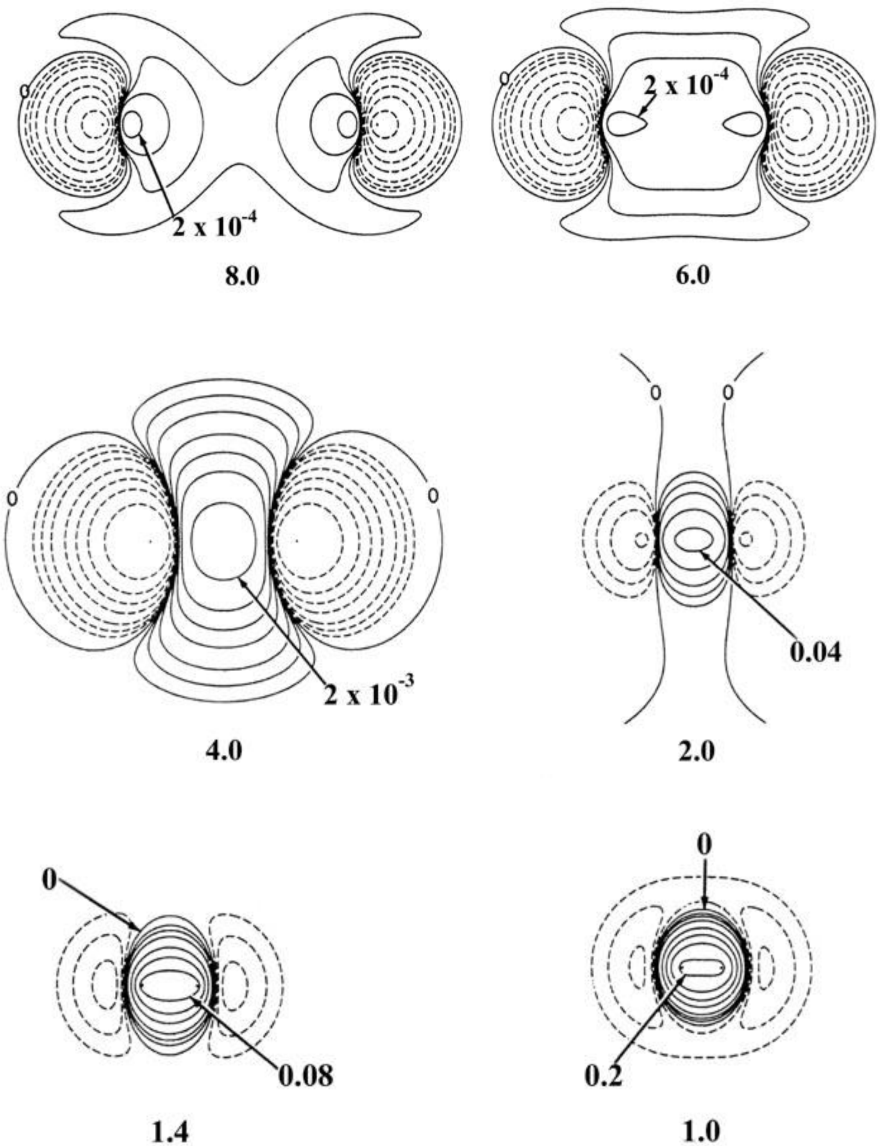
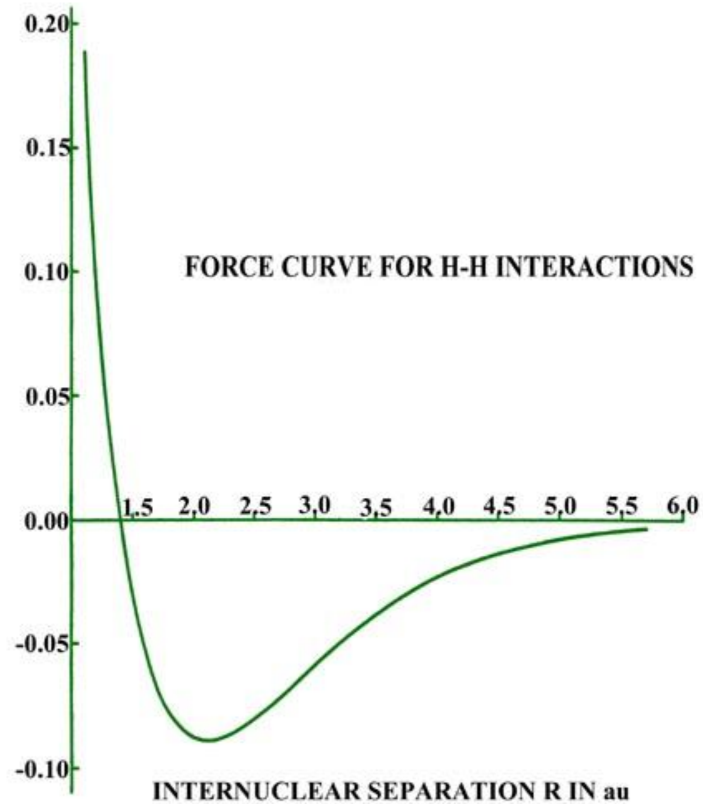
Scope of the Lecture

1. Molecular gain media
2. Vibronic, vibrational and rotational transitions
3. Energy bands in bulk semiconductor
4. Bulk density of states
5. Electron concentration
6. Selection rules for electronic transition in semiconductor
7. Absorption and emmision
8. Necessary condition for gain
9. Recombination channels
10. Electronic states in quantum wells
11. Quantum wires, quantum dots

