FE Review Session

Materials Science

By

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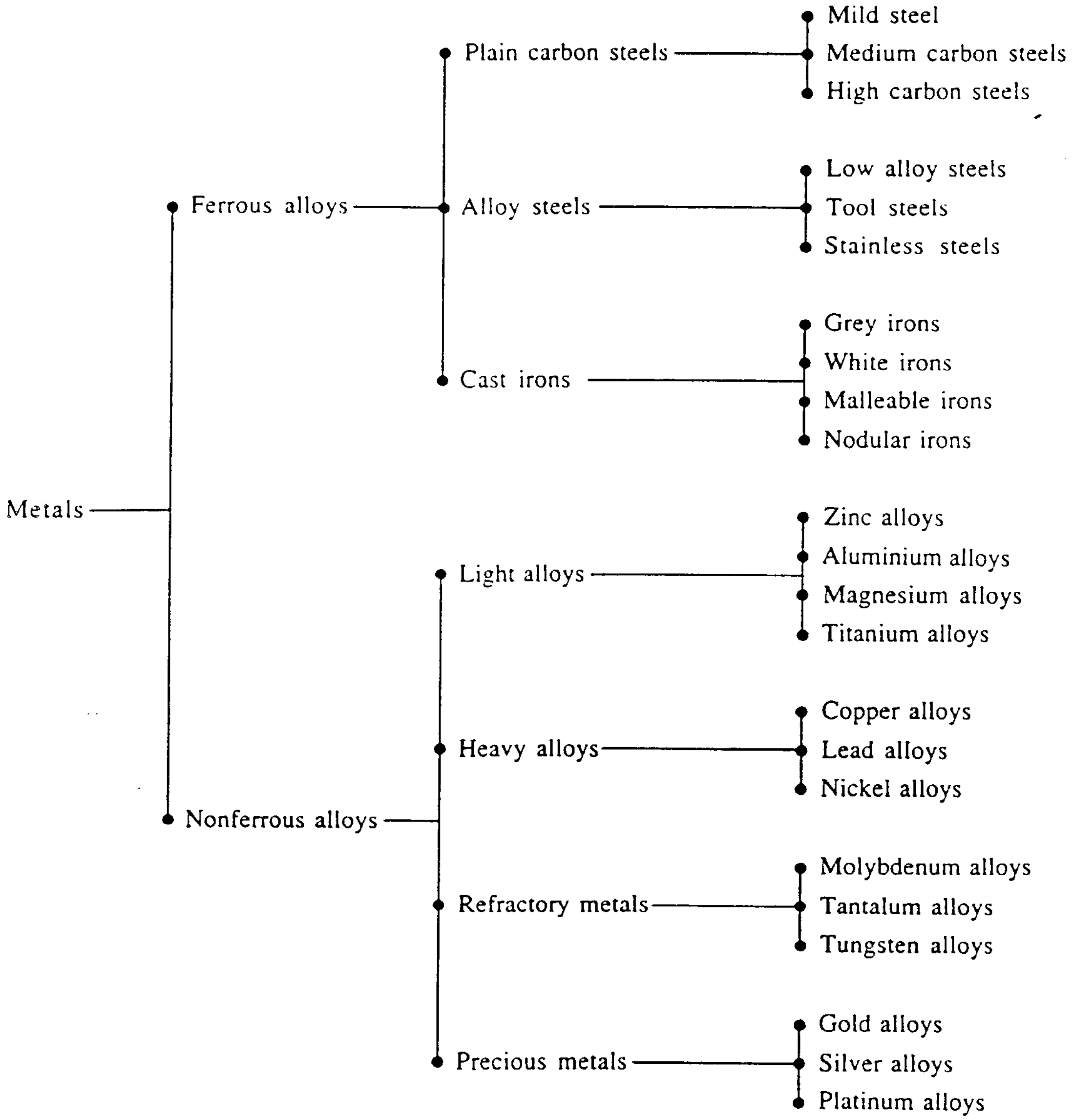
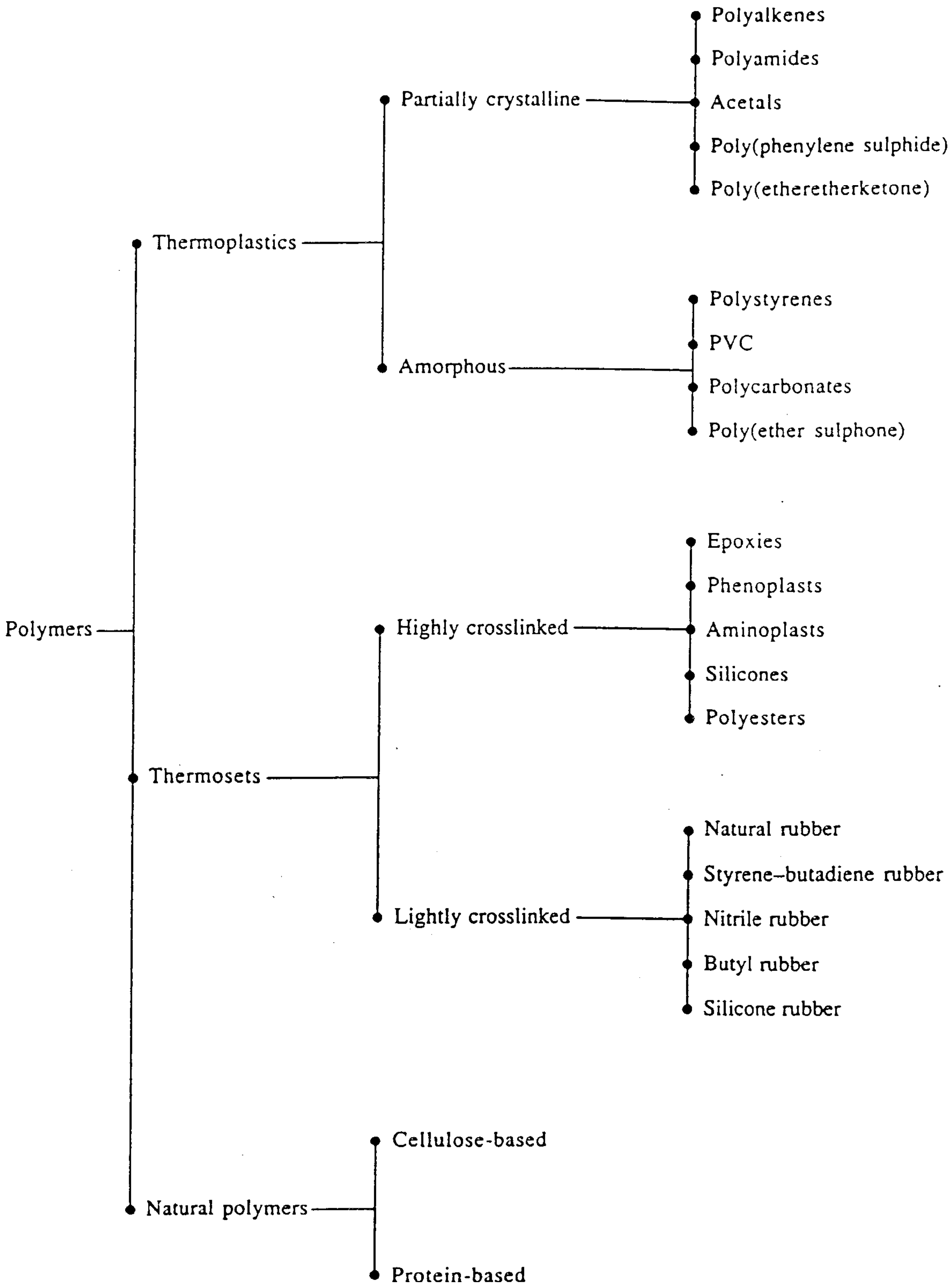
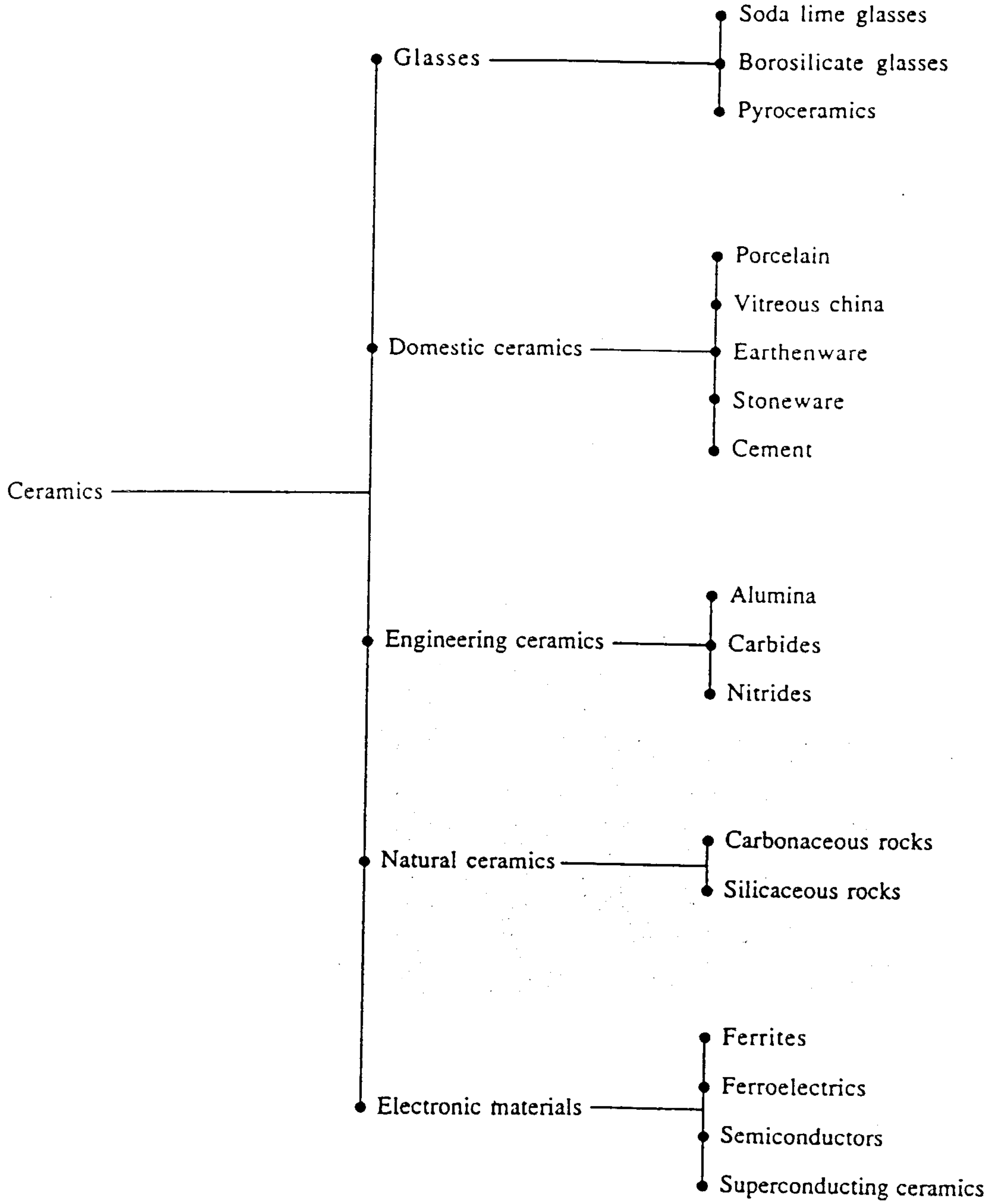
METALS HIERARCHY



POLYMERS HIERARCHY



CERAMICS HIERARCHY



- Ceramics
  - Glasses
    - Soda lime glasses
    - Borosilicate glasses
    - Pyroceramics
  - Domestic ceramics
    - Porcelain
    - Vitreous china
    - Earthenware
    - Stoneware
    - Cement
  - Engineering ceramics
    - Alumina
    - Carbides
    - Nitrides
  - Natural ceramics
    - Carbonaceous rocks
    - Silicaceous rocks
  - Electronic materials
    - Ferrites
    - Ferroelectrics
    - Semiconductors
    - Superconducting ceramics

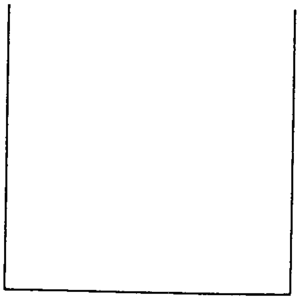
Corrosion

A. Requirements

1.

