Solid State Physics (PHY210)

Vorlesung / Lectures: Wednesday 13h00 – 15h45
Raum / Room: Y36-K-08
http://www.physik.uzh.ch/lectures/fkp/
Exam: Oral (most likely 9-10th of June – details to be announced)

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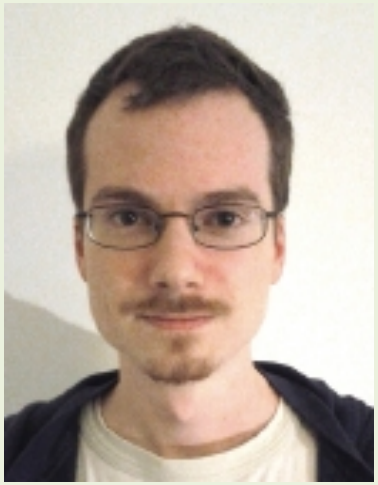
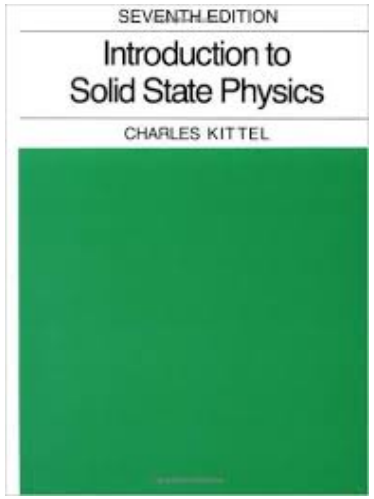
Übungen / Exercise class: Fridays 15h00 – 15h45
Raum / Room: Y36-K-08

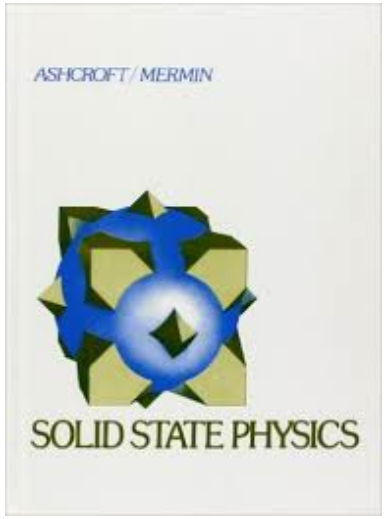
Daniel Destraz
destraz@physik.uzh.ch

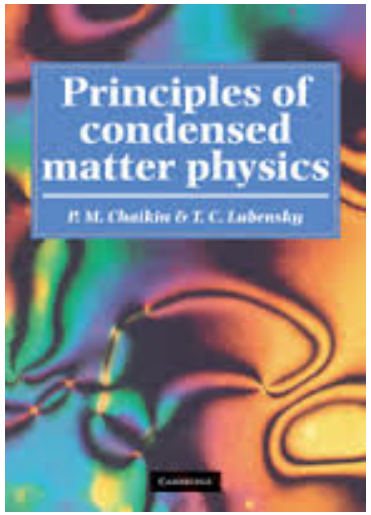
Stefan Holenstein
stefan.holenstein@psi.ch