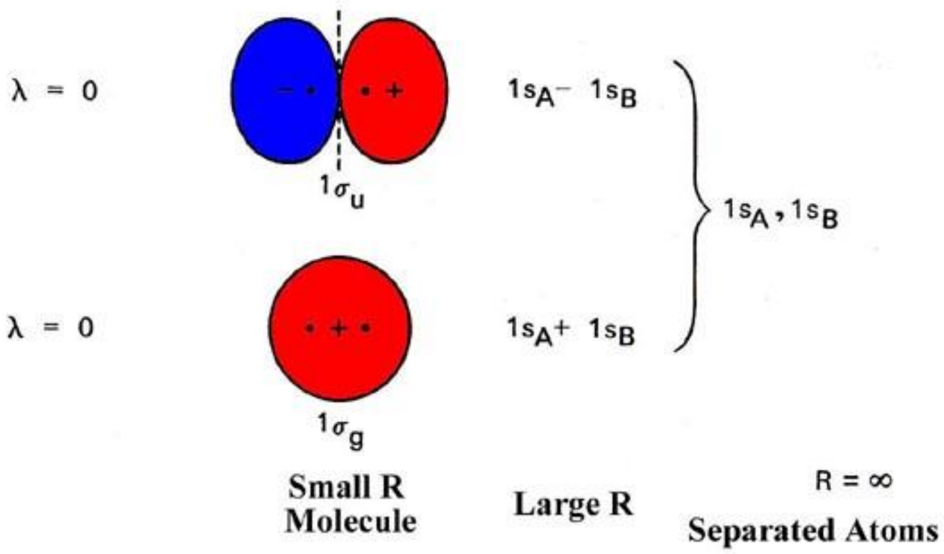
Reading: Ch. 3

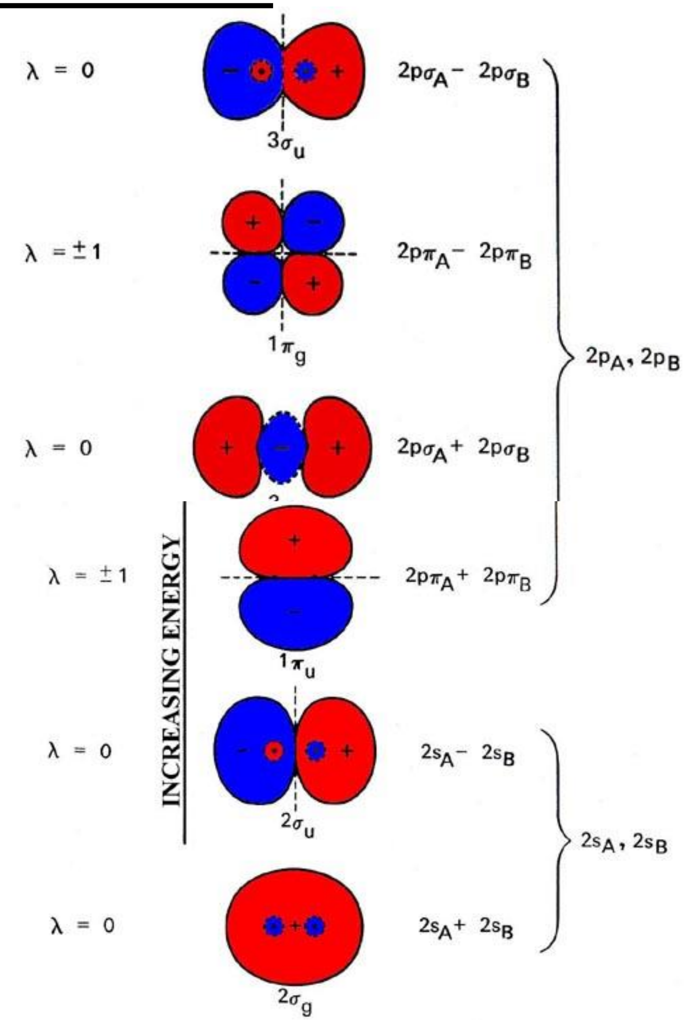
Formation of H_2

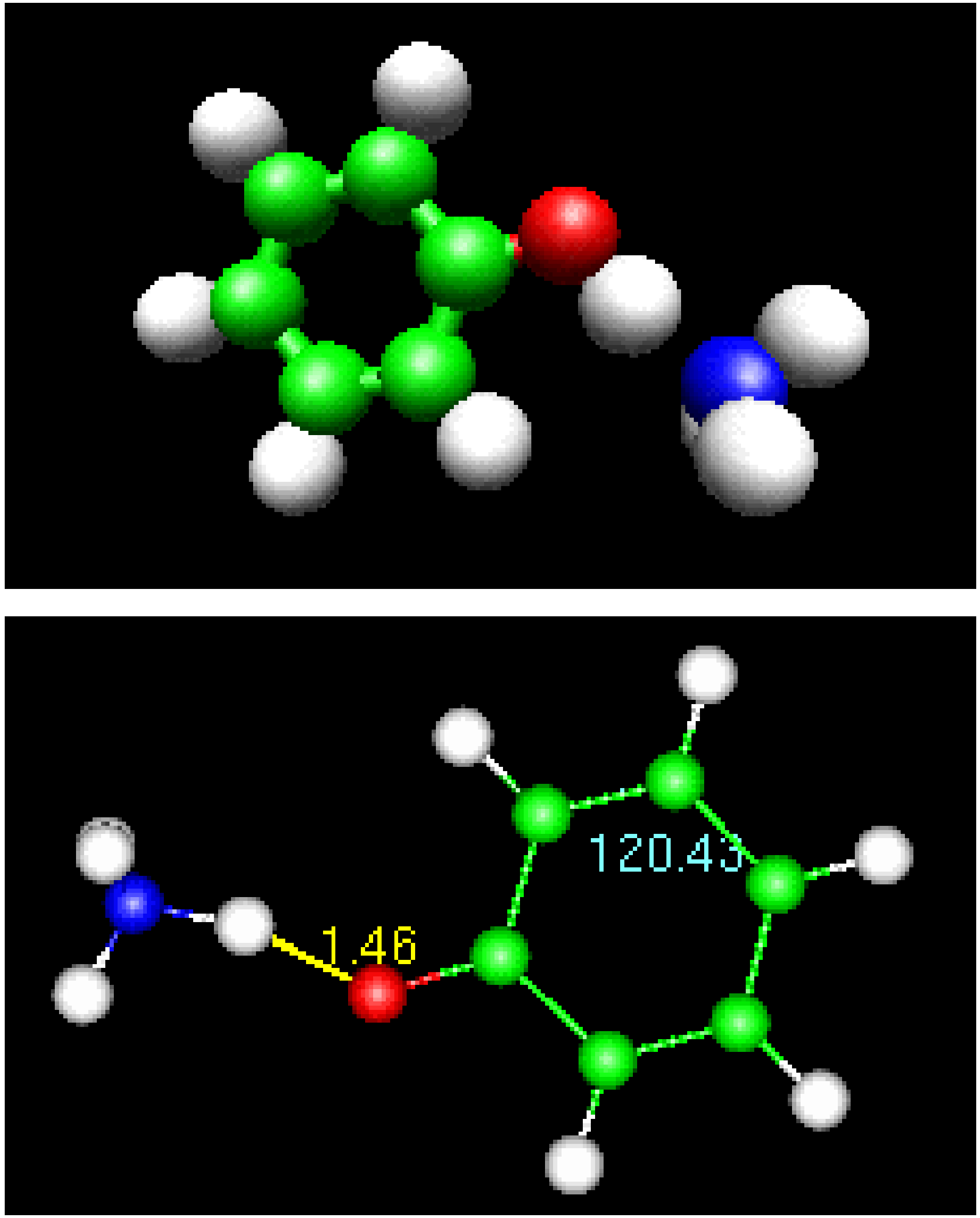




Orbitals in homonuclear diatomic molecules






1.46
120.43

Electronic levels in N_2 molecule

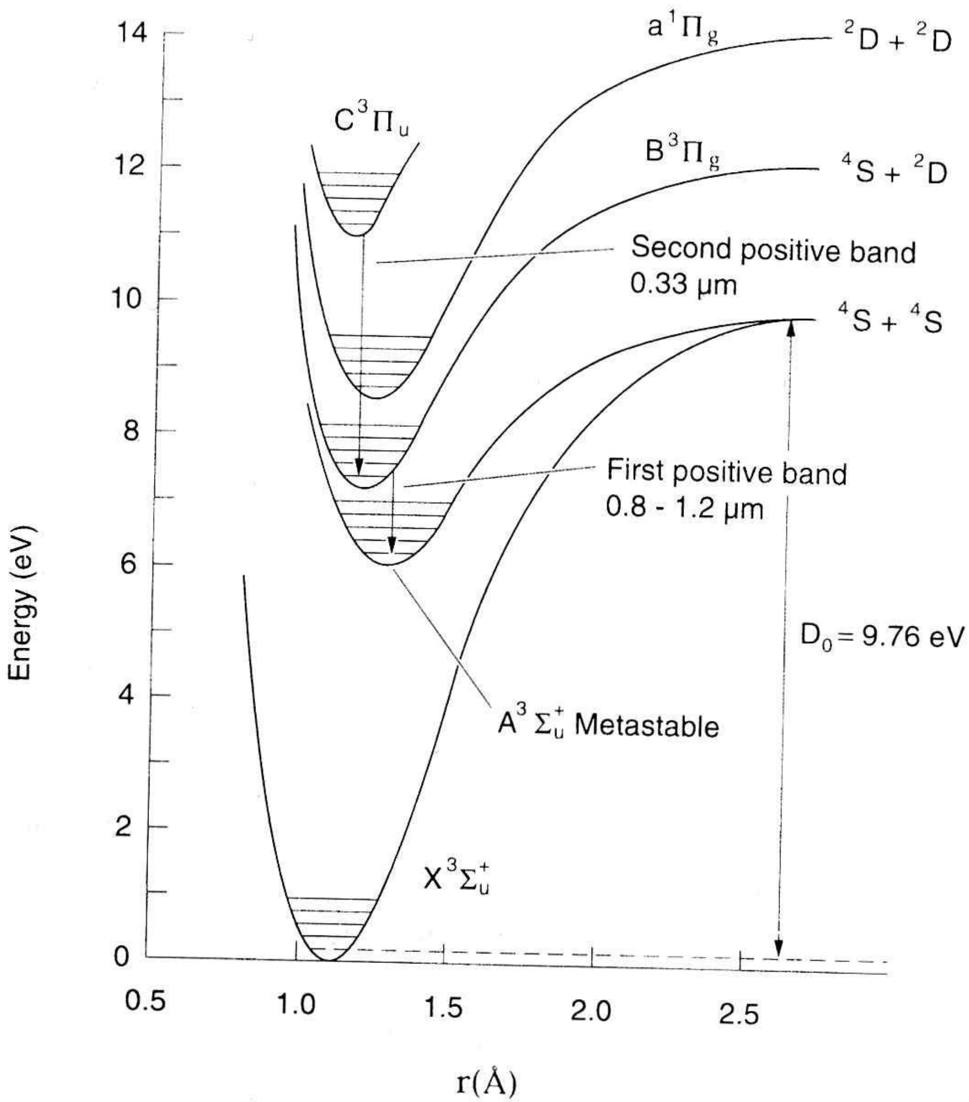


Figure 5-7 Energy levels of molecular nitrogen as a function of separation distance *r* between the two nitrogen atoms and also the dissociation energy D_0

