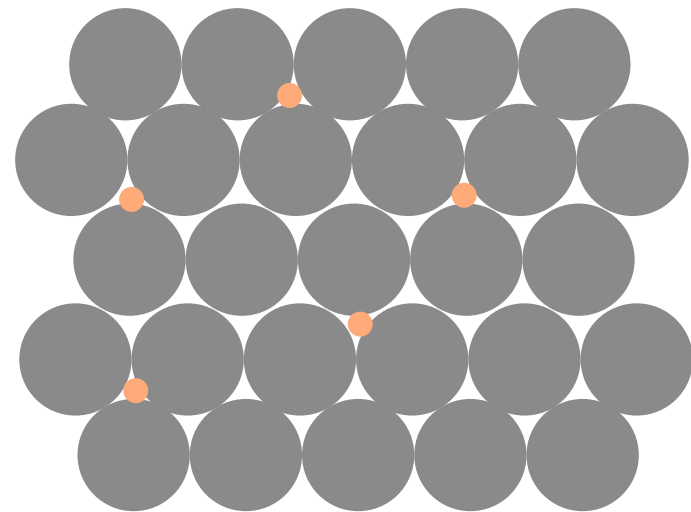
Two outcomes if impurity (B) added to host (A):

- **Solid solution** of **B** in A (i.e., random dist. of point defects)



**Substitutional** solid soln.  
(e.g., **Cu** in Ni)

OR



**Interstitial** solid soln.  
(e.g., **C** in Fe)

# Imperfections in Solids

## Edge Dislocation

- extra half-plane of atoms inserted in a crystal structure
- $\mathbf{b} \perp$  to dislocation line

Edge  
dislocation  
line

Burgers vector

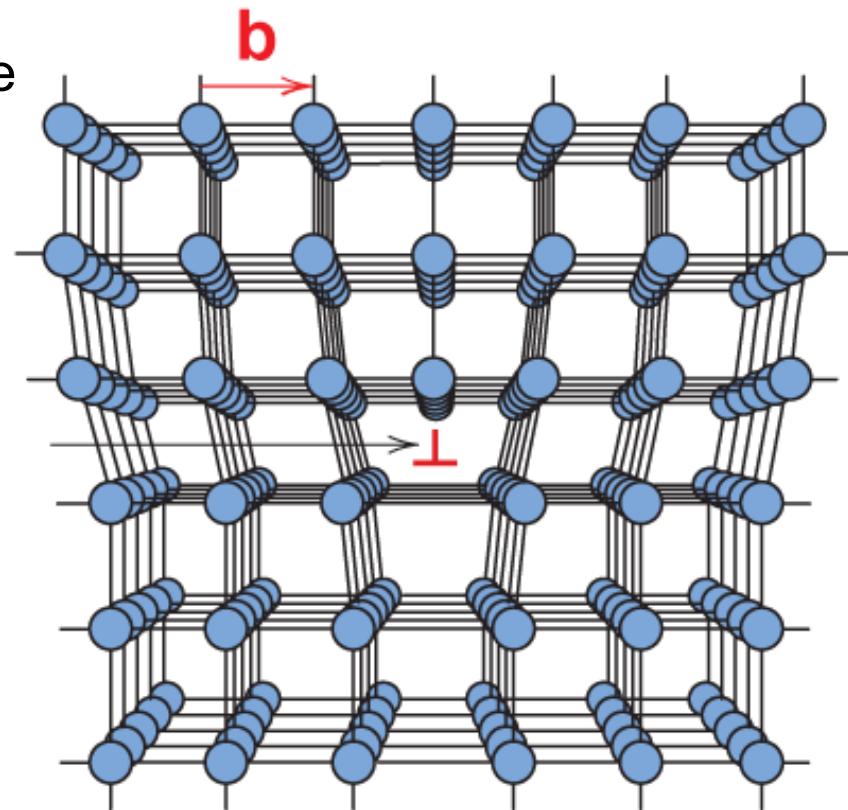


Fig. 4.3, Callister 7e.