2.

3.



B. Anodic Reaction

C. Cathodic Reactions

1. Hydrogen reduction

2. O_2 reduction acid solution

3. O_2 reduction basic or neutral solution

3. D. EMF Table (p.61*[*])

Standard Oxidation Potentials for Corrosion Reactions*

Corrosion Reaction	Potential, E_o, Volts vs. Normal Hydrogen Electrode †
$Au \rightarrow Au^{3+} + 3e$	−1.498
$2H_2O \rightarrow O_2 + 4H^+ + 4e$	−1.229
$Pt \rightarrow Pt^{2+} + 2e$	−1.200
$Pd \rightarrow Pd^{2+} + 2e$	−0.987
$Ag \rightarrow Ag^+ + e$	−0.799
$2Hg \rightarrow Hg_2^{2+} + 2e$	−0.788
$Fe^{2+} \rightarrow Fe^{3+} + e$	−0.771
$4(OH)^- \rightarrow O_2 + 2H_2O + 4e$	−0.401
$Cu \rightarrow Cu^{2+} + 2e$	−0.337
$Sn^{2+} \rightarrow n^{4+} + 2e$	−0.150
$H_2 \rightarrow 2H^+ + 2e$	0.000
$Pb \rightarrow Pb^{2+} + 2e$	+0.126
$Sn \rightarrow Sn^{2+} + 2e$	+0.136
$Ni \rightarrow Ni^{2+} + 2e$	+0.250
$Co \rightarrow Co^{2+} + 2e$	+0.277
$Cd \rightarrow Cd^{2+} + 2e$	+0.403
$Fe \rightarrow Fe^{2+} + 2e$	+0.440
$Cr \rightarrow Cr^{3+} + 3e$	+0.744
$Zn \rightarrow Zn^{2+} + 2e$	+0.763
$Al \rightarrow Al^{3+} + 3e$	+1.662
$Mg \rightarrow Mg^{2+} + 2e$	+2.363
$Na \rightarrow Na^+ + e$	+2.714
$K \rightarrow K^+ + e$	+2.925

* Measured at 25°C. Reactions are written as anode half-cells. Arrows are reversed for cathode half-cells.

† In some chemistry texts, the signs of the values (in this table) are reversed; for example, the half-cell potential of zinc is given as −0.763 volt. The present convention is adopted so that when the potential E_o is positive, the reaction proceeds spontaneously as written.

Flinn, Richard A. and Paul K. Trojan, *Engineering Materials and Their Applications*, 4th Edition. Copyright © 1990 by Houghton Mifflin Company. Table used with permission.

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[*] Pages numbers listed are from the Fundamentals of Engineering Discipline Specific Reference Handbook.

Atomic Bonding

A. Primary Bonding

1.Metallic

2. Ionic

3.Covalent

B. Secondary

1. van derWaals or hydrogen bonding

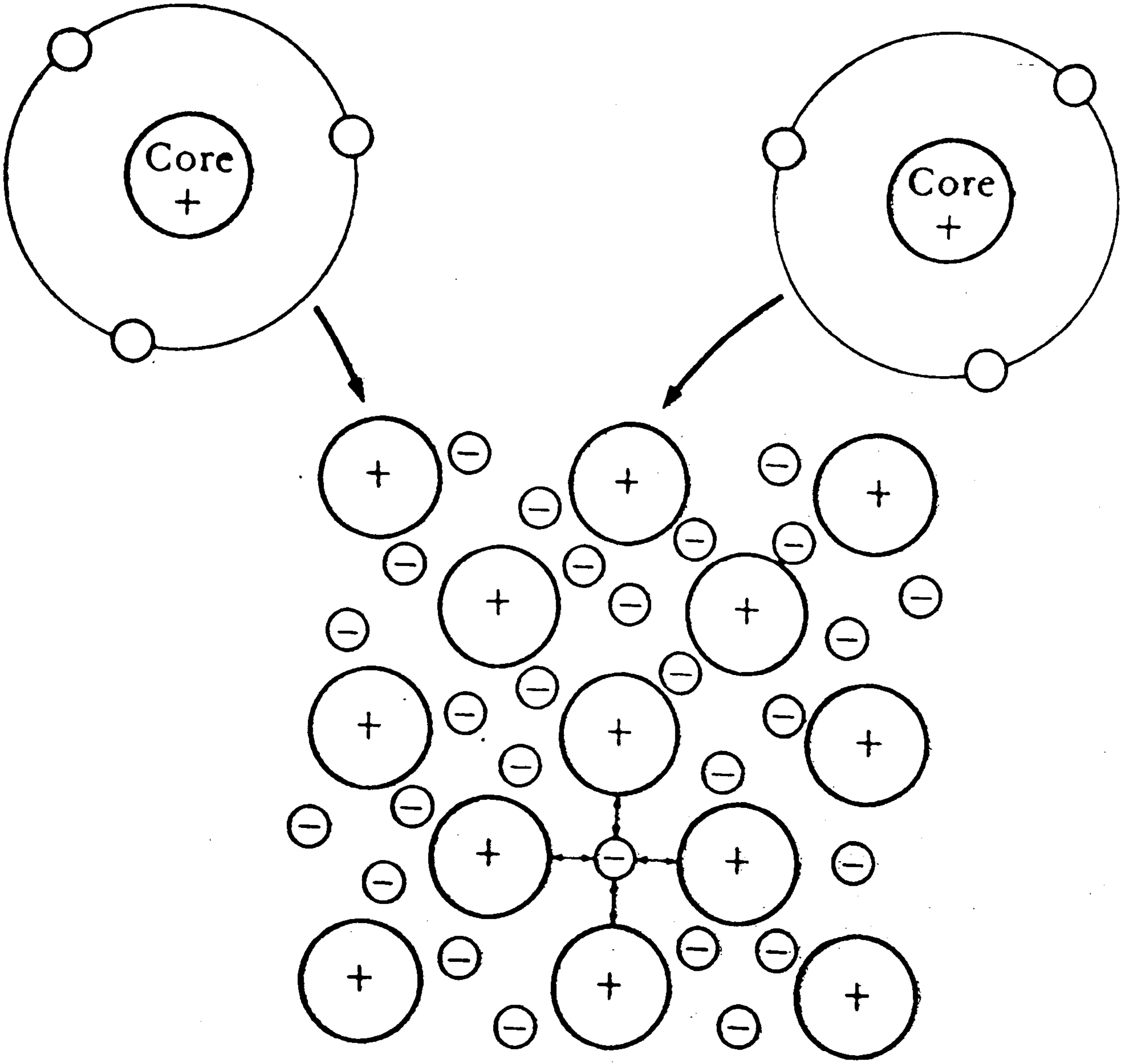


FIGURE 2-6 The metallic bond forms when atoms give up their valence electrons, which then form an electron sea. The positively charged atom cores are bonded by mutual attraction to the negatively charged electrons.

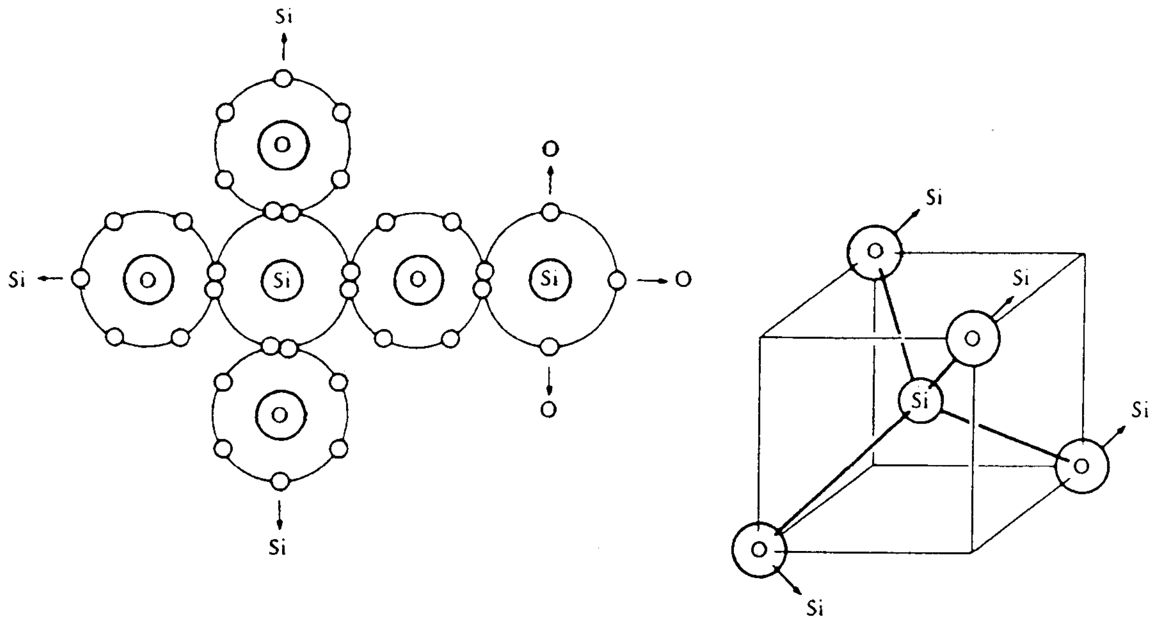


FIGURE 2-10 The tetrahedral structure of silica (SiO_2), which contains covalent bonds between silicon and oxygen atoms.