Vibronic, vibrational-rotational, rotational transitions

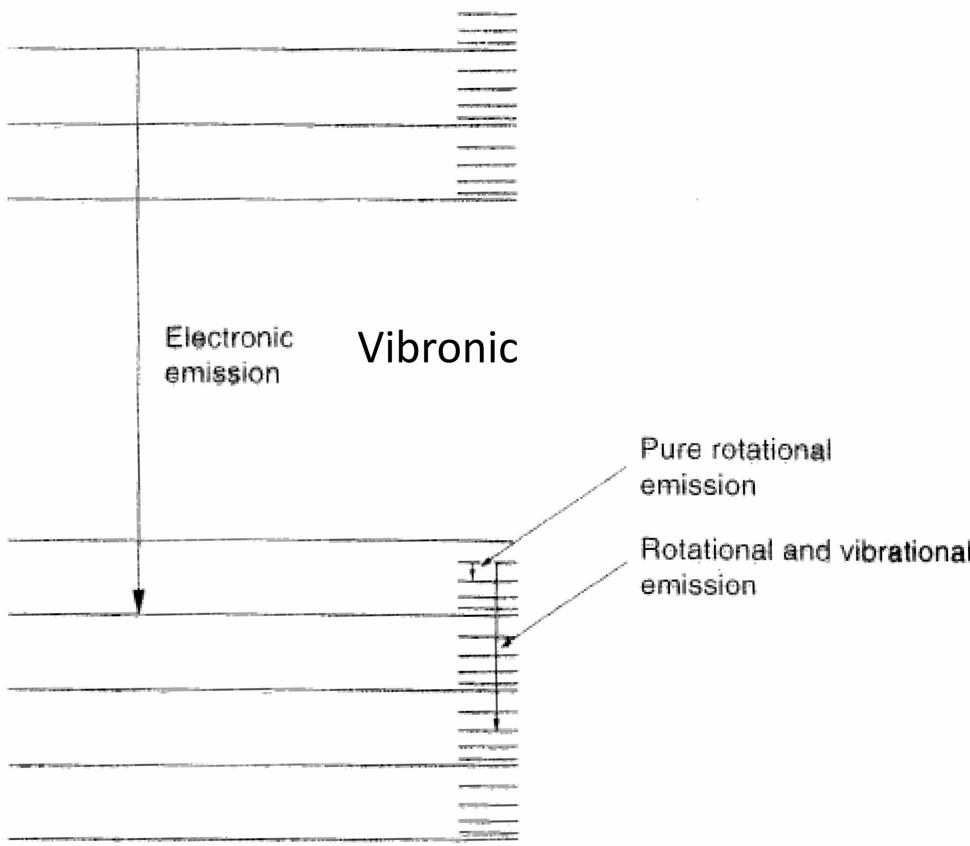


Figure 5-2 Energy levels of a molecule, indicating electronic emission as well as pure rotational emission and rotational–vibrational emission

Franck-Condon principle

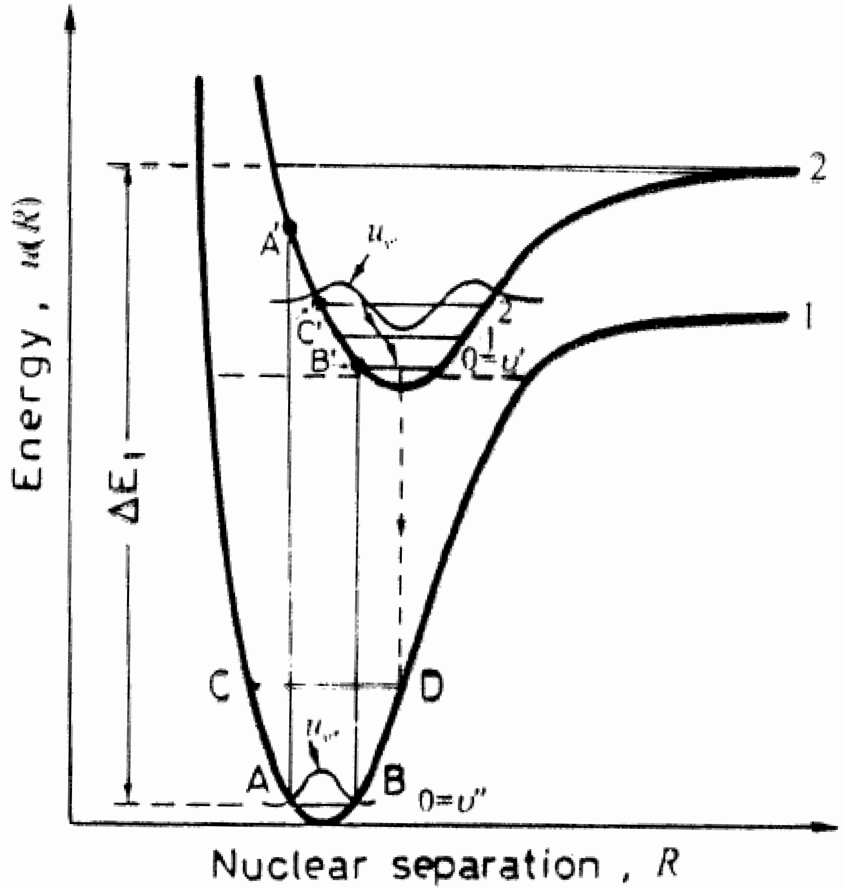


FIG. 3.6. Allowed vibronic transitions for a diatomic molecule.

Stokes law

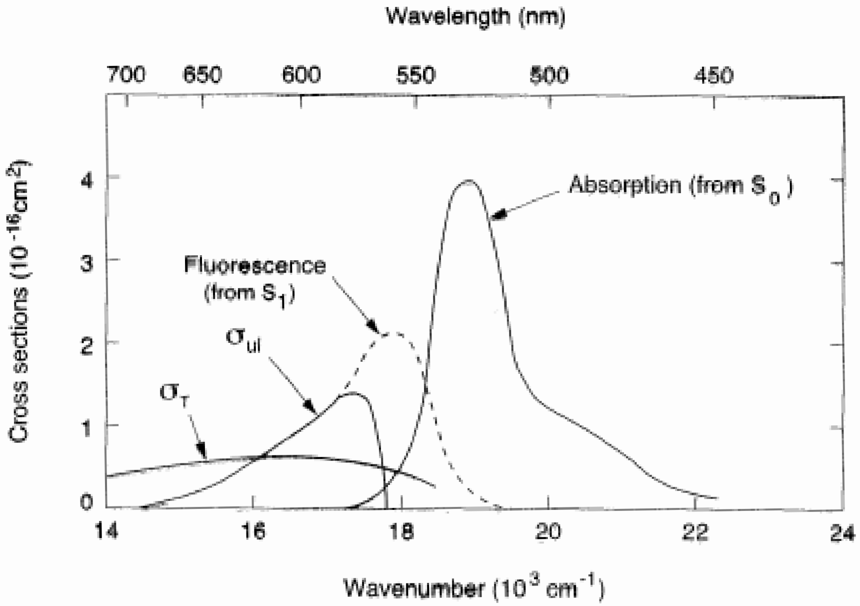
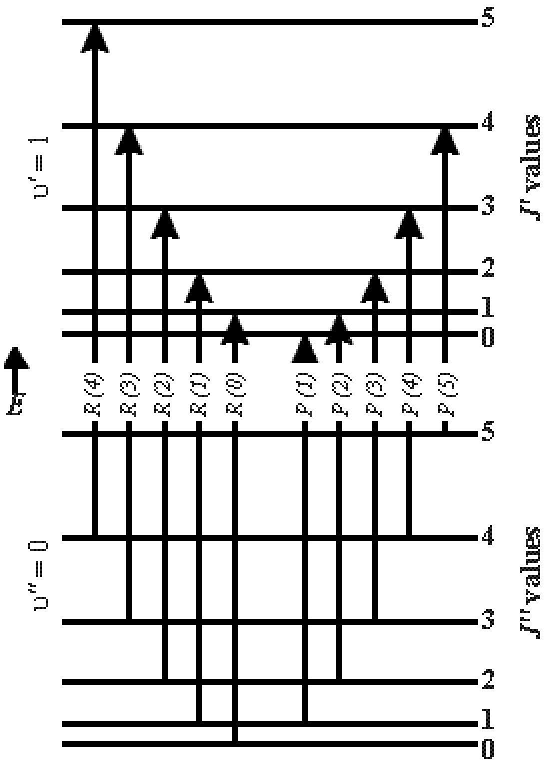
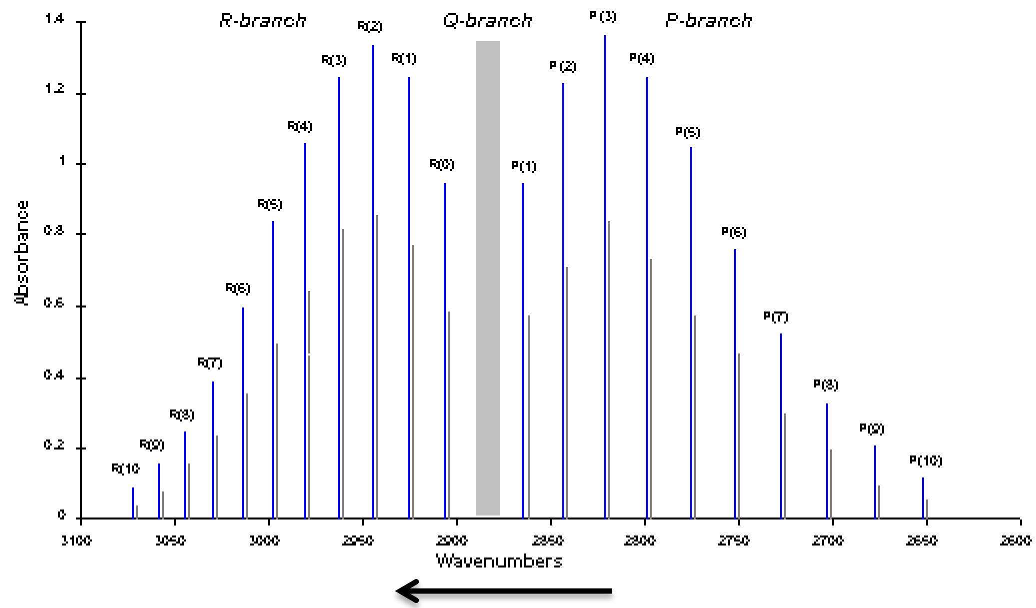