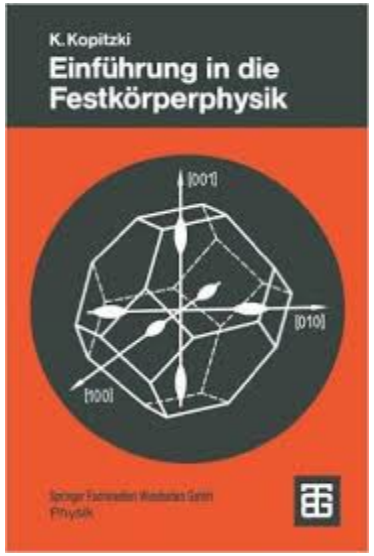


Literature


SEVENTH EDITION
Introduction to
Solid State Physics
CHARLES KITTEL


ASHCROFT / MERMIN
SOLID STATE PHYSICS

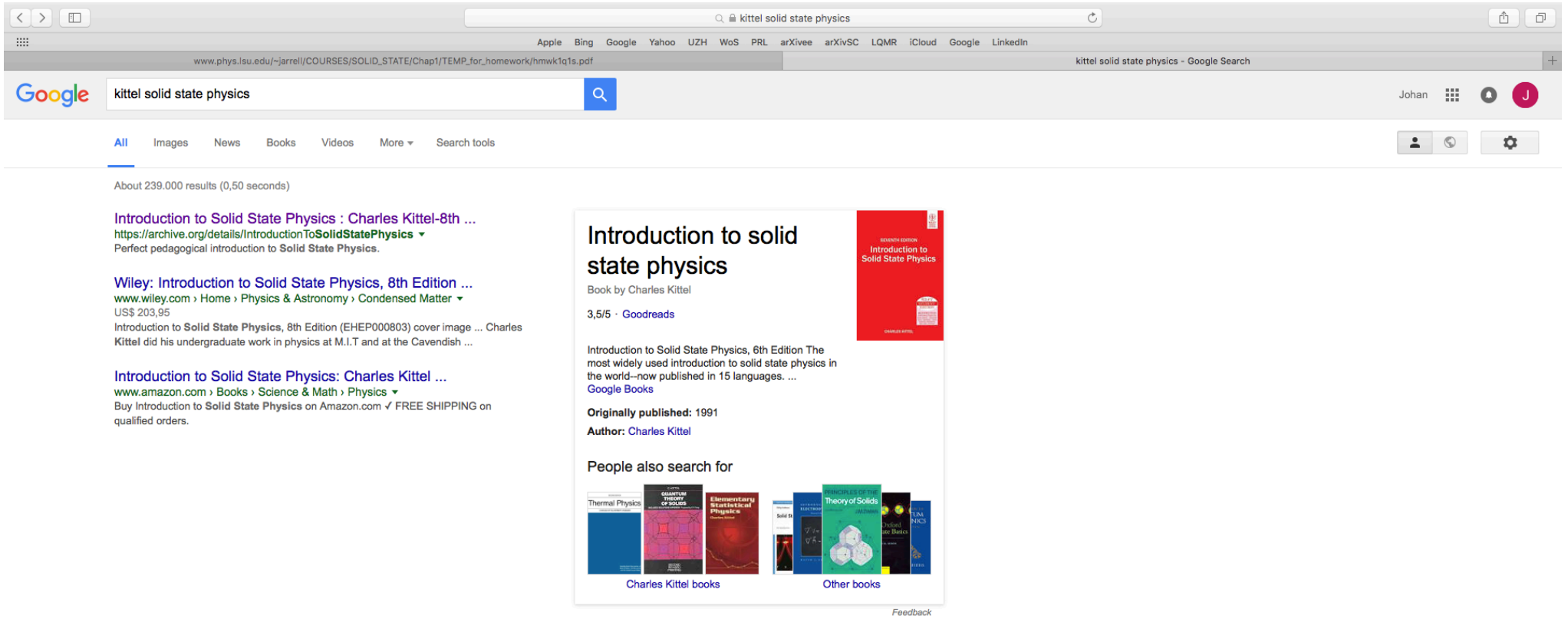

Principles of
condensed
matter physics
P. M. Chaikin & T. C. Lubensky


K. Kopitzki
Einführung in die
Festkörperphysik
[001]
[010]
[100]


K.-H. Hellwege
Einführung
in die
Festkörperphysik
Springer-Verlag
Berlin Heidelberg New York