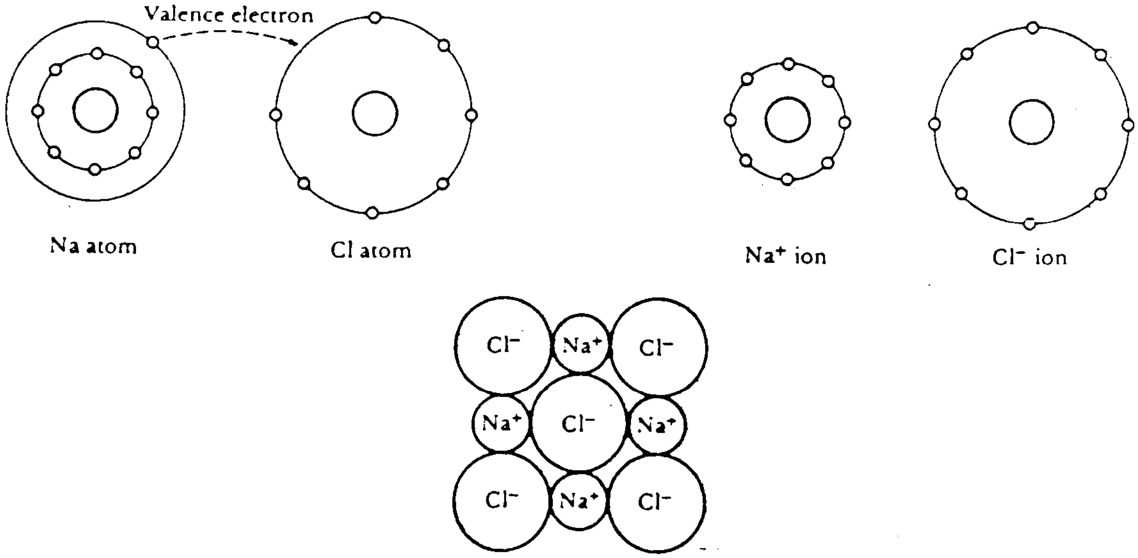


FIGURE 2-11 The ionic bond is created between two unlike atoms with different electronegativities. When sodium donates its valence electron to chlorine, each becomes an ion, attraction occurs, and the ionic bond is formed.

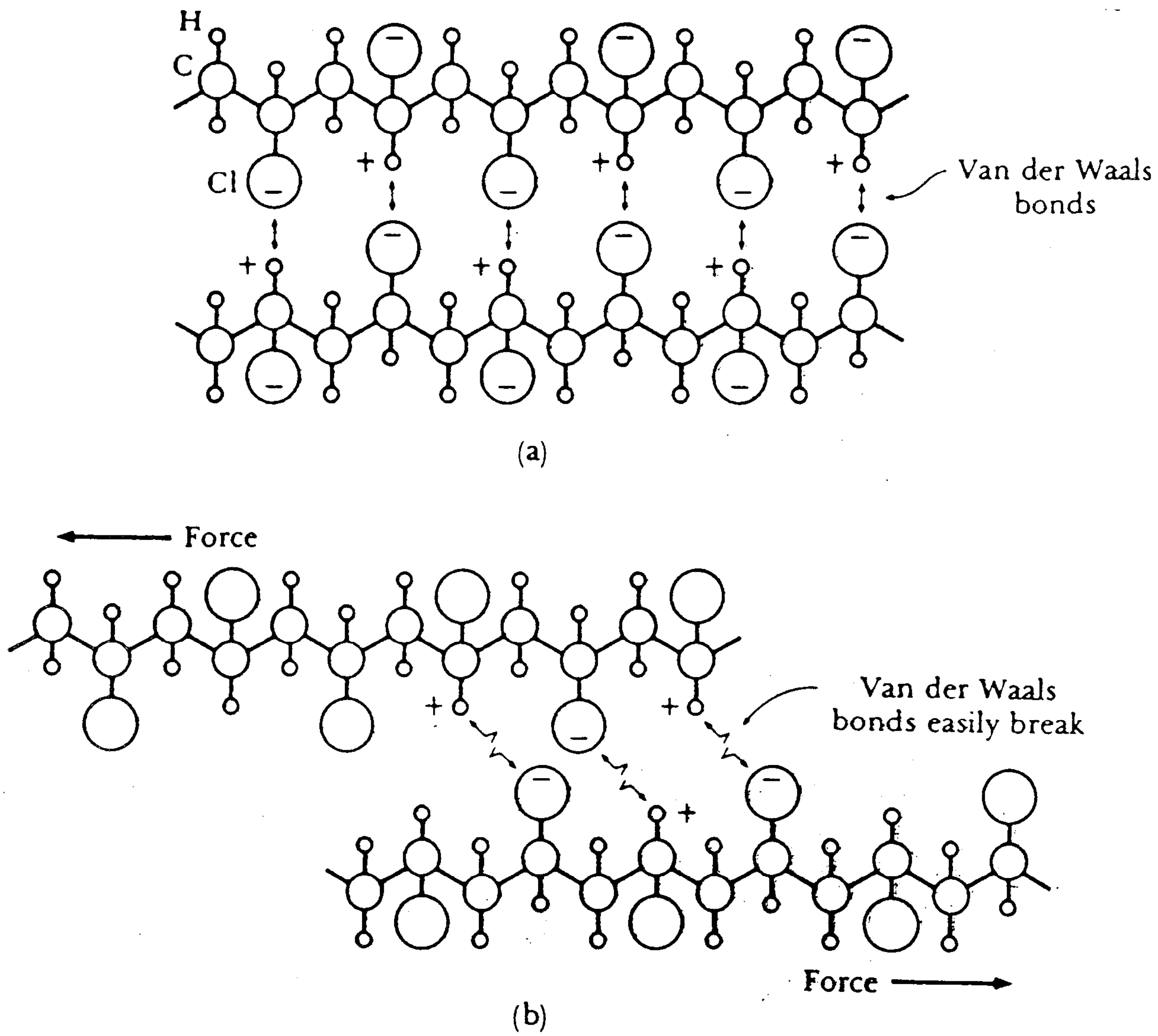
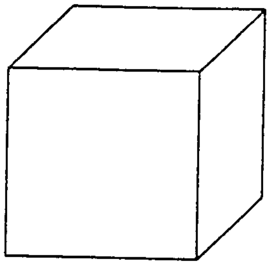


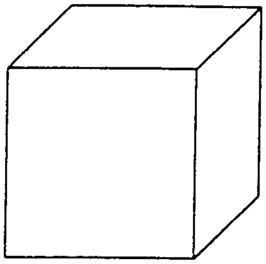
FIGURE 2-14 (a) In polyvinyl chloride, the chlorine atoms attached to the polymer chain have a negative charge and the hydrogen atoms are positively charged. The chains are weakly bonded by Van der Waals bonds. (b) When a force is applied to the polymer, the Van der Waals bonds are broken and the chains slide past one another.

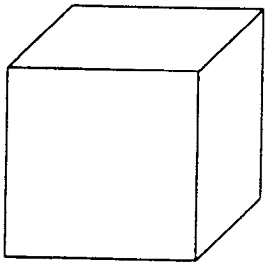
Crystallography

A. Crystal planes

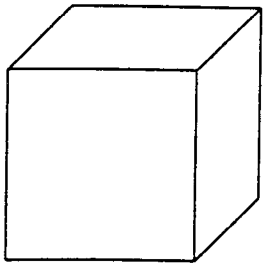
1. Miller Indices

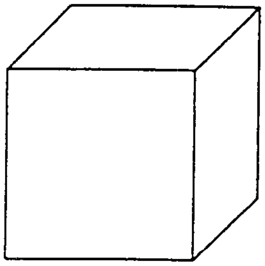


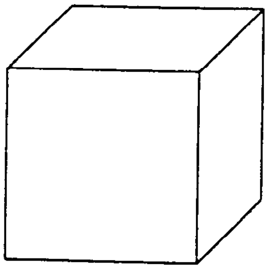




B. Directions

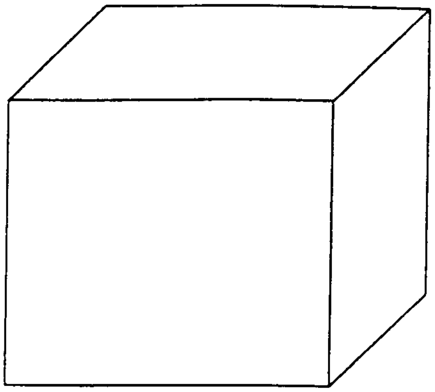






Crystallography

A. bcc



r = f(a)

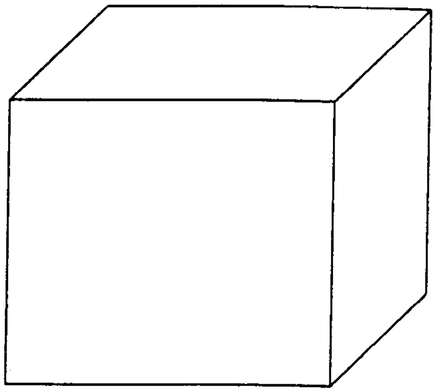
1. atoms/unit cell

2. coordination number (CN)

3. packing factor

Crystallography

B. fcc



r = f(a)

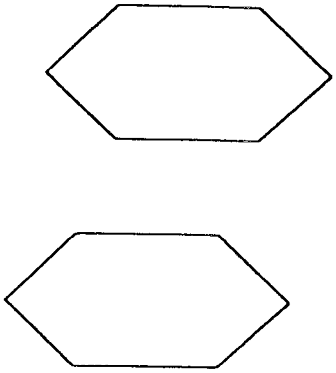
3. atoms/unit cell

4. coordination number (CN)

3. packing factor

Crystallography

C. hcp



r = f(a)

5. atoms/unit cell

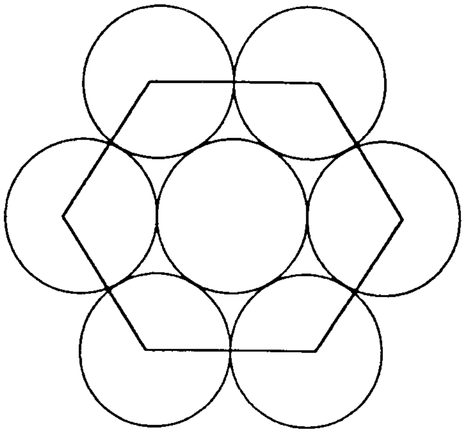
6. coordination number (CN)