Figure 9-17 Absorption processes associated with absorption from S_0 and absorption from T_1 (σ_T), where wavenumber is the reciprocal of wavelength

GROUND-STATE ABSORPTION IN DYE LASERS Organic dye lasers have an overlap between the absorption (pumping) spectrum and the emission spectrum, as shown in Figure 5-10 for the dye RhB. This overlap is determined by the relationship of the singlet ground-state S_0 and excited-state S_1 energy levels shown in Figure 5-12.

Ro-vibrational transitions





Selection rules :

Δv=±1

ΔJ=0,±1

Spectral branches :

ΔJ= 0 Q-branch (might be absent)

ΔJ= +1 R-branch

ΔJ= -1 P-branch

Population of rotational states

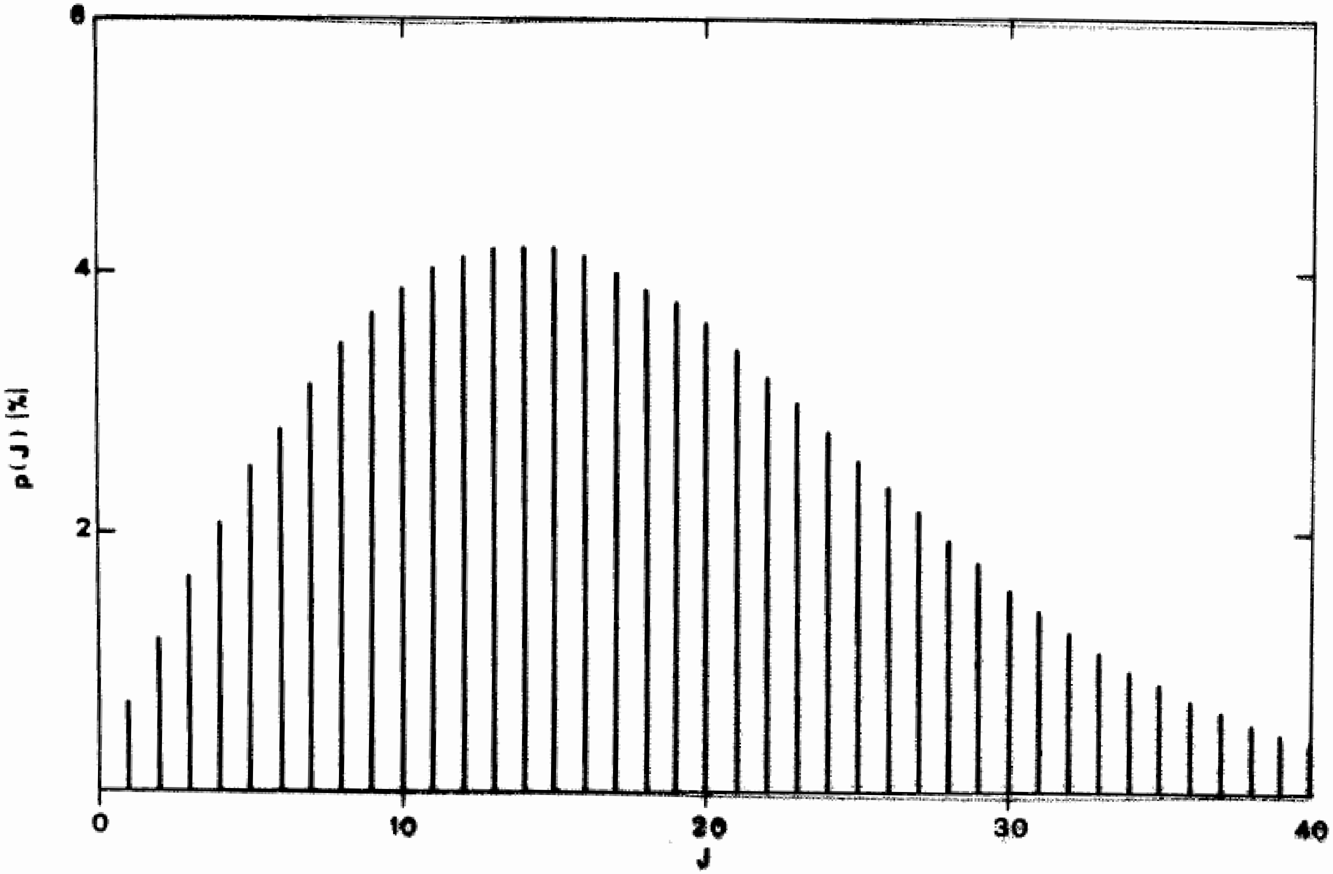


FIG. 3.5. Population distribution among rotational levels of a given vibrational state.