# Diffusion

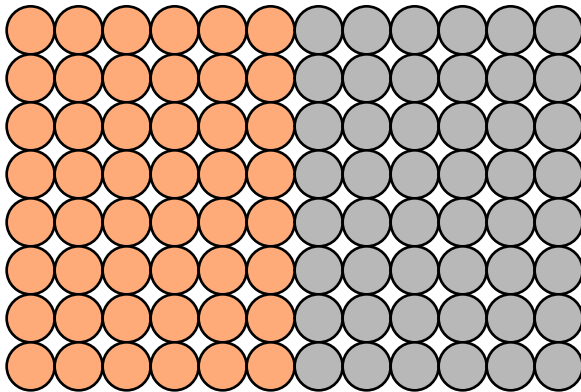
- Mechanisms, concentration gradients, diffusion coefficient
- Ficks laws
- Effects of T on diffusion coefficients



# Diffusion

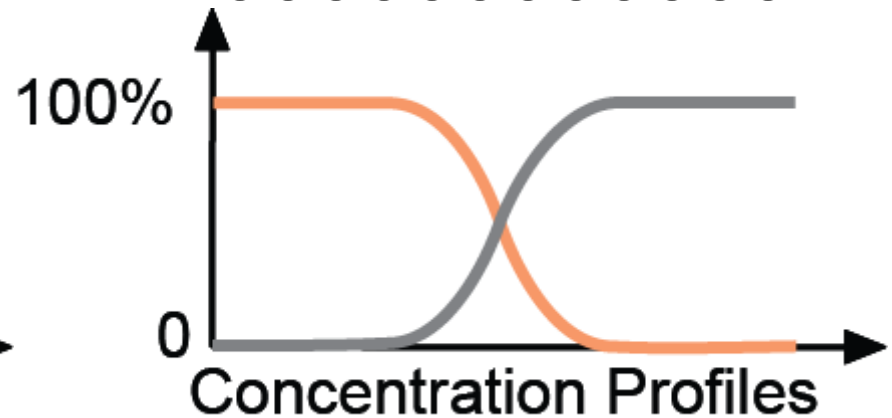
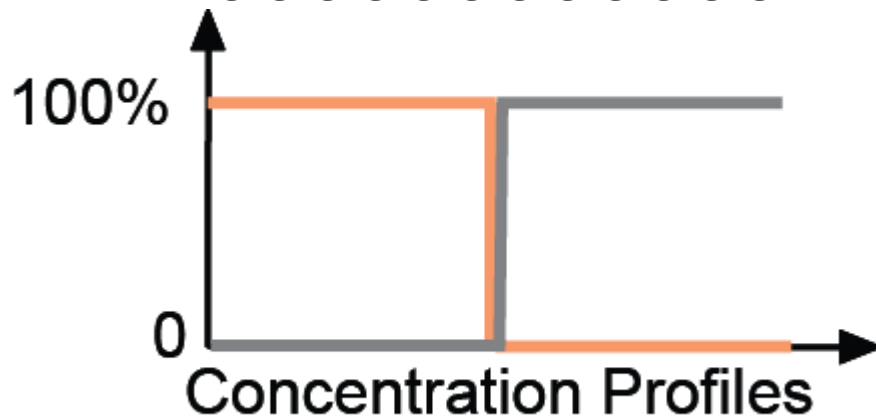
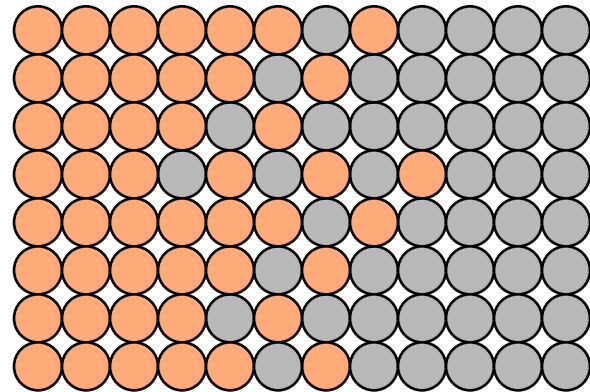
- **Interdiffusion:** In an alloy, atoms tend to migrate from regions of high conc. to regions of low conc.