H. M. ROSENBERG
The
Solid State
THIRD EDITION
OXFORD SCIENCE PUBLICATIONS

Google - power



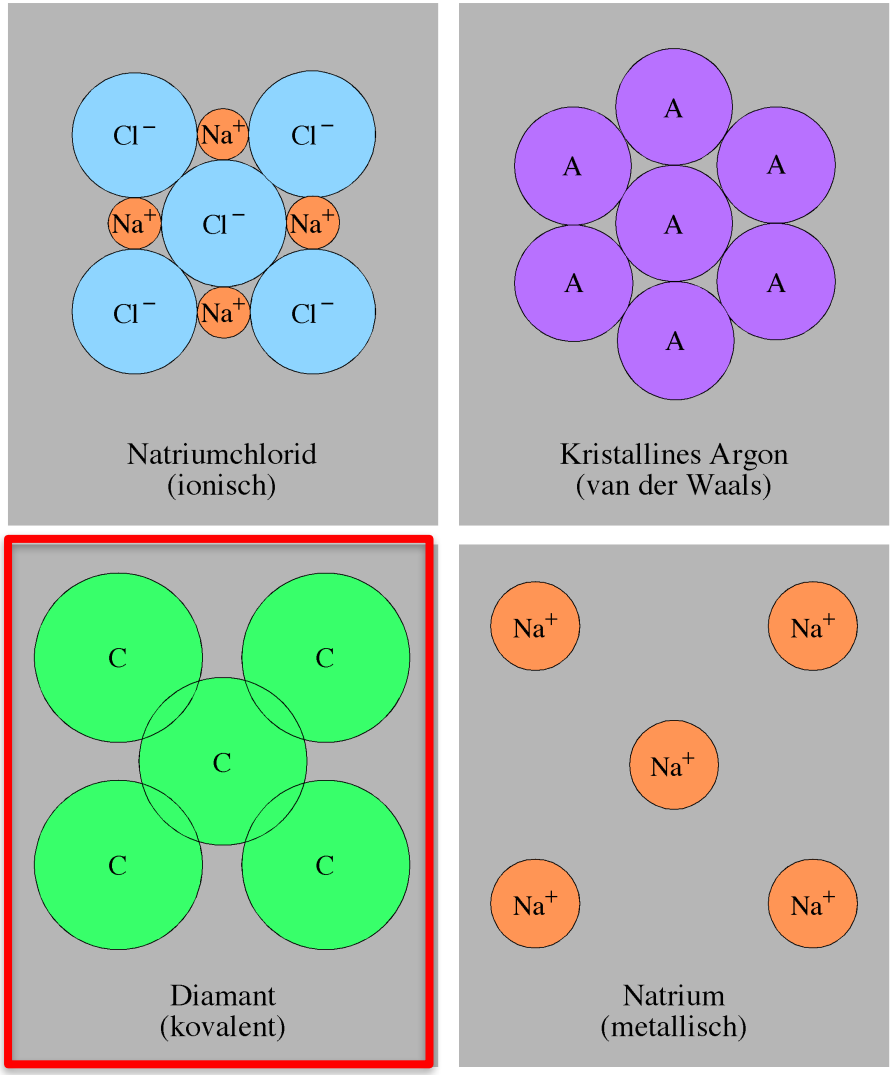
Last weeks exercise 2 solved in chapter 3 (page 71 in my version)

Last weeks exercise 3 is exercise 5 of chapter 3 in Kittel. Solution can actually be googled.

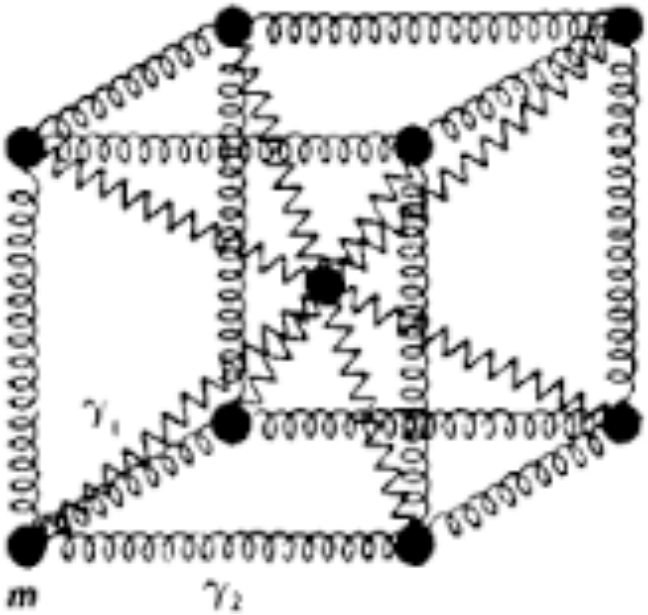
(Last weeks exercise 1a,b was basically solved during the lecture.)