3. packing factor

Crystallography

A. Density

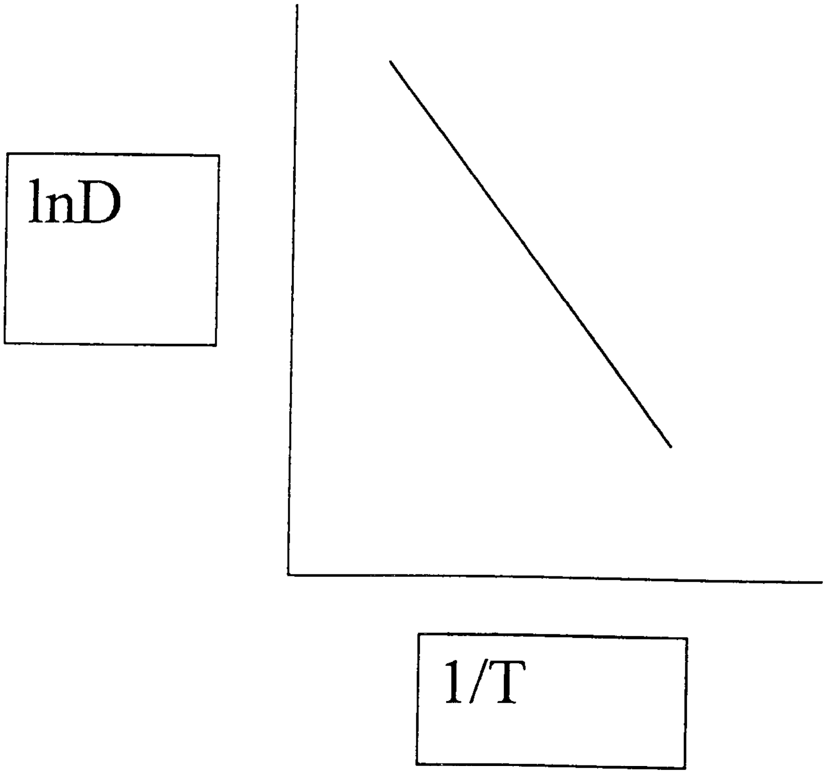
B. Close packed plane and close packed directions



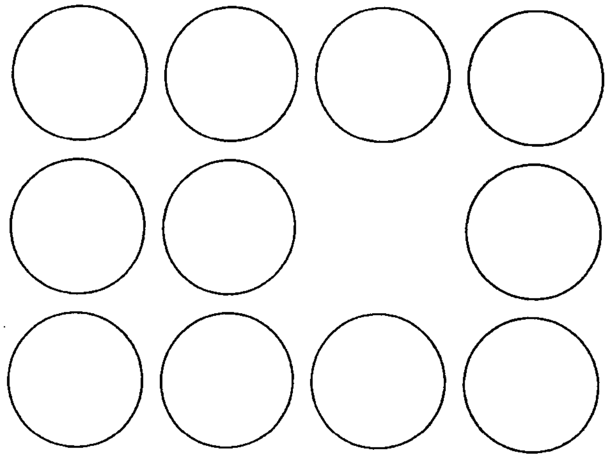
Diffusion (Thermally Activated Process)

$$Rate \propto \left(e^{-\frac{Q}{RT}}\right)$$

$$D = D_0\left(e^{-\frac{Q}{RT}}\right)$$



1. vacancy



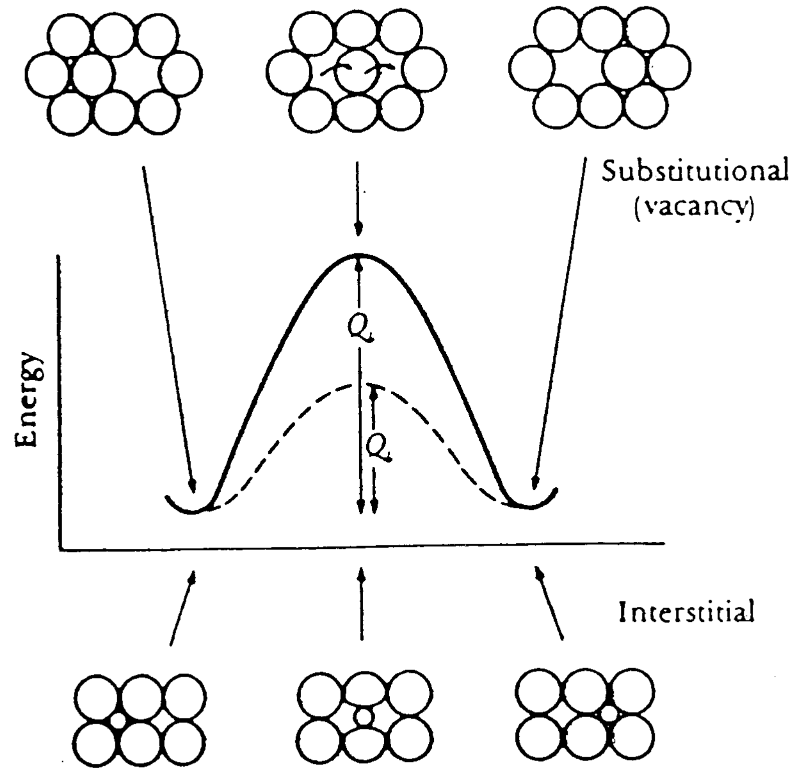
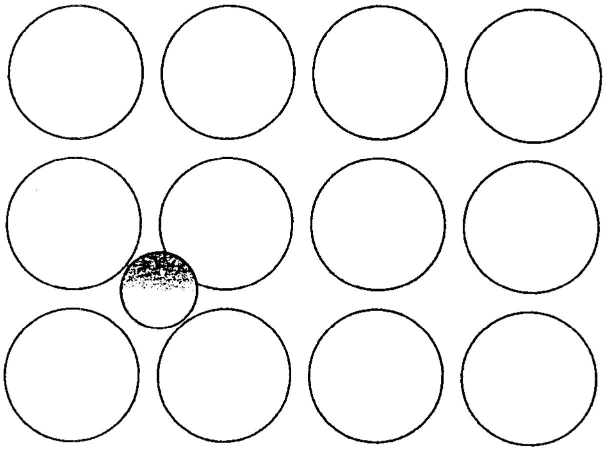


FIGURE 5-4 As atoms squeeze past one another during diffusion, a high energy is required. This energy is the activation energy Q. Generally more energy is required for a substitutional atom than for an interstitial atom.

2. interstitial



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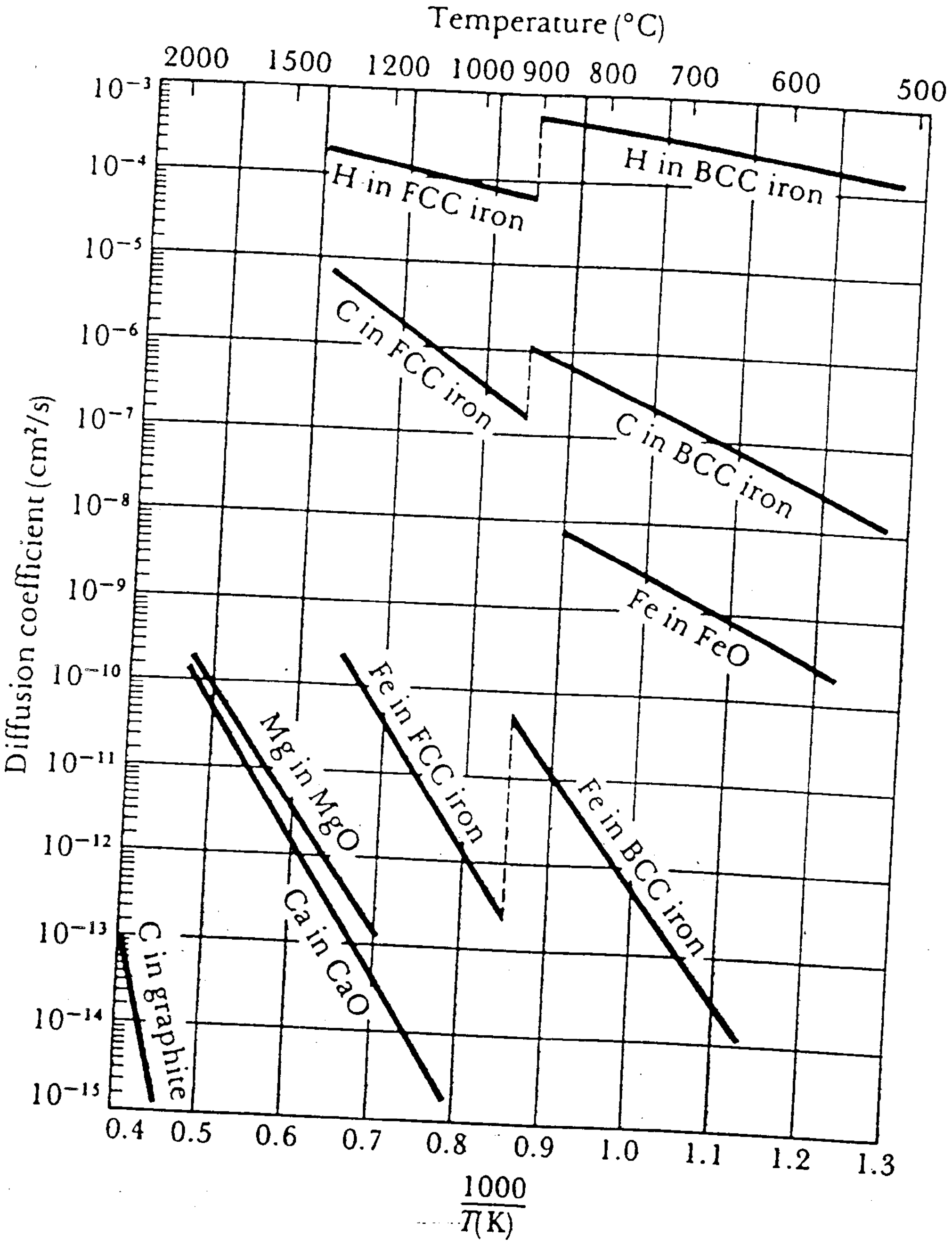
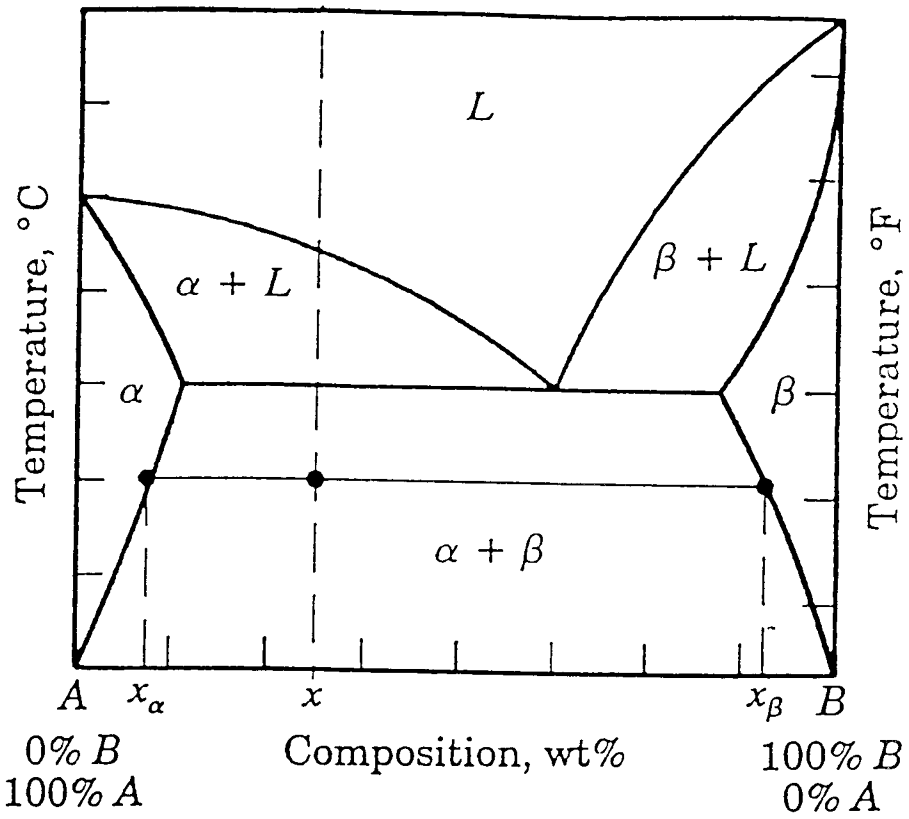


FIGURE 5-7 The diffusion coefficient **D** as a function of reciprocal temperature for several metals and ceramics. In this Arrhenius plot, **D** represents the rate of the diffusion process.