Initially



Adapted from  
Figs. 5.1 and  
5.2, Callister  
7e.

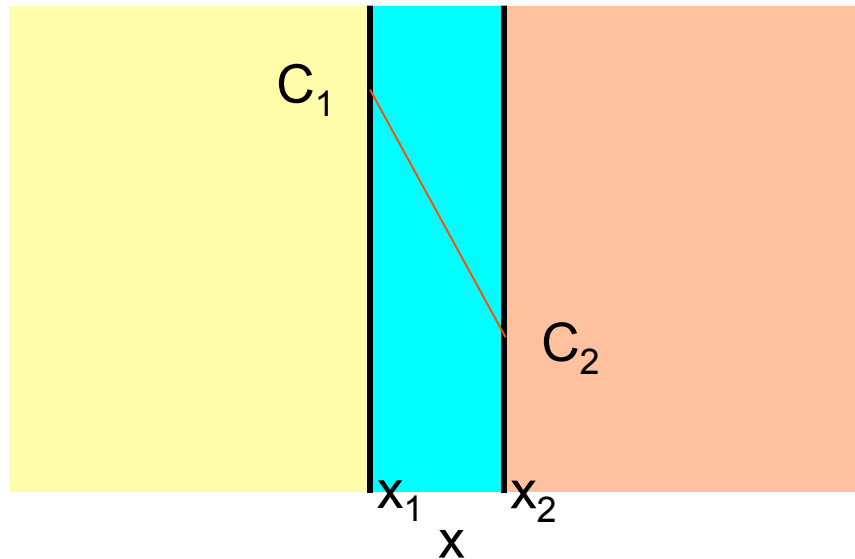
After some time



# Steady-State Diffusion

Rate of diffusion independent of time

Flux proportional to concentration gradient =  $\frac{dC}{dx}$



Fick's first law of diffusion

$$J = -D \frac{dC}{dx}$$

if linear  $\frac{dC}{dx} \cong \frac{\Delta C}{\Delta x} = \frac{C_2 - C_1}{x_2 - x_1}$

$D \equiv$  diffusion coefficient

# Non-steady State Diffusion

- The concentration of diffusing species is a function of both time and position  $C = C(x,t)$
- In this case **Fick's Second Law** is used