Today's lecture

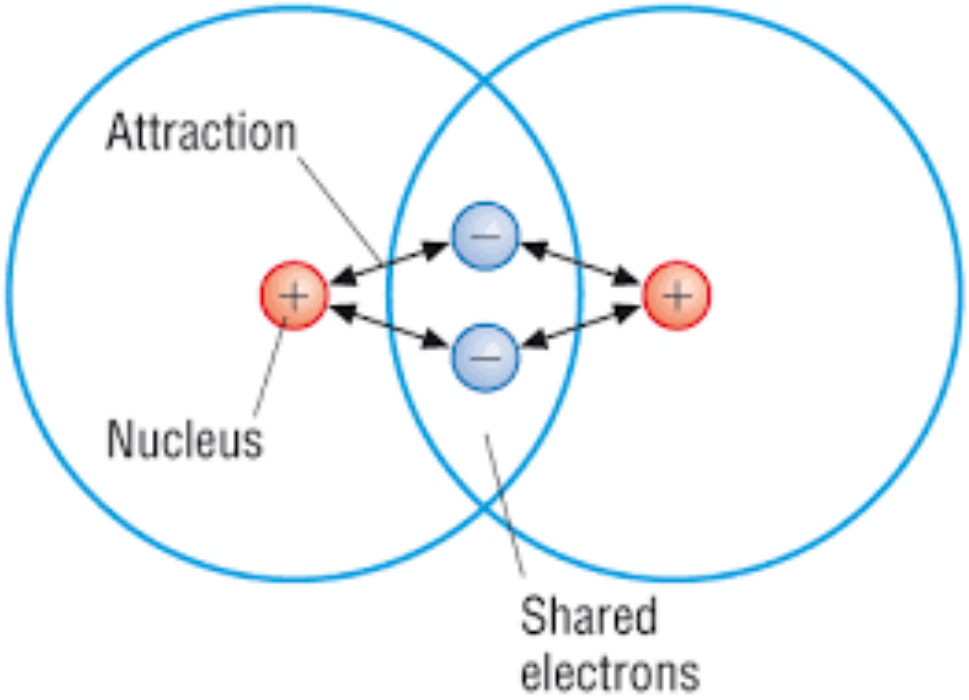
Crystal binding mechanisms



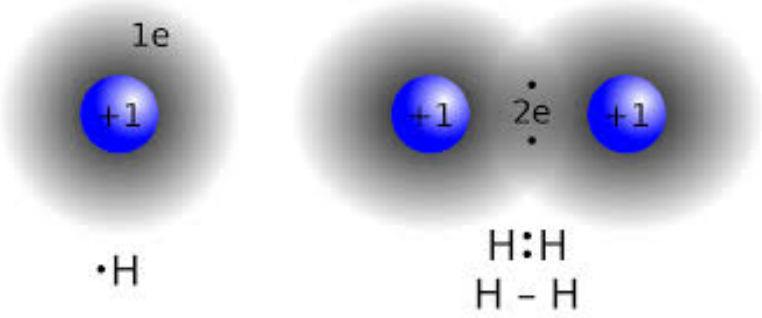
Lattice vibrations



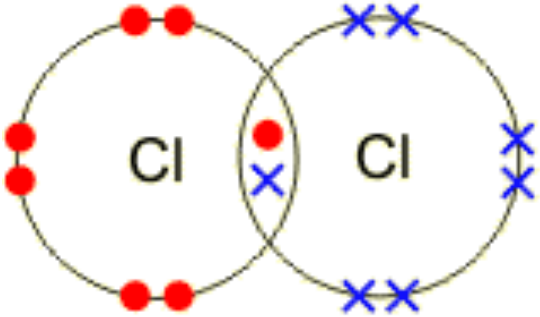
Covalent Crystals



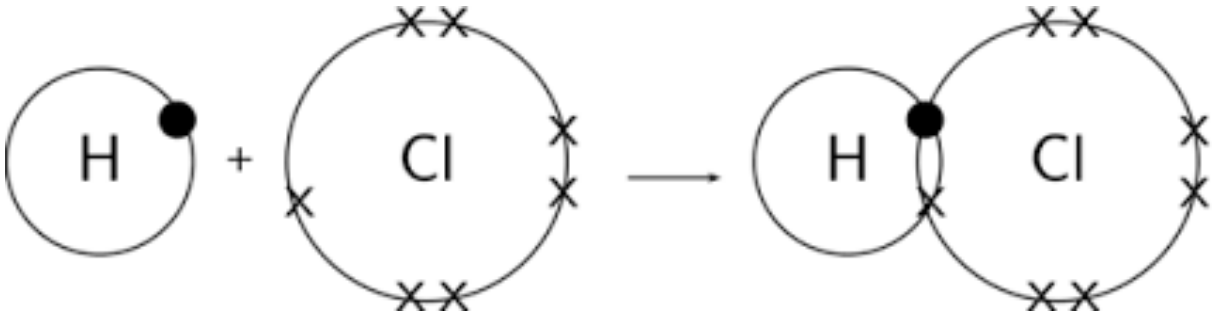
Example 1