Phase Diagrams

A. Eutectic diagrams

Eutectic reaction



B. Gibb's Phase Rule

P + F = C + 2

For solids, pressure generally can be ignored and the Gibb's phase rule may be written as:

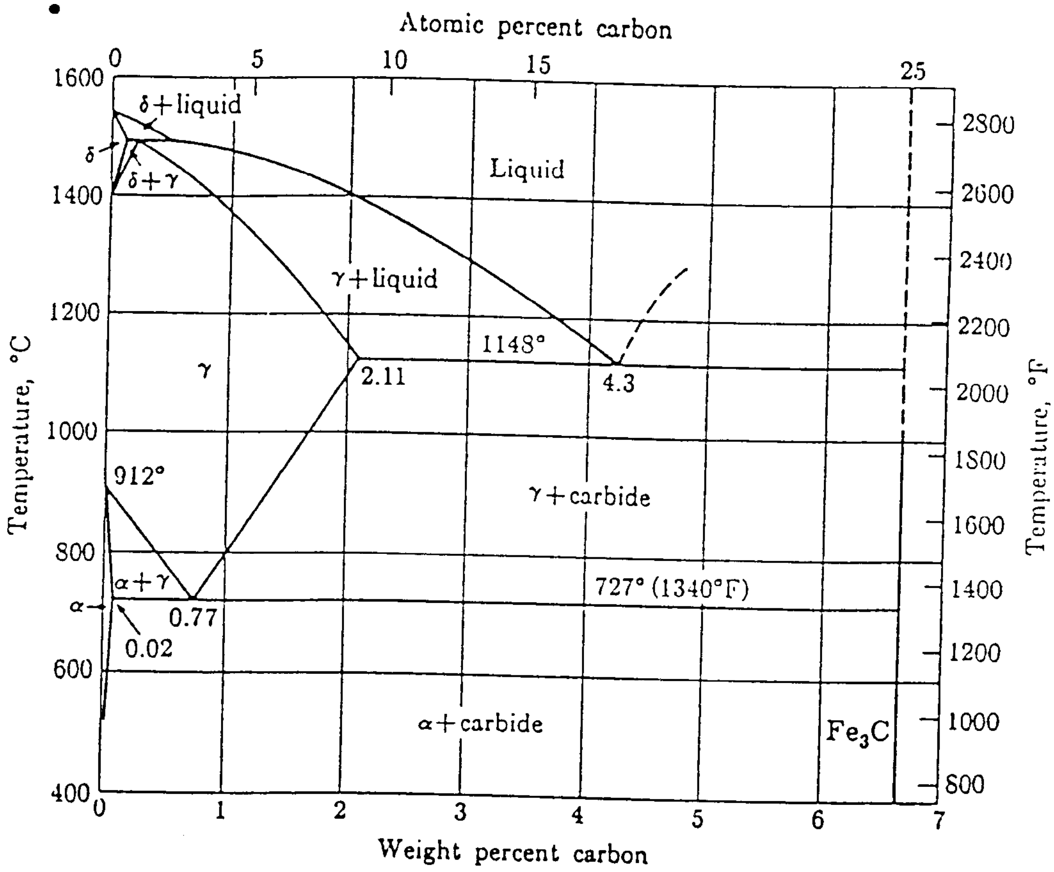
F = C - P + 1

Phase Diagrams

A. Eutectoid diagrams

Iron-Iron Carbide Phase Diagram

-



Eutectoid reaction

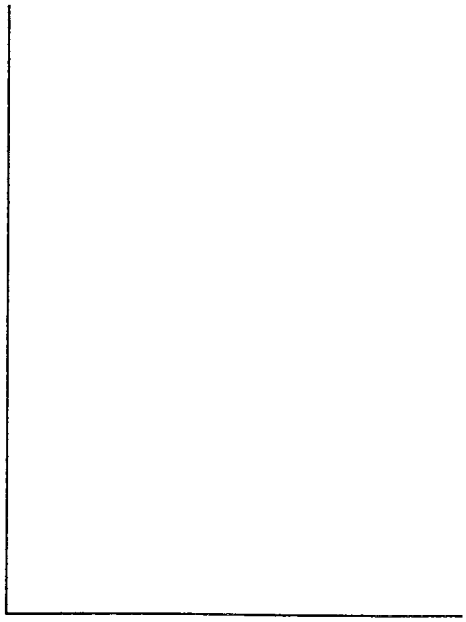
Peritectic reaction

Peritectoid reaction

Thermal Processing

A. Cold working (strain or work hardening)

$T < 1/3T_{M.Pt.}$



B. Annealing

1. Recovery

2. Recrystallization

3. Grain growth

Figure 3.15 The effects of different amounts of cold work on mechanical properties [Lawrence Van Vlack, *Elements of Materials Science*, fig. 6.26, © 1964, Addison-Wesley Publishing Co., Inc., Reading, Massachusetts. Reprinted with permission of the publisher]

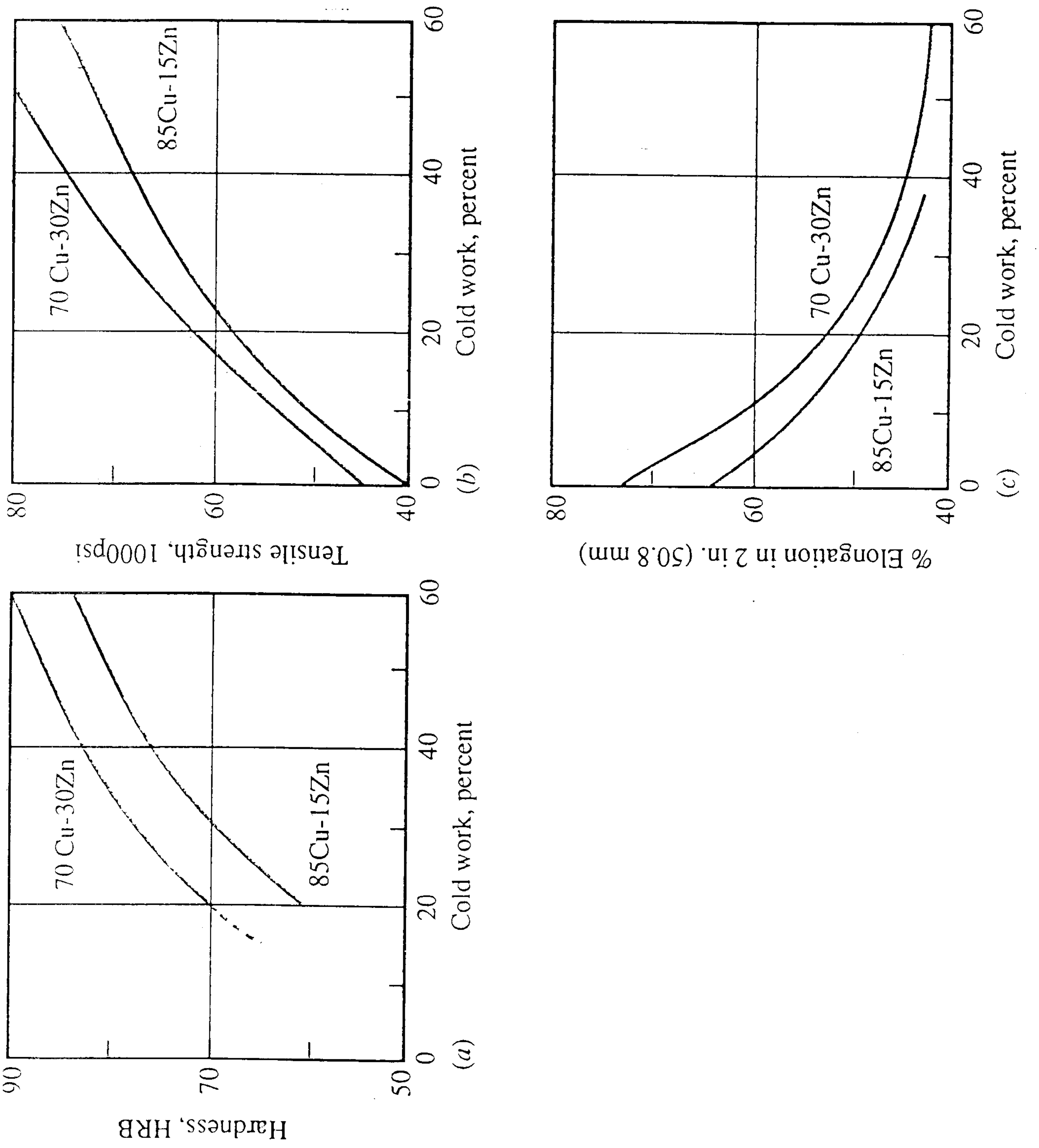
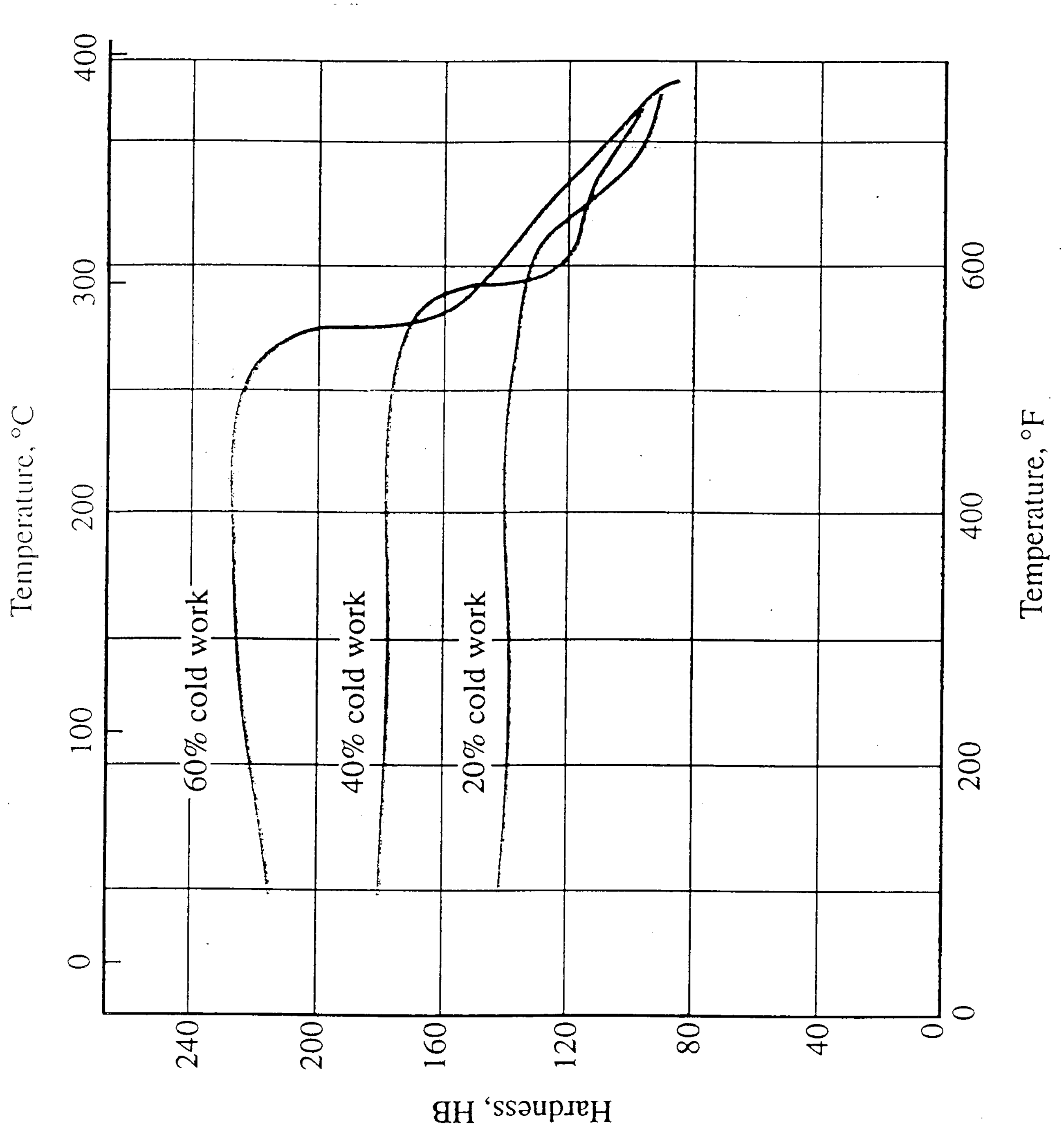