Fick's Second Law

$$\frac{\partial C}{\partial t} = D \frac{\partial^2 C}{\partial x^2}$$

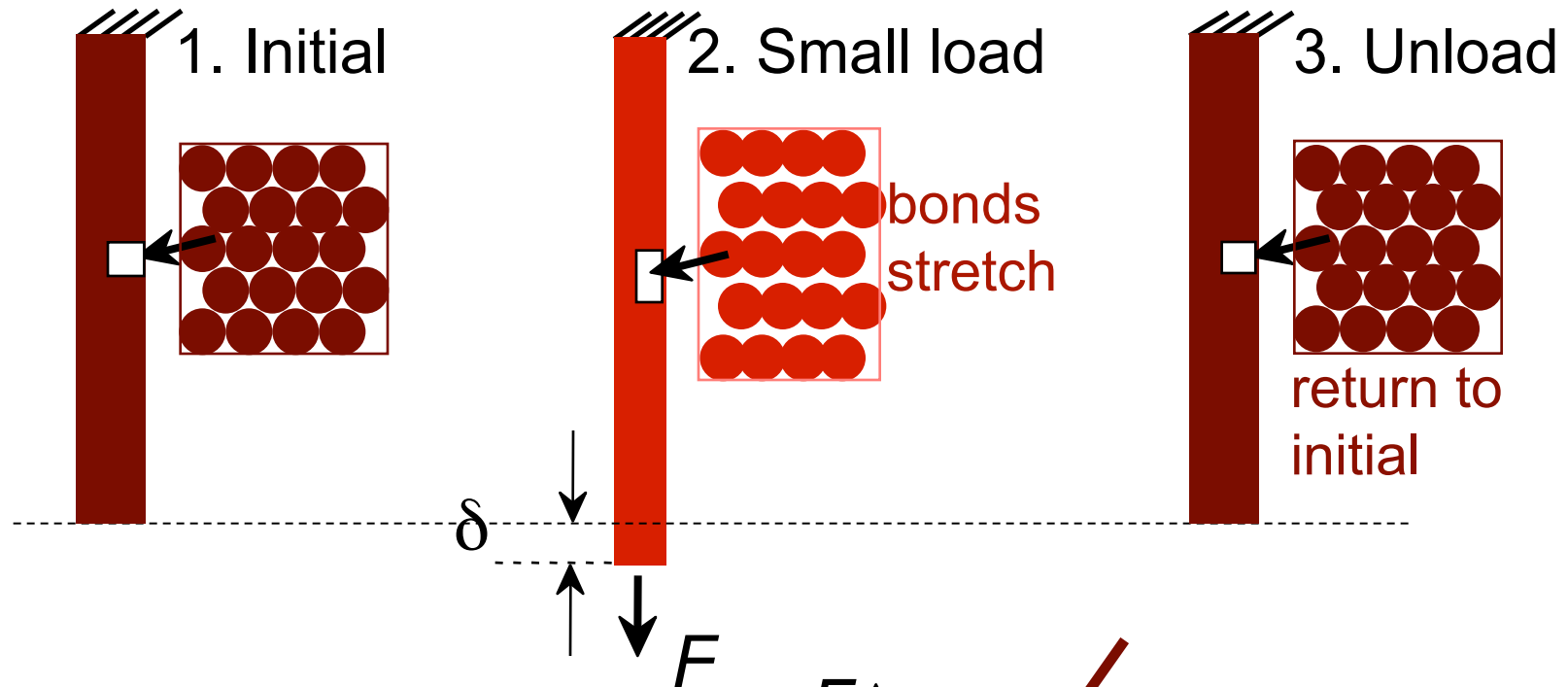


# Mechanical properties

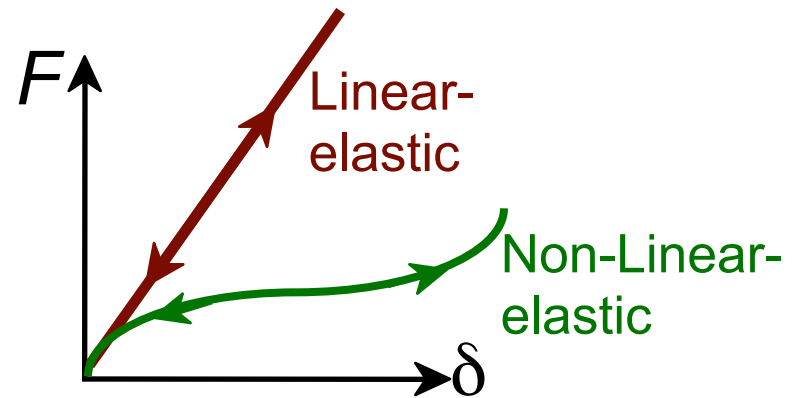
- Definition of stress, strain, elastic modulus
- Analysis of stress-strain curves
- Yield strength, tensile strength, Poisson's ratio, ductility, resilience, and toughness
- Hardness



# Elastic Deformation



Elastic means **reversible**!

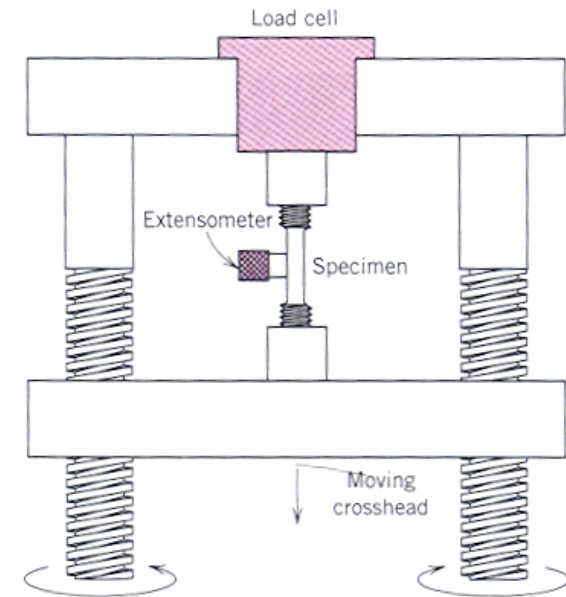
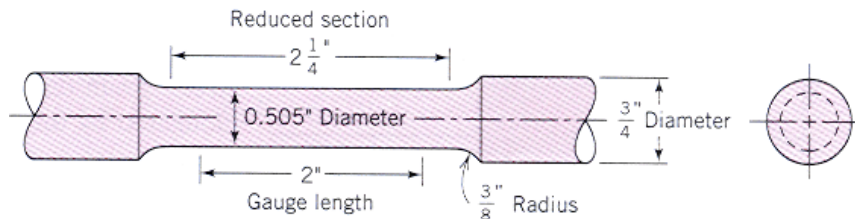