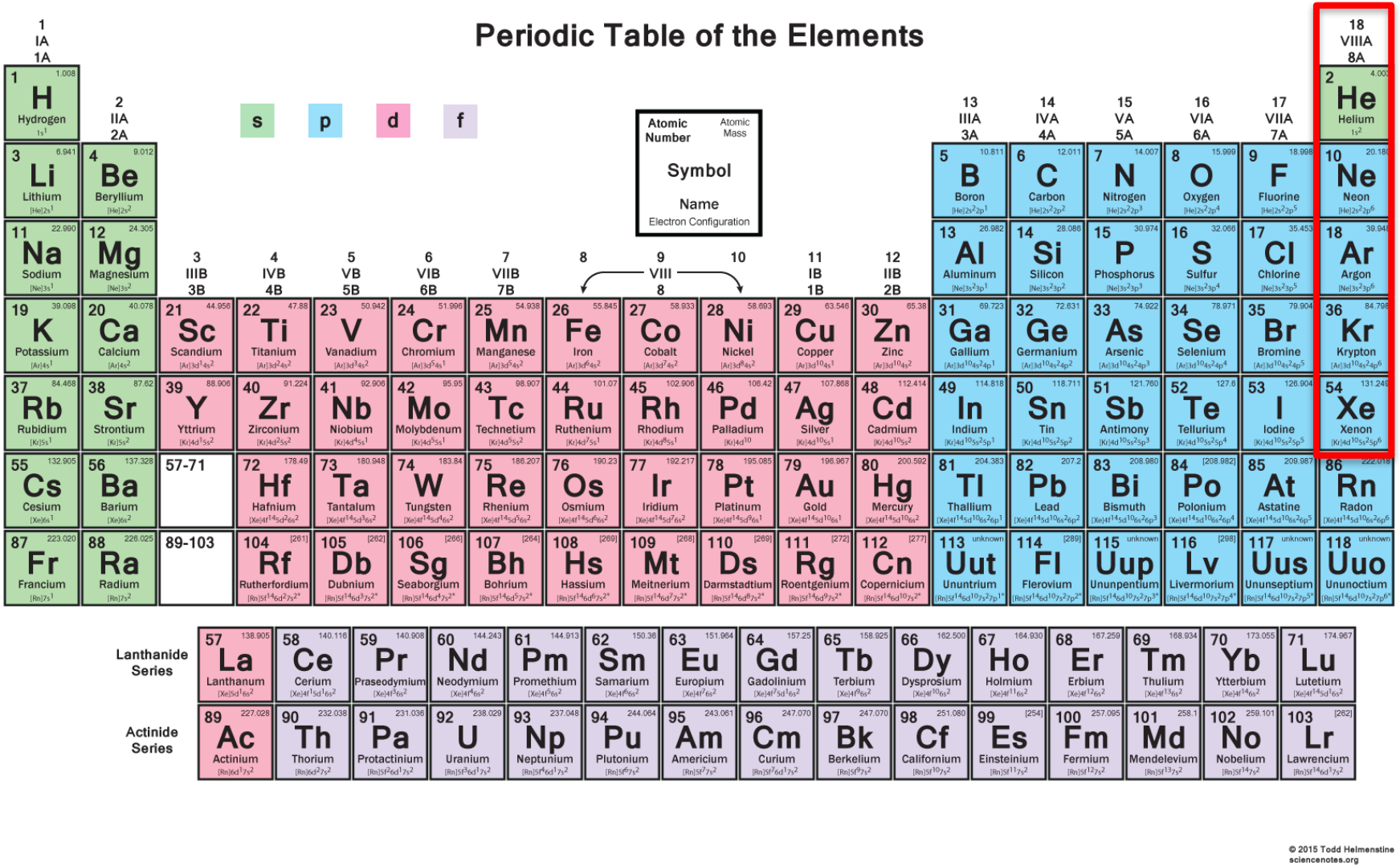
Example 2



Example 3

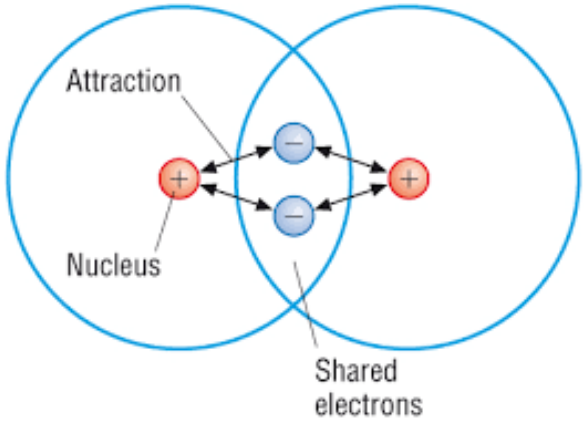


Periodic table

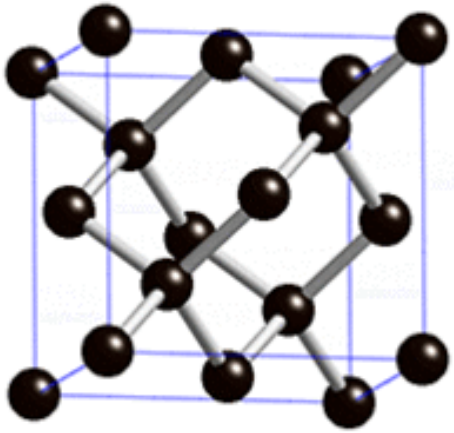


http://sciencenotes.org/periodic-table-showing-shells/

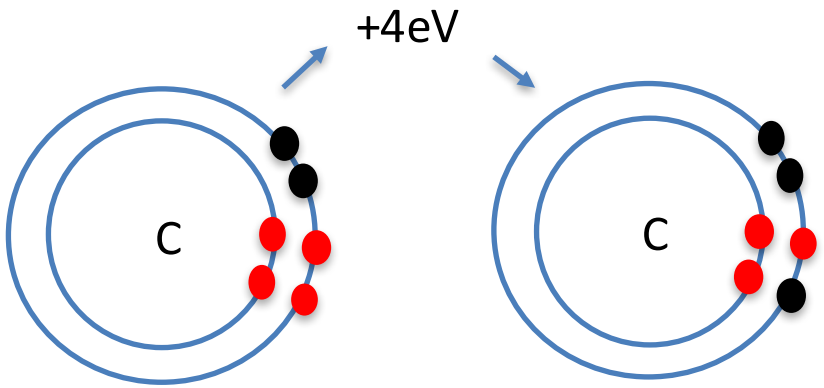