Figure 3.9 Effect of heating on hardness of cold-worked 65% Cu, 35% Zn brass, 1 hr. [Lawrence Van Vlack, *Elements of Materials Science*, fig. 6.28, © 1964, Addison-Wesley Publishing Co., Inc., Reading, Massachusetts. Reprinted with permission of the publisher]



C. Heat treatment

1. Quenched and Tempered

Austenitize

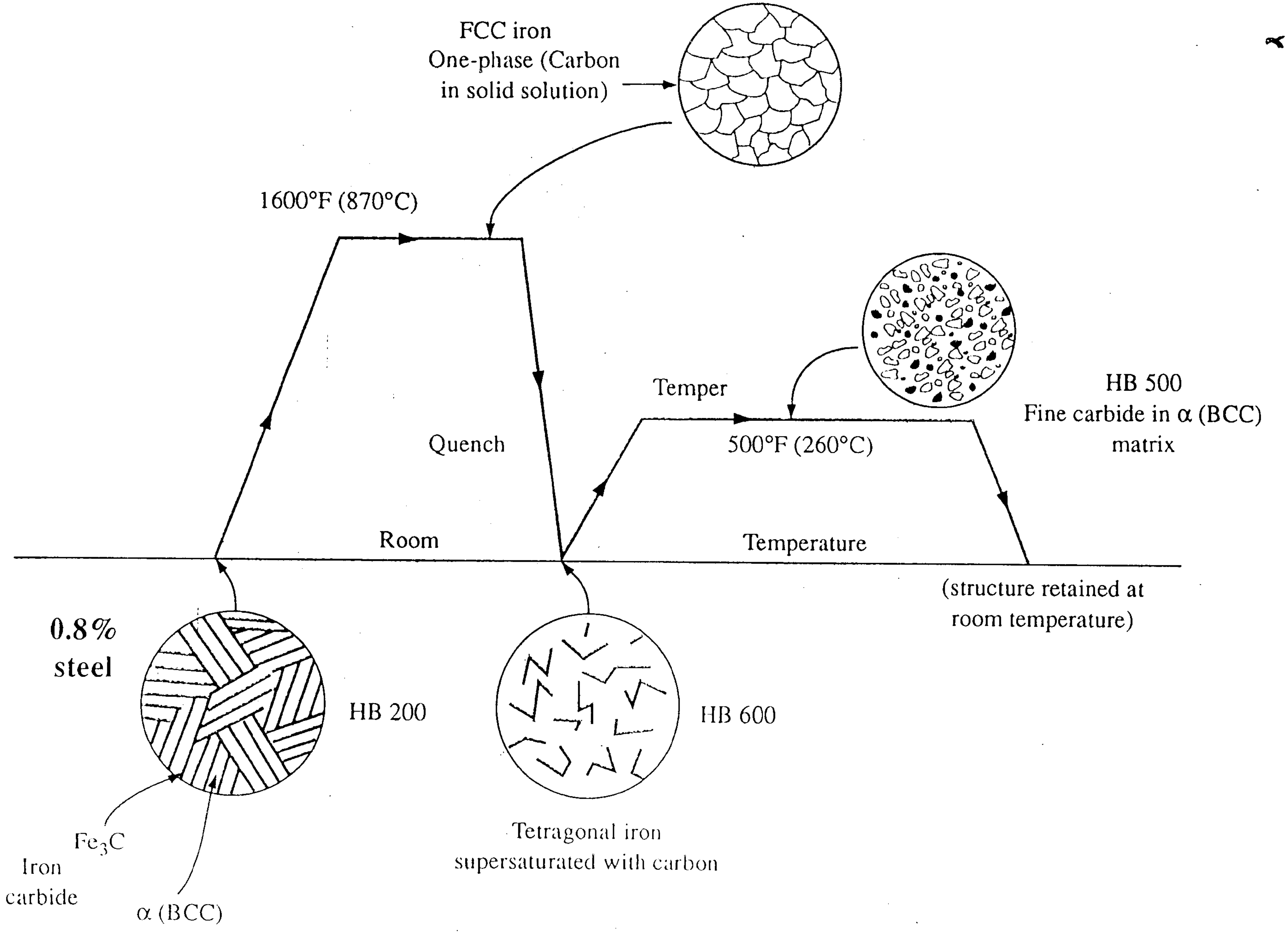
Quench

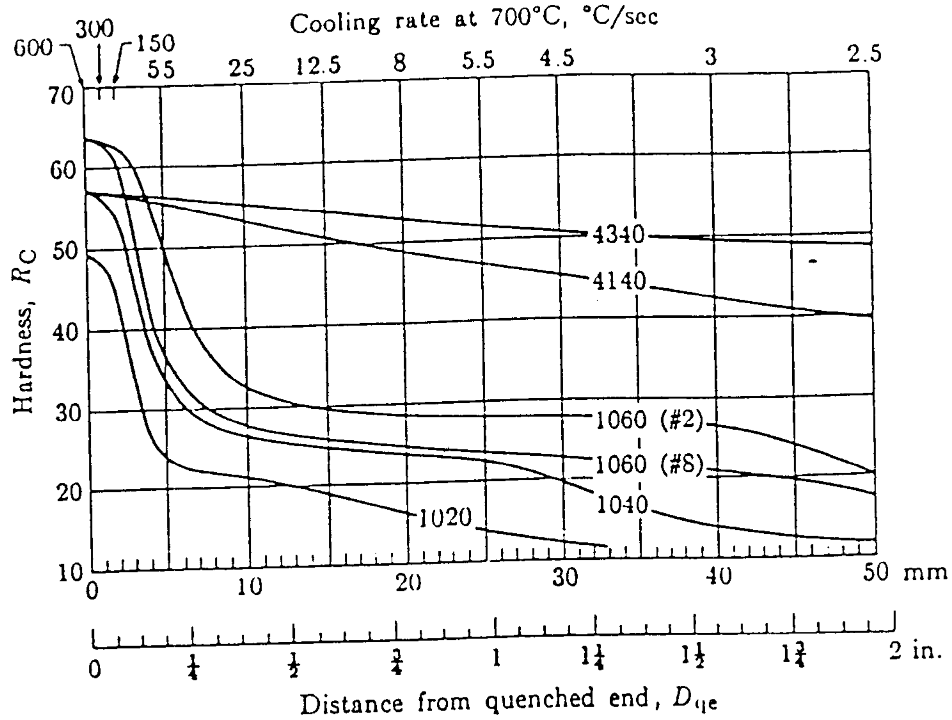
Temper

2. Hardenability

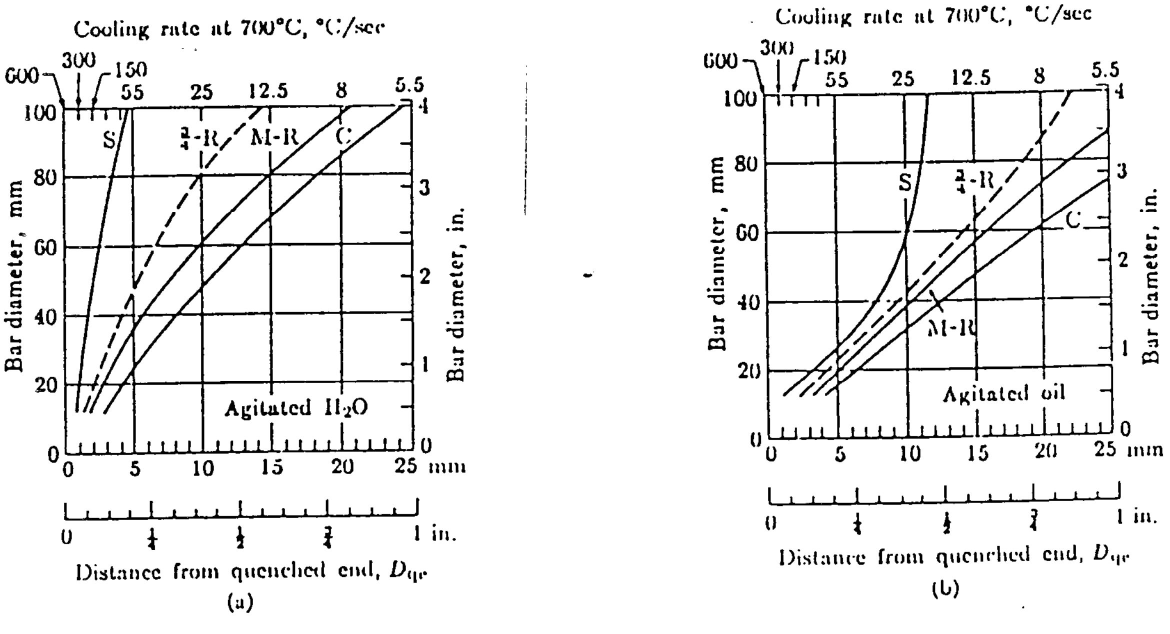
Jominy Hardenability Curve

Figure 5.1 Schematic diagram of a thermal treatment for a 0.8% carbon steel





(#2) and (#8) indicate grain size
Hardenability Curves For Six Steels



(a)