Formation of solids

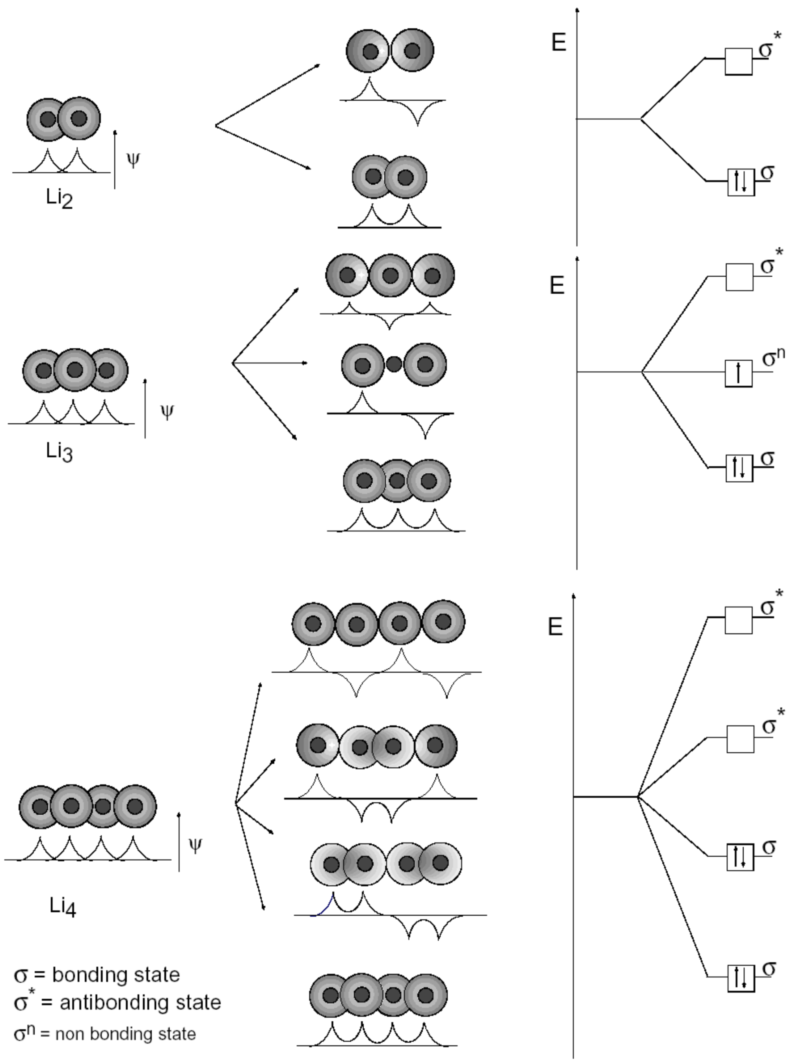
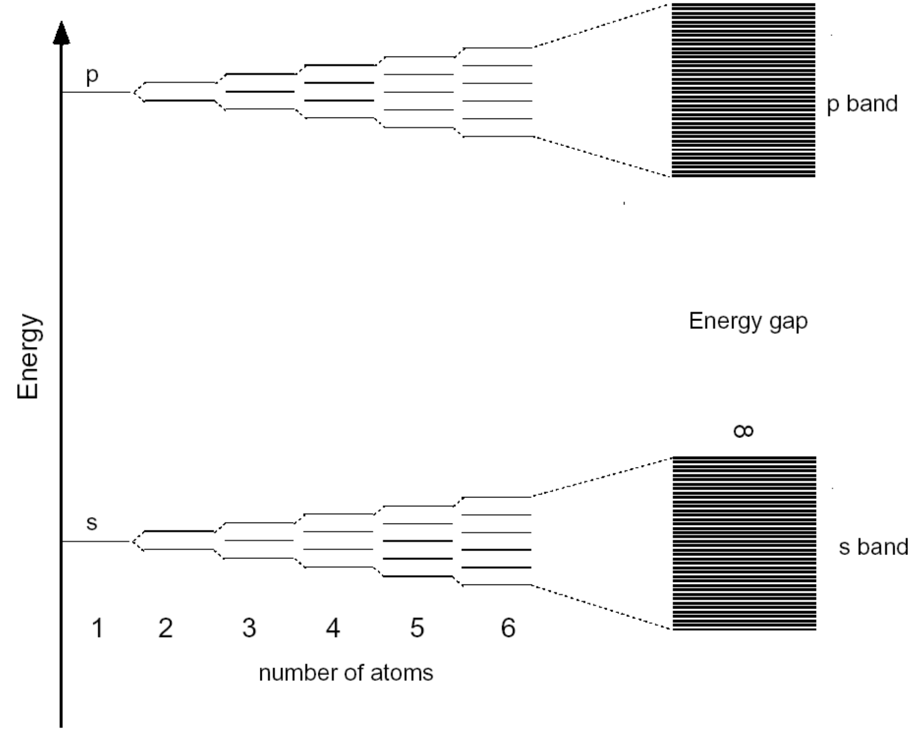
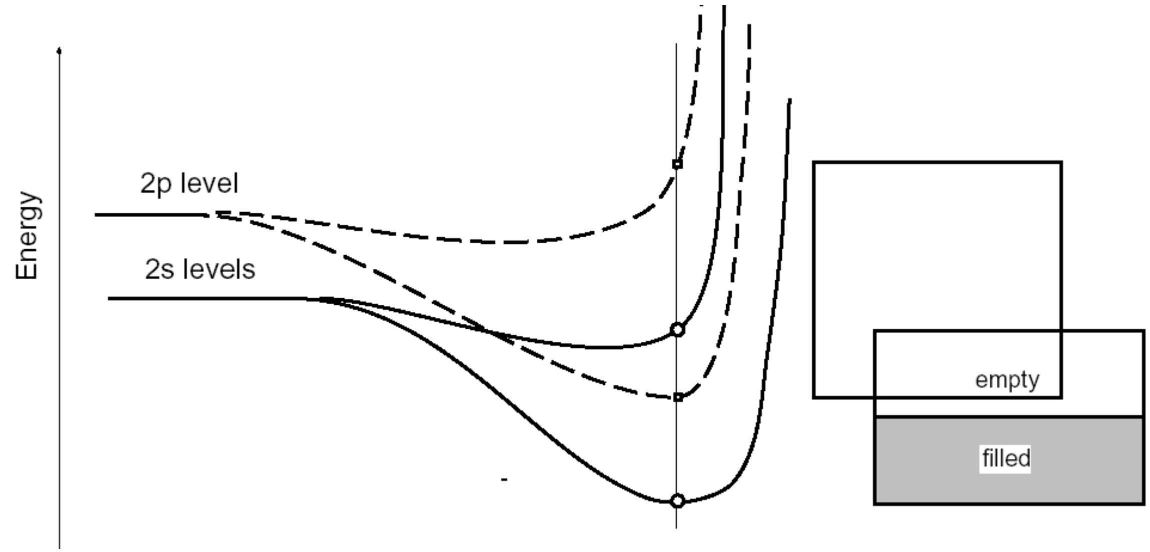


Figure 3 Formation of molecular chains of lithium atoms.

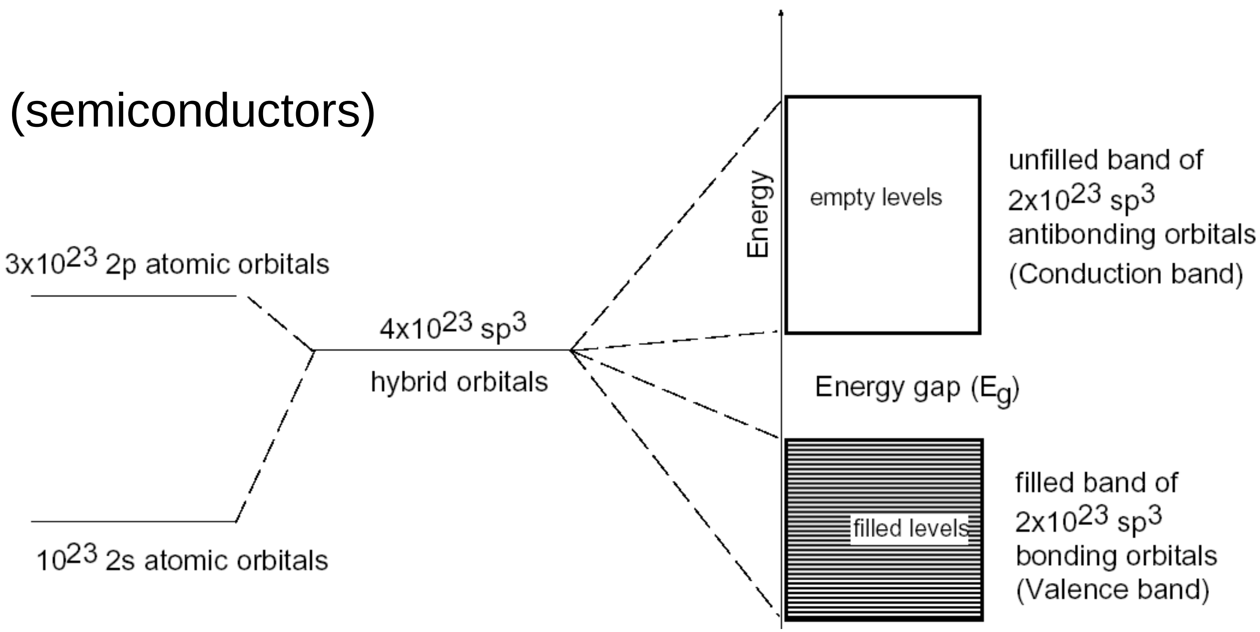


Formation of energy bands in solids

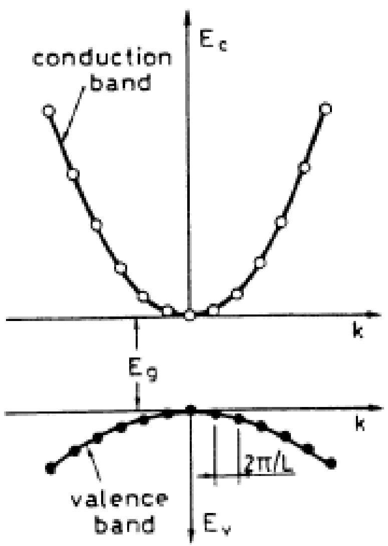
Metals



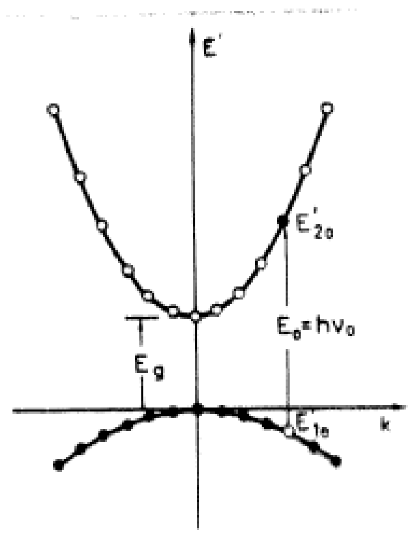
Dielectrics (semiconductors)