Covalent Crystals



Diamond structure



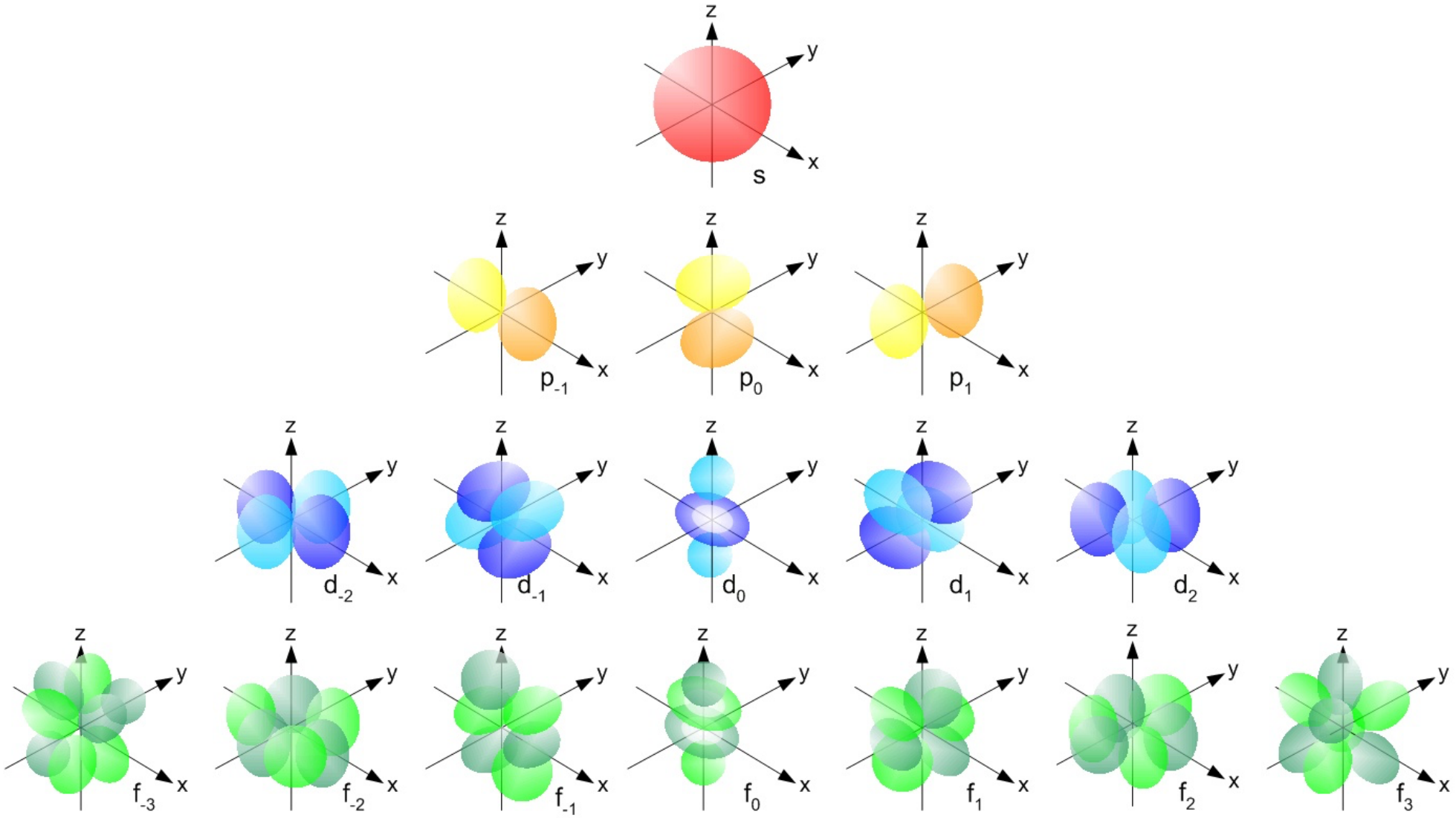
4 covalent bonds



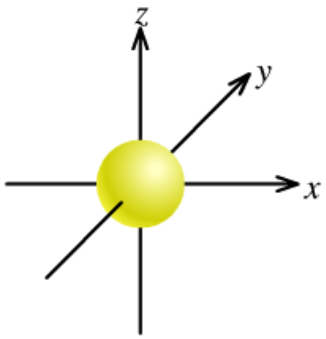
$1s^2 2s^2 2p^2$

$1s^2 2s 2p^3$

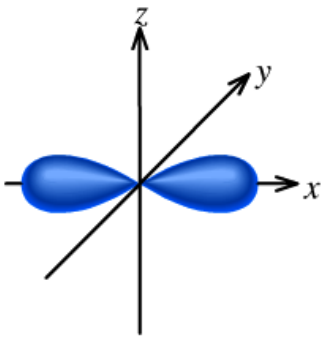
Electronic orbitals