(b)

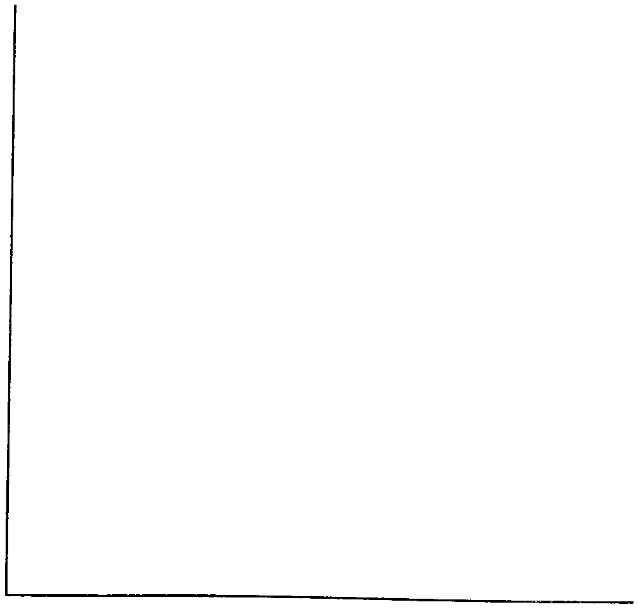
Cooling Rates For Round Bars Quenched in
(a) Agitated Water and (b) Agitated Oil.

3. Precipitation Hardening

Solution treatment

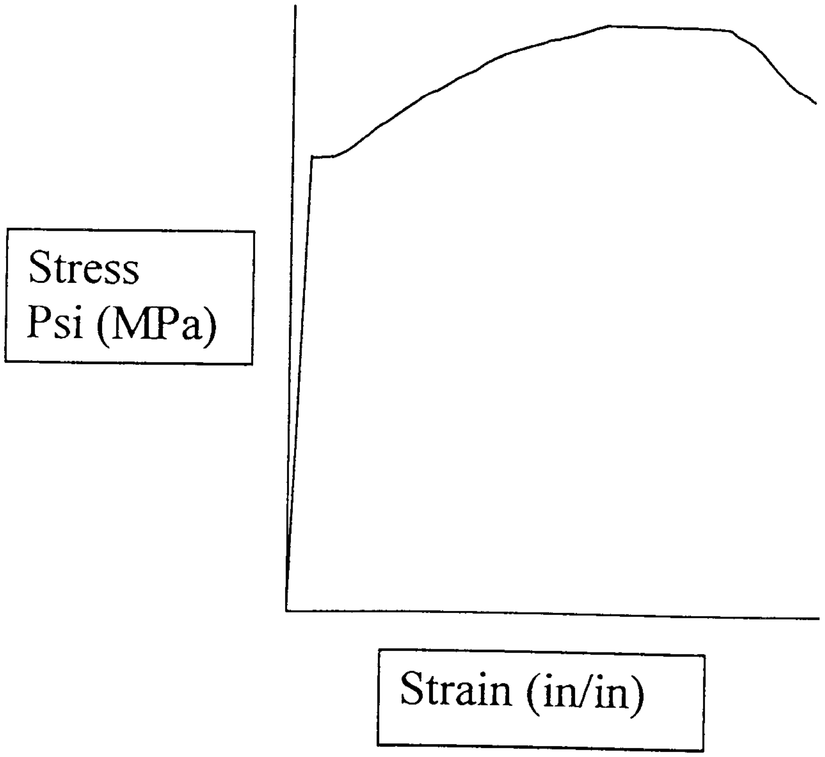
Quenching

Aging



Mechanical Testing

A. Tensile Test



E, Modulus of Elasticity

Yield strength

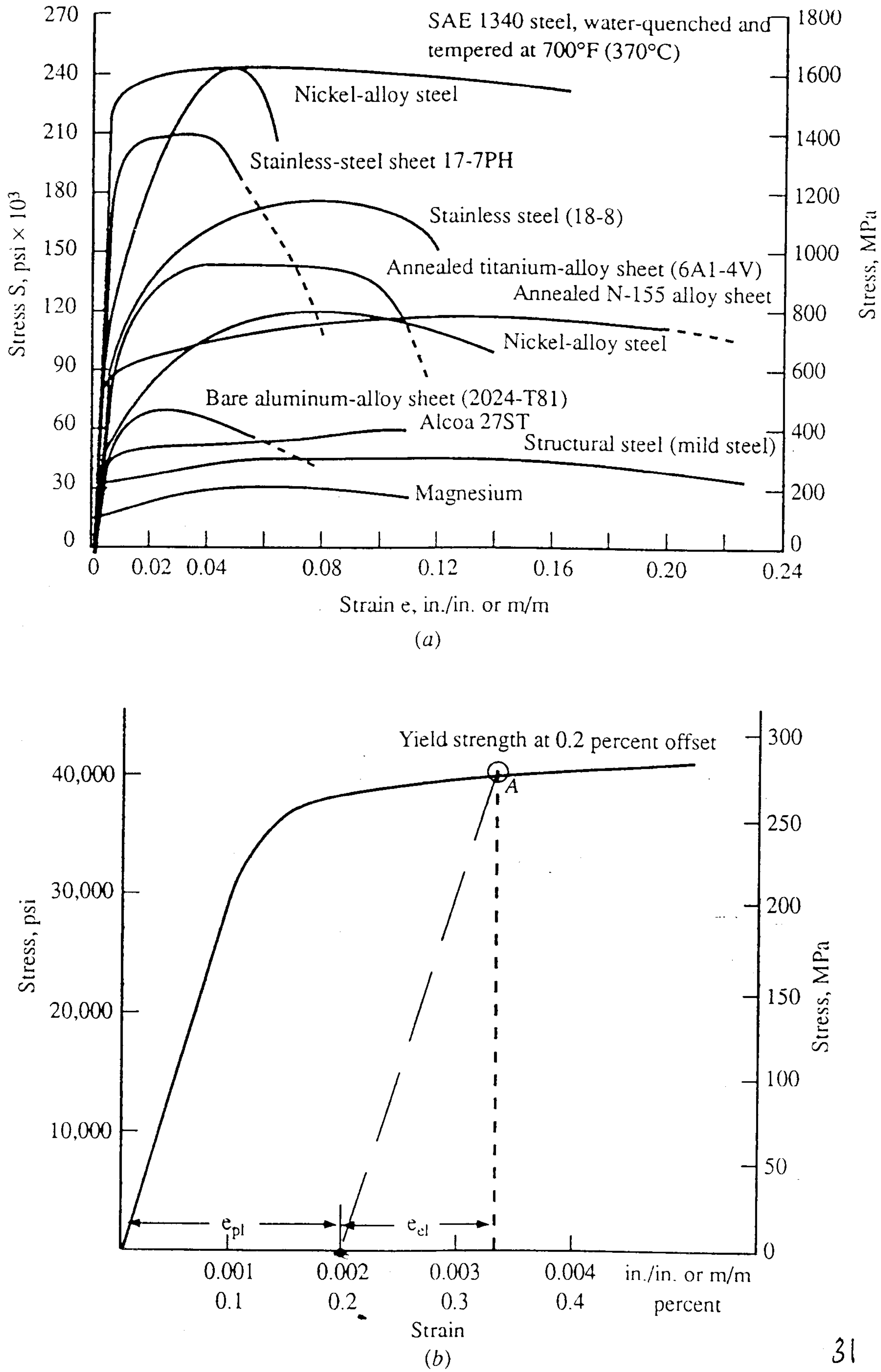
- 0.2% YS

Tensile Strength (Ultimate Tensile Strength)

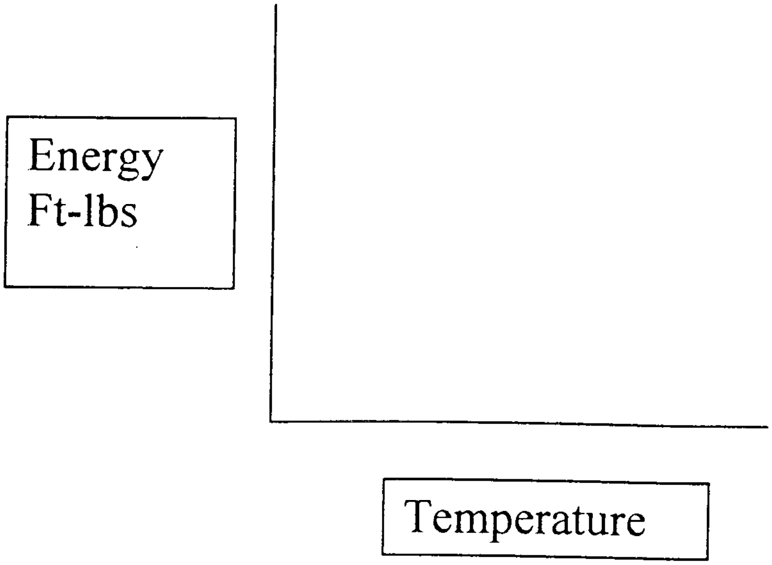
Ductility

- %Elongation
- %Reduction in Area

Figure 2.8 (*a*) Stress-strain curves for various alloys. (*b*) Details of an engineering stress-strain curve for mild steel (0.3% carbon) [Part (*a*) from J. Marin, *Mechanical Behavior of Engineering Materials*, © 1962, pp. 24, Reprinted by permission of Prentice-Hall, Inc., Englewood Cliffs, N.J.]