# Concepts of stress and strain

- Tension tests
  - engineering stress
  - engineering strain

$$\sigma = \frac{F}{A_0}$$

$$\epsilon = \frac{l_i - l_0}{l_0} = \frac{\Delta l}{l_0}$$

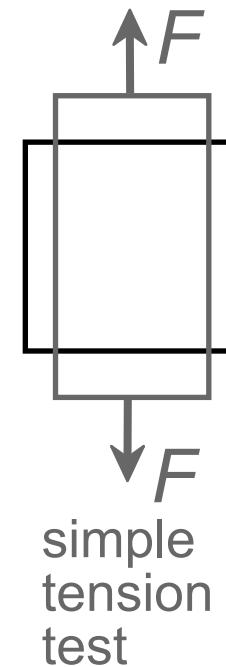
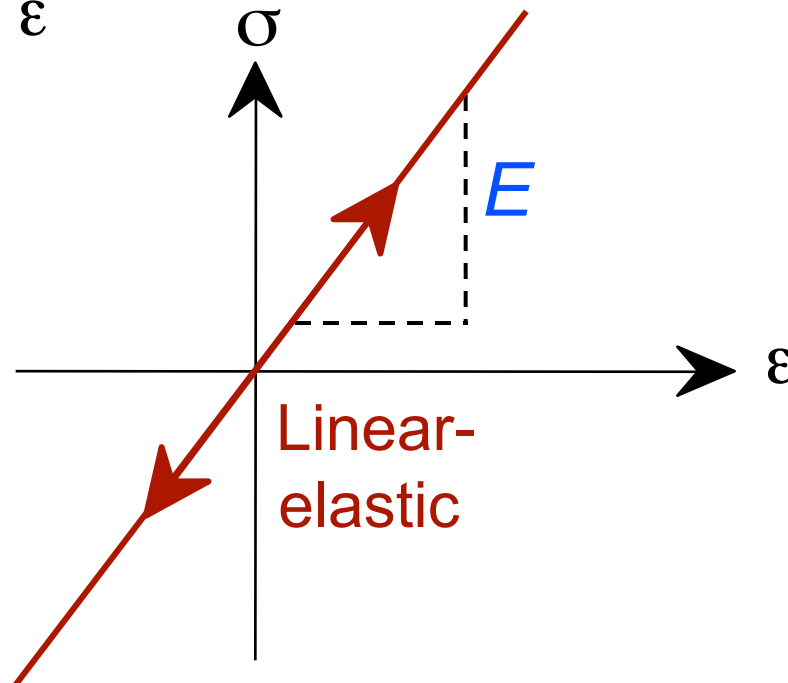


- Compression tests

# Linear Elastic Properties

- **Modulus of Elasticity,  $E$ :**  
(also known as Young's modulus)
- **Hooke's Law:**