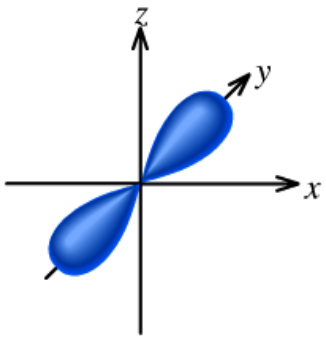
Orbital hybridization



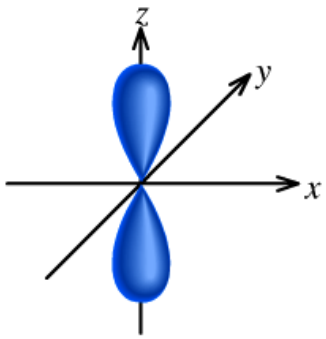
ψ_s



ψ_{px}



ψ_{py}



ψ_{pz}

ψsp^3_1

ψsp^3_2

ψsp^3_3

ψsp^3_4

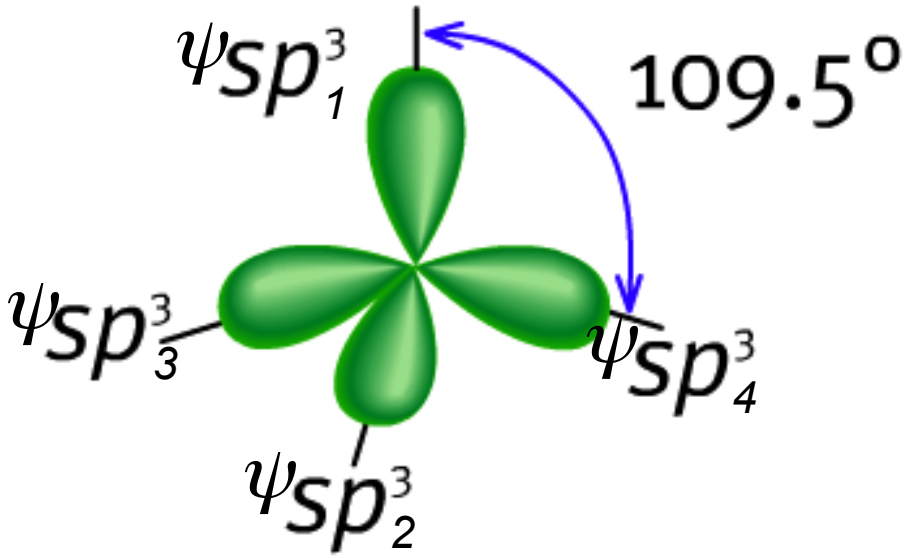
$1/2(\psi_s + \psi_{px} + \psi_{py} + \psi_{pz})$