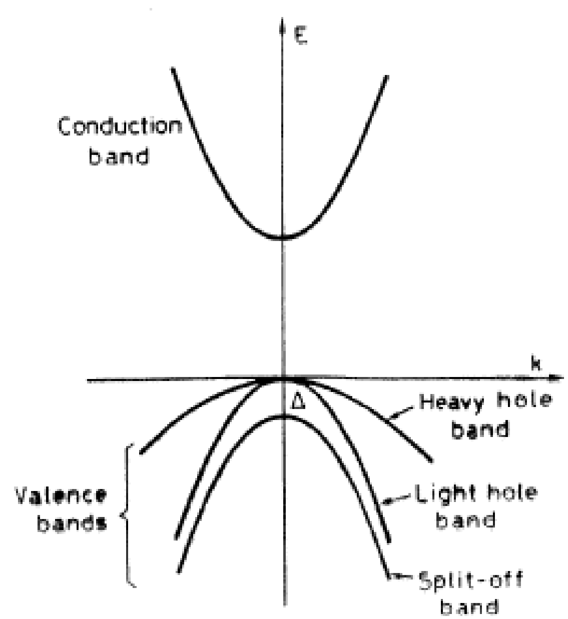
Electronic bands in direct-bandgap semiconductor



(a)



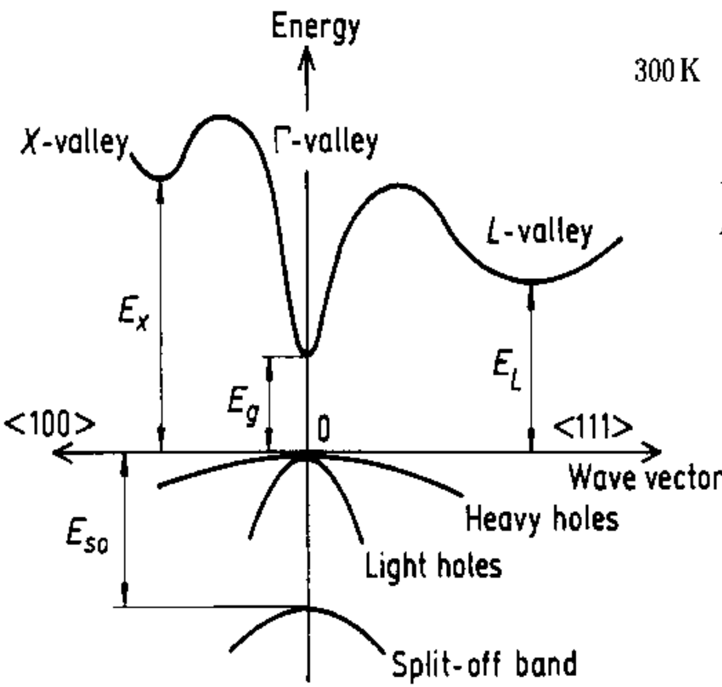
(b)



Direct and indirect bandgap semiconductors

GaAs (InAs, InP, InSb, etc.)

Si (Ge, GaP, etc.)