$$\sigma = E \epsilon$$

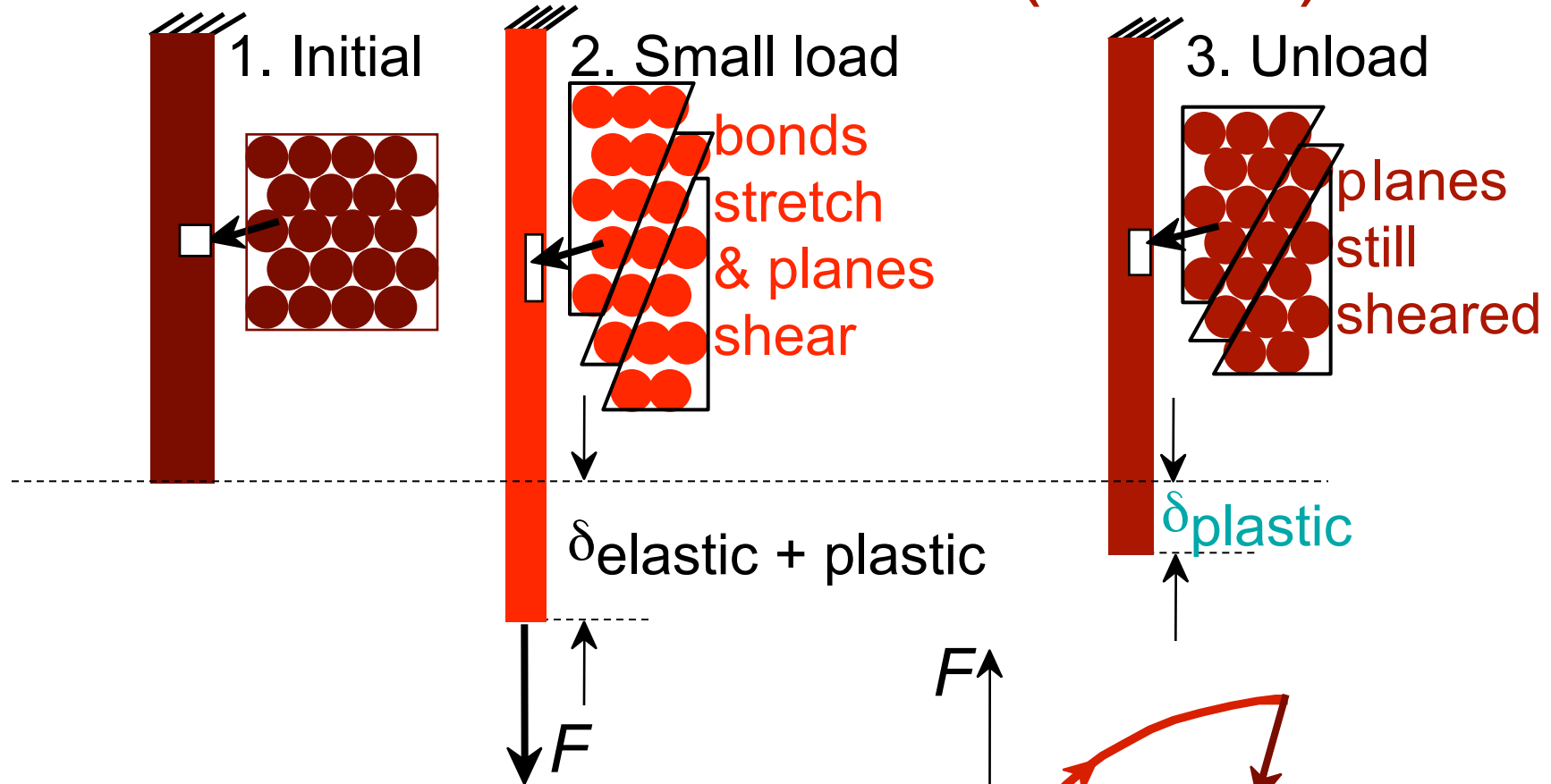


# Plastic deformation

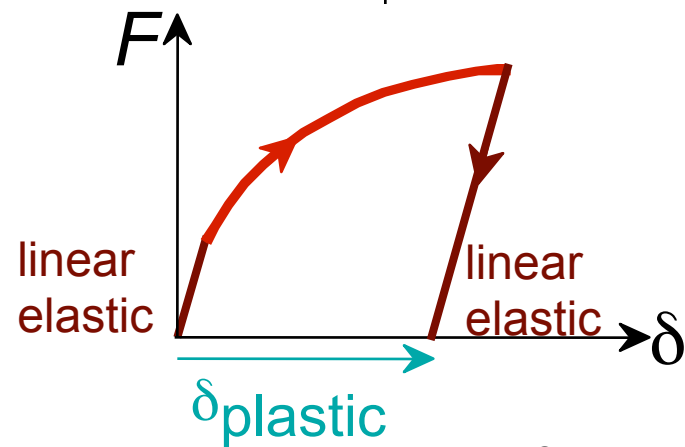
- Slip plane, direction and system, resolved shear stress
- Mechanism of plastic deformation
- Strengthening mechanisms
- Recovery, recrystallization, and grain growth