$1/2(\psi_s + \psi_{px} - \psi_{py} - \psi_{pz})$

$1/2(\psi_s - \psi_{px} + \psi_{py} - \psi_{pz})$

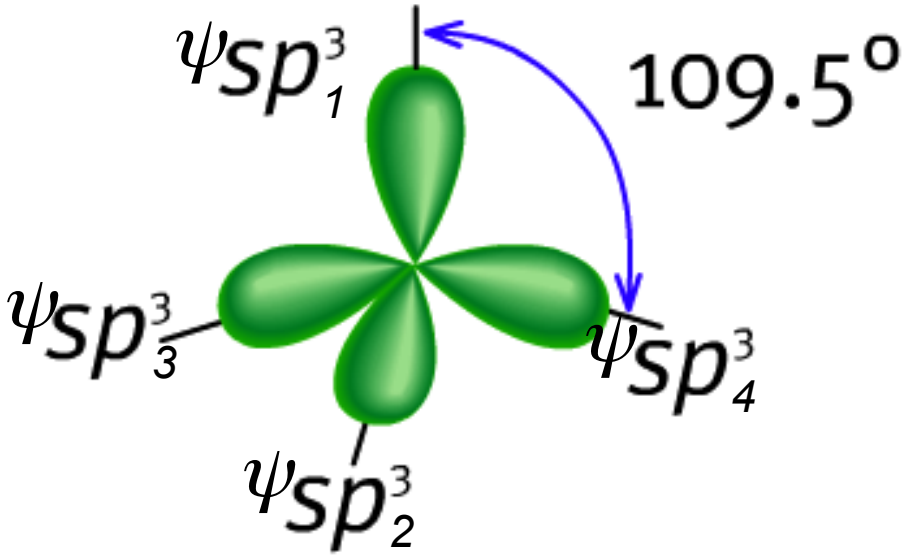
$1/2(\psi_s - \psi_{px} - \psi_{py} + \psi_{pz})$

Orbital hybridization

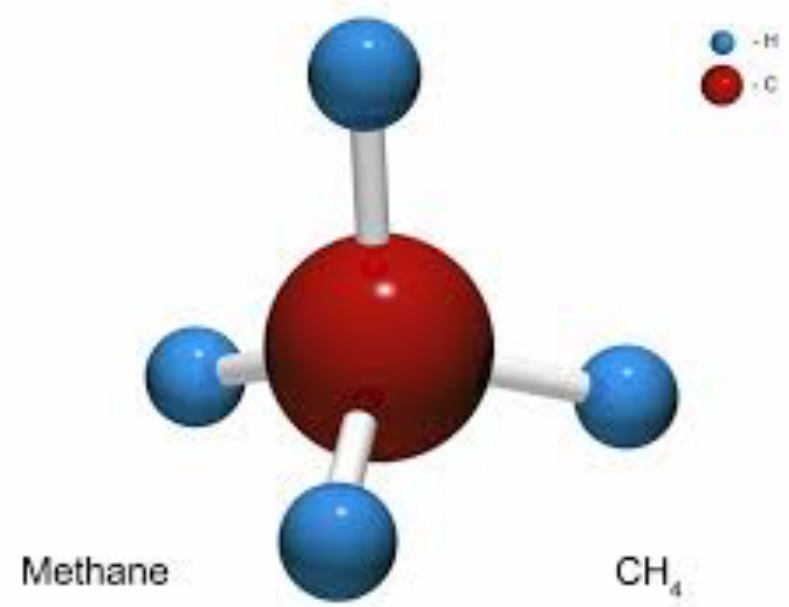


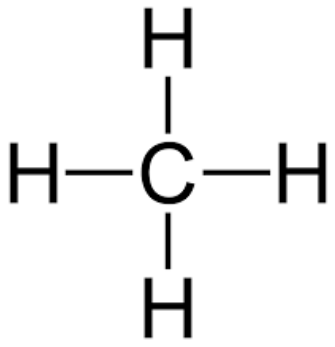
Tetraeder

Orbital molecular theory: Example CH_4 (Methane)