300 K $E_g = 1.42$ eV
$E_L = 1.71$ eV
$E_X = 1.90$ eV
$E_{so} = 0.34$ eV

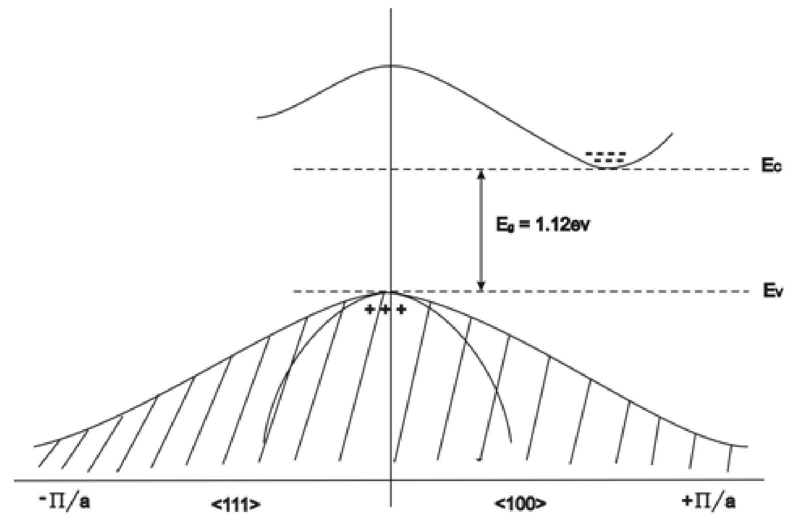


Figure1.58 (b) Silicon

Fermi-Dirac distribution

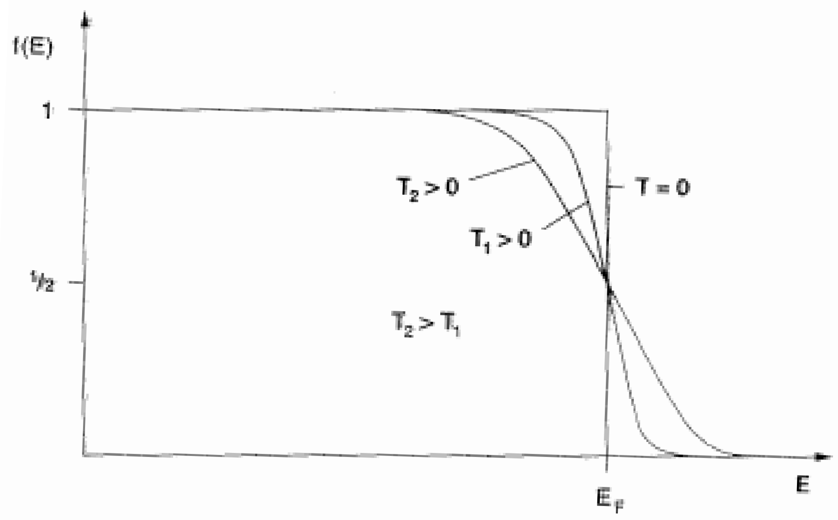


Figure 5-21 Fermi–Dirac distribution function

Density of states, Fermi-Dirac distribution, electron (hole) density

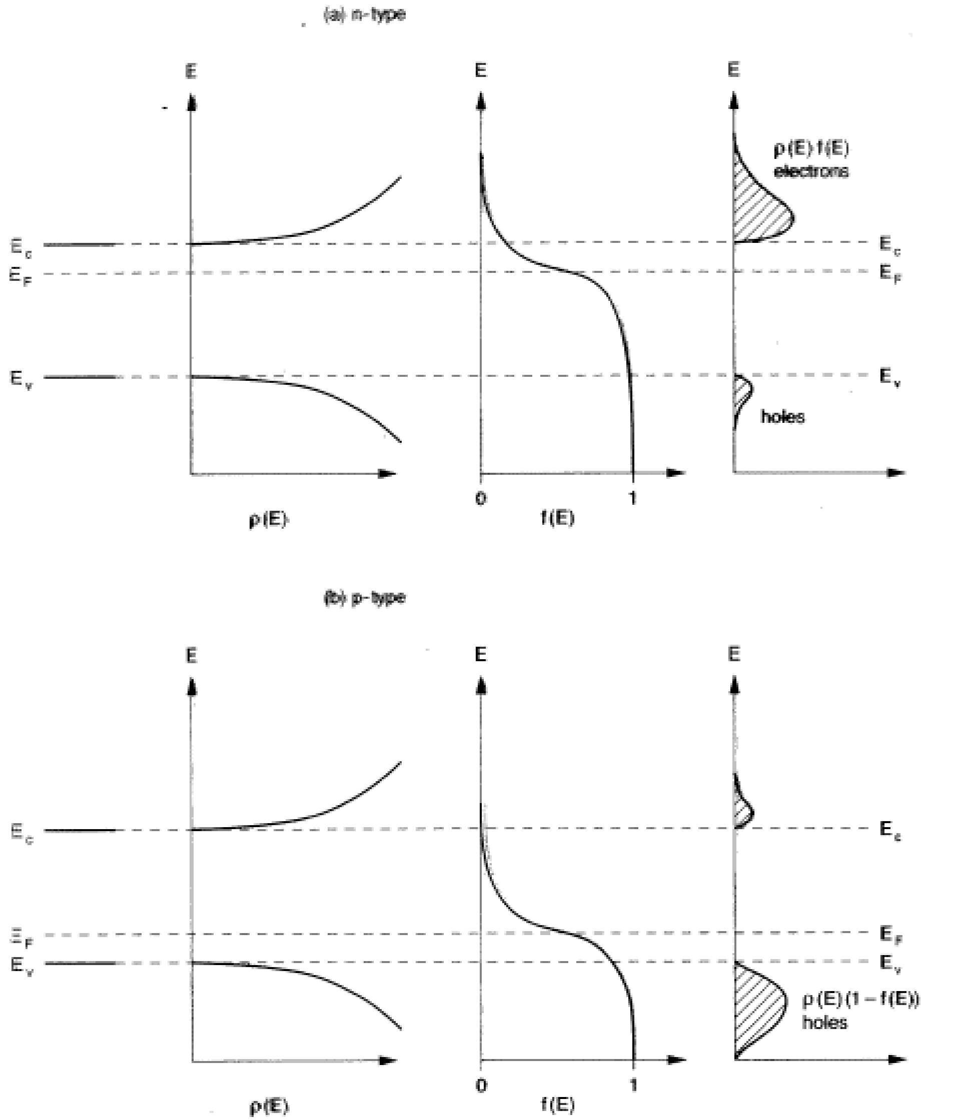
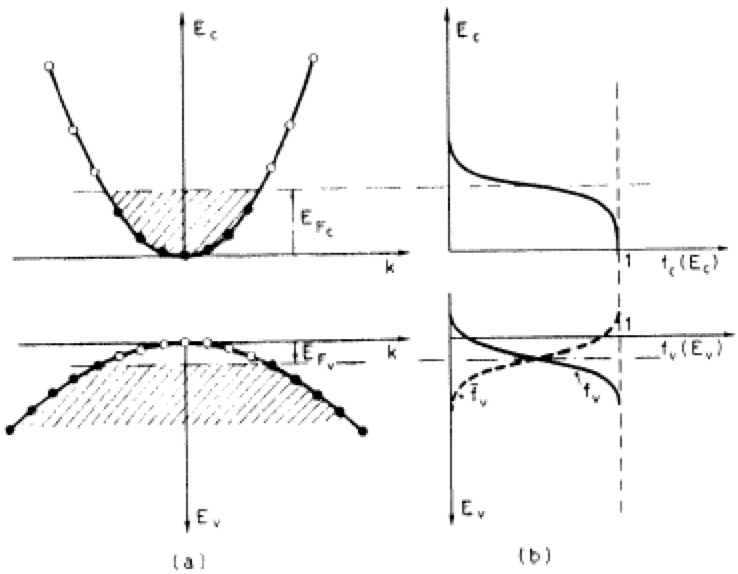
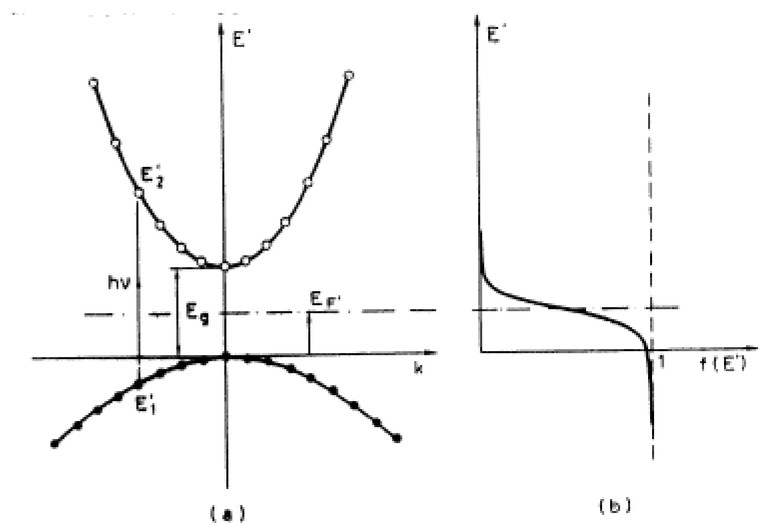


Figure 5-24 Carrier distribution in the conduction band and valence band for an extrinsic semiconductor for (a) n-type doping (excess electrons) and (b) p-type doping (excess holes)

Fermi level and quasi-Fermi levels





Electron density at transparency

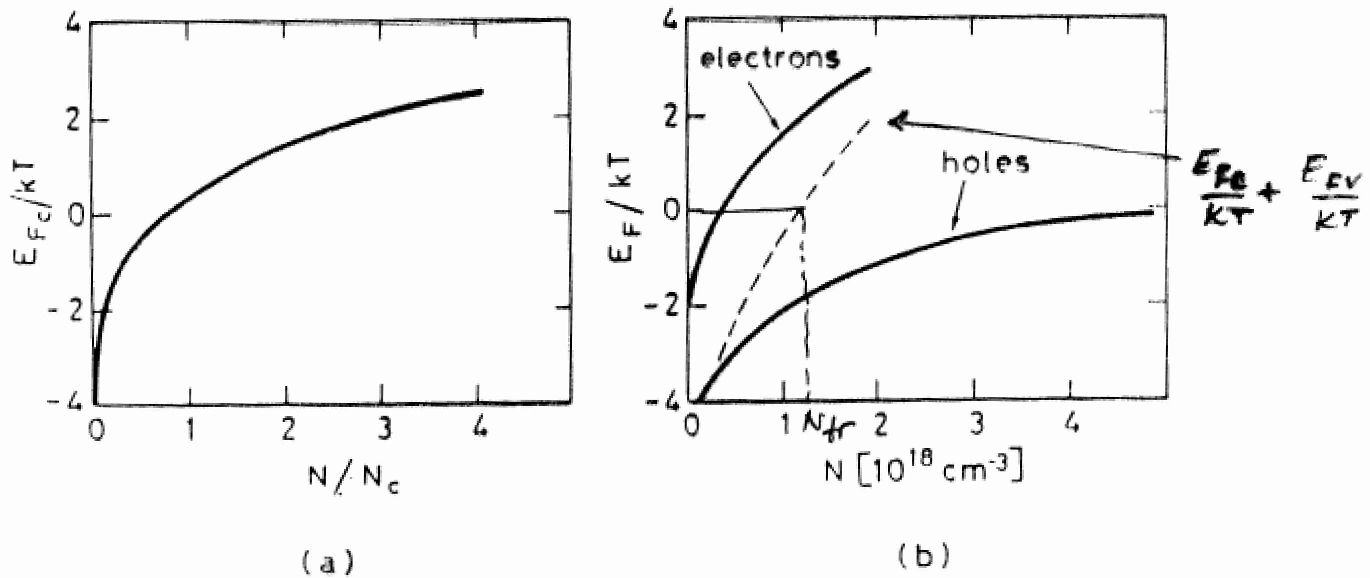
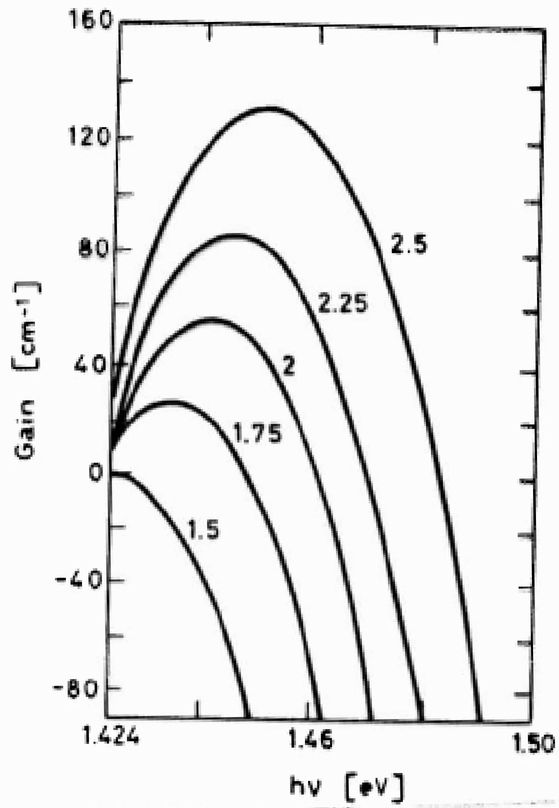
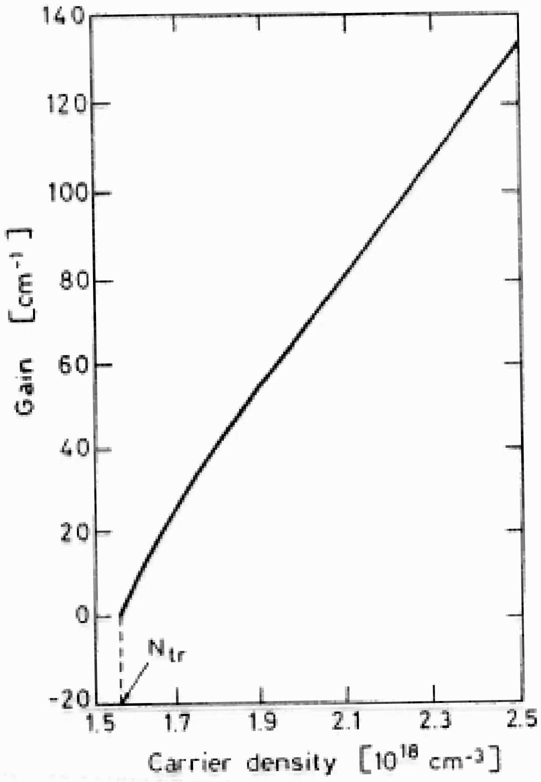