# Plastic Deformation (Metals)



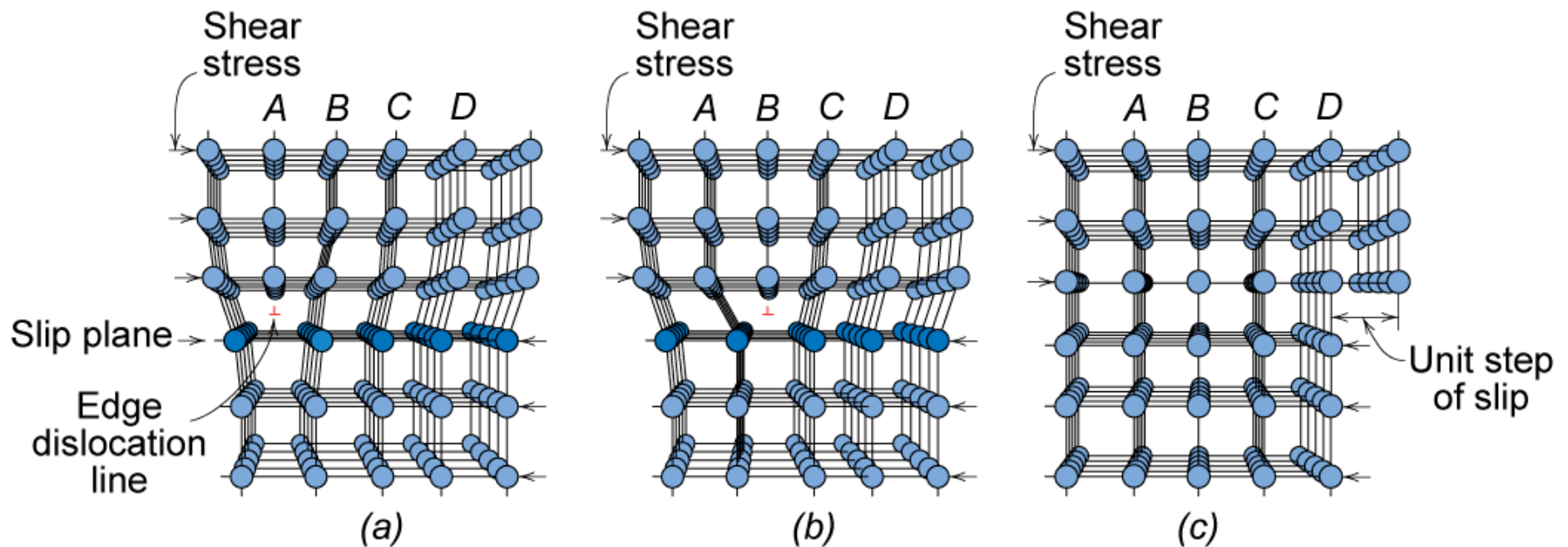
Plastic means **permanent!**



# Dislocation Motion

## Dislocations & plastic deformation

- Cubic & hexagonal metals - plastic deformation by **plastic shear or slip** where one plane of atoms slides over adjacent plane by defect motion (dislocations).



- If dislocations don't move, deformation doesn't occur!

Adapted from Fig. 7.1,  
Callister 7e.

Chapter 2 - 23



# Failure

- Ductile vs brittle fracture
- Stress concentrations and fracture toughness
- Creep and fatigue failure



## Aside: a touch of Thermodynamics

Enthalpy~ Internal Energy

↓

$$\Delta G = \Delta H - T\Delta S$$

↗ ↖

Gibb's free Energy      Entropy~ disorder~ probability

A transformation will occur spontaneously if  $\Delta G$  is negative.