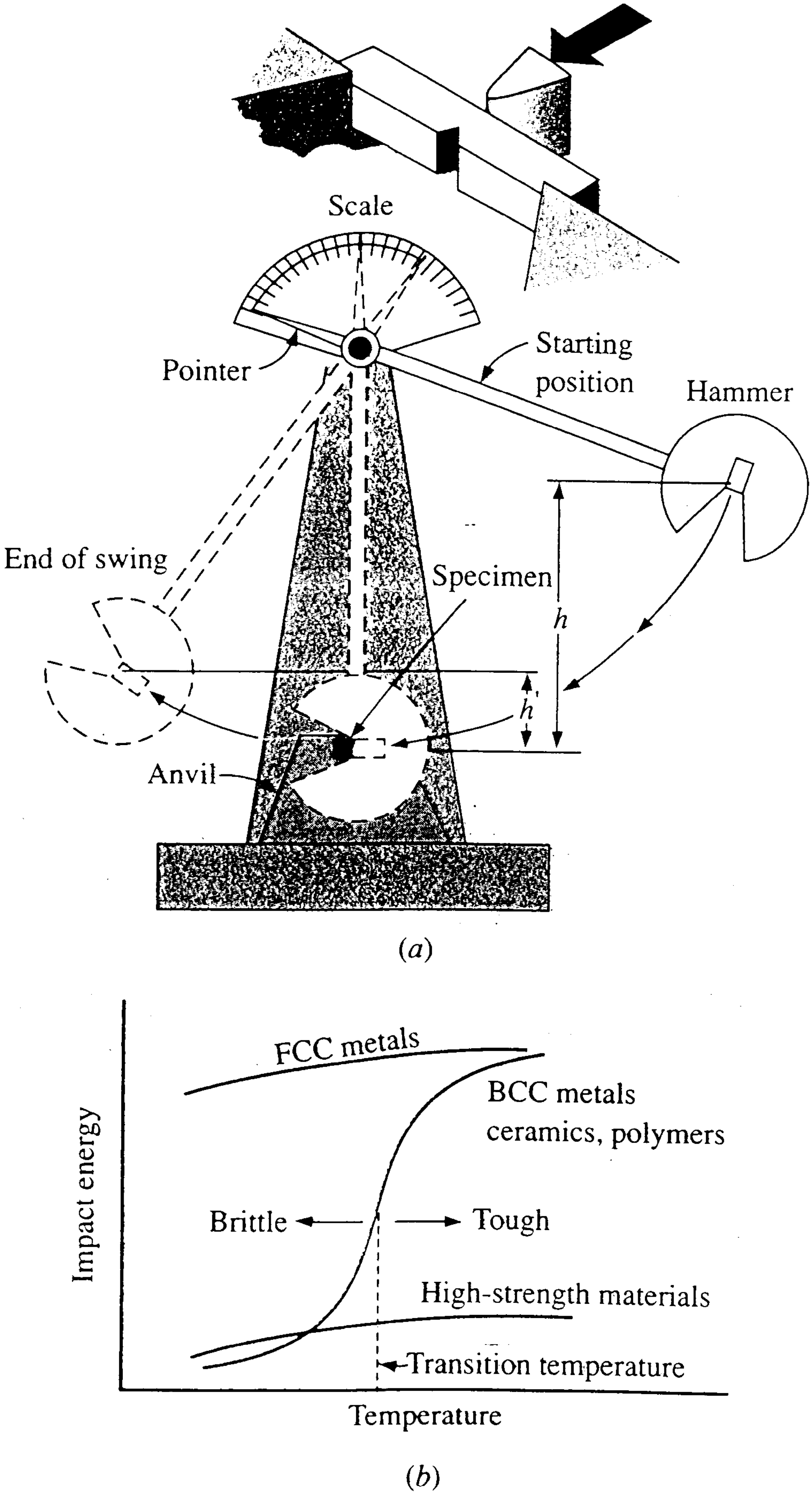


B. Impact Test



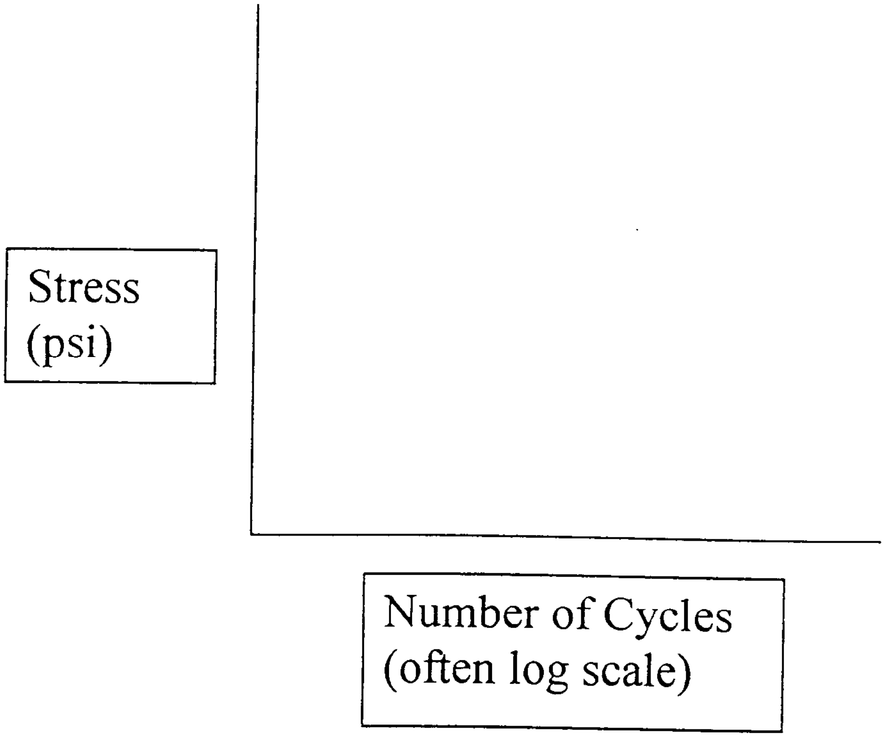
DBTT

Figure 3.6 (*a*) Operation of a Charpy impact test. (*b*) Effect of temperature on the impact strength of various materials (schematic) [Part (*a*) from H.W. Hayden, W.G. Moffatt, and John Wulff, *The Structure and Properties of Materials*, Vol. 3: *Mechanical Behavior*, John Wiley & Sons, New York, 1965]



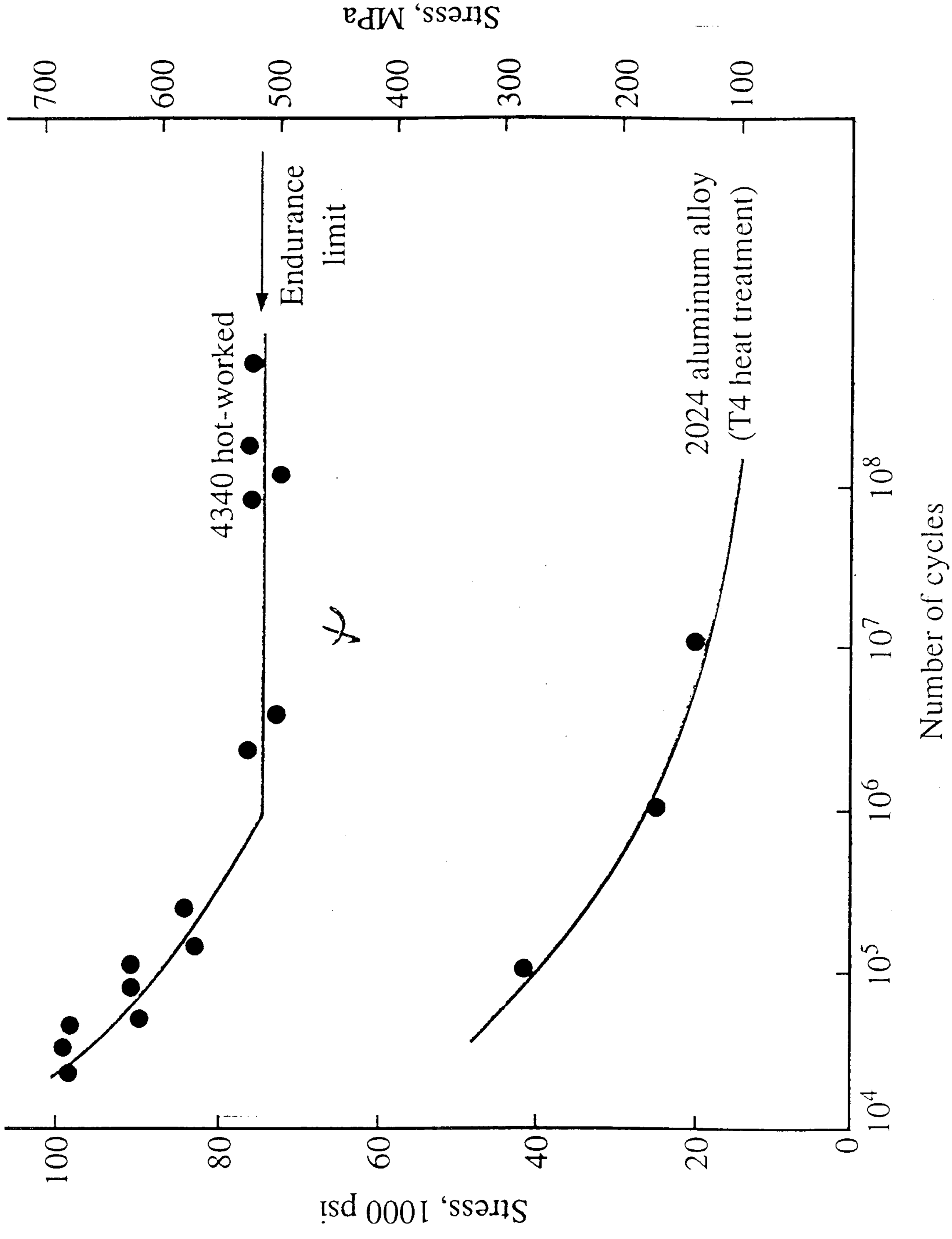
C. Fatigue Test (Endurance Test)

S-N approach



Flinn/Trojan: *Engineering Materials and Their Applications*, Fourth Edition

Figure 2.29 Typical S-N curves for ferrous and nonferrous alloys [Courtesy of H. Mindlin, Battelle]



ASTM Grain Size

A. Surface area: $S_v = 2P_L$

B. Grain size: $N_{(0.0645\ \mathrm{mm}^2)} = 2^{n-1}$

$$\bar{l} = l / n\ (M)$$

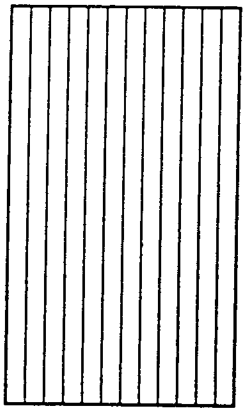
Composite Materials

A. Rule of Mixtures

$$\rho = \Sigma f_i \rho_i$$

$$c = \Sigma f_i c_i$$

$$E = \Sigma f_i E_I$$



parallel

perpendicular