FIG. 3.15. (a) Normalized plot of the quasi-Fermi energy of the conduction band E_{F_c} versus the normalized concentration of injected electrons, N. The same normalized relation also holds for holes in the valence band. (b) Normalized plots of the quasi-Fermi levels of both valence and conduction bands E_F/kT versus the concentration of injected carriers N for GaAs.

Optical gain in semiconductors





Bandgap engineering in semiconductors

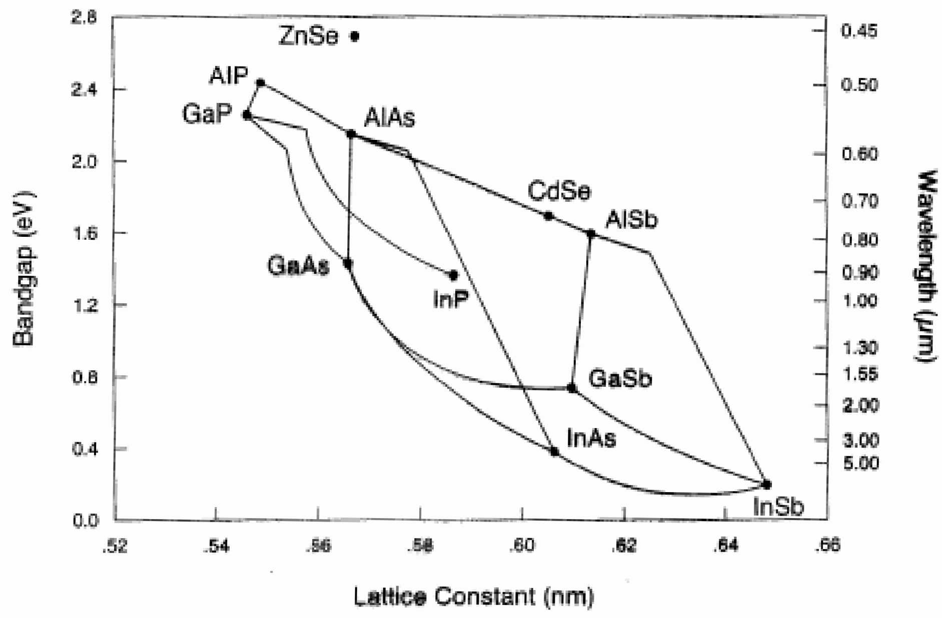
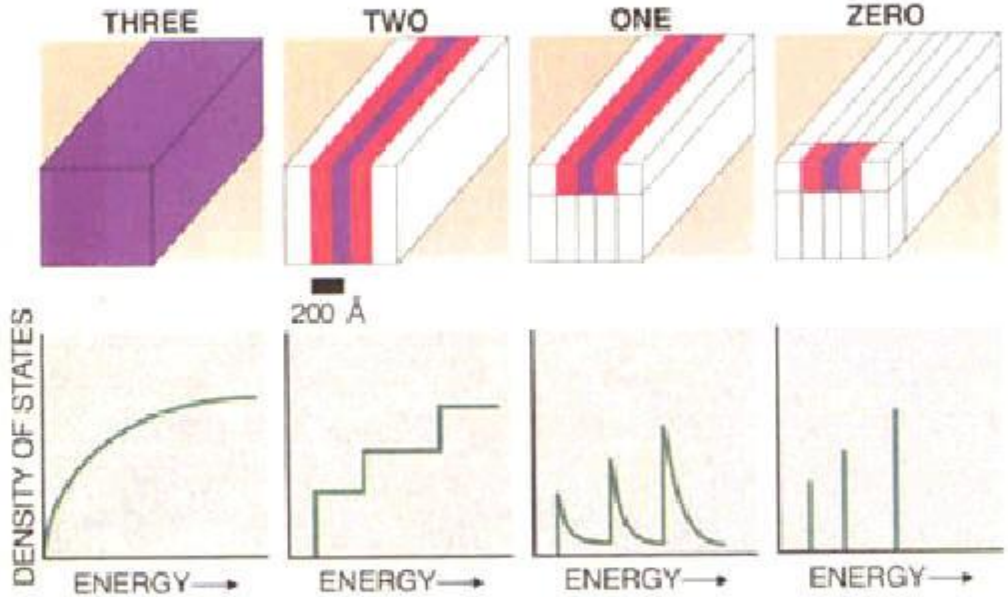
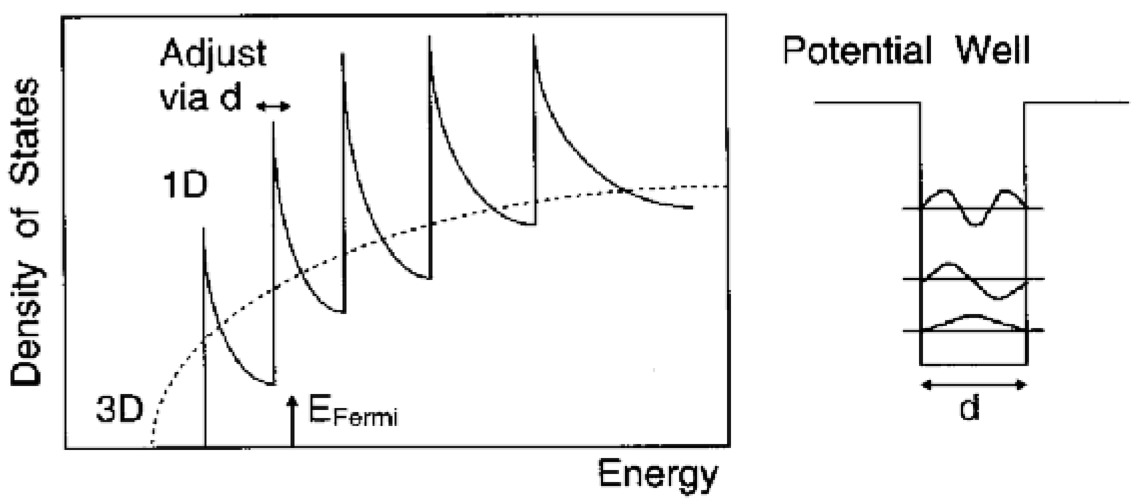


Figure 5-31(a) Potential laser wavelengths for semiconductor laser materials with bandgaps ranging from 0.2 eV to 2.8 eV

Mesoscopic structures

Quantum wells - 2D, Quantum wires – 1D, Quantum dots – 0D





Main Keywords

Molecular orbitals
Vibrational and rotational degrees of freedom
Frank-Condon principle
Stoke's law
Conduction and valence bands
Electron and hole effective mass
Density of states
Fermi level, Quasi-Fermi levels
Joint density of states
Transparency carrier density
Recombination: radiative, nonradiative, Auger
Subbands in quantum wells
Strained quantum wells
Quantum wires, quantum dots

Problems

3.7, 3.8, 3.9, 3.10

Examples: 3.5 (error correction: $m_v = m_{hh}$), 3.6, 3.7, 3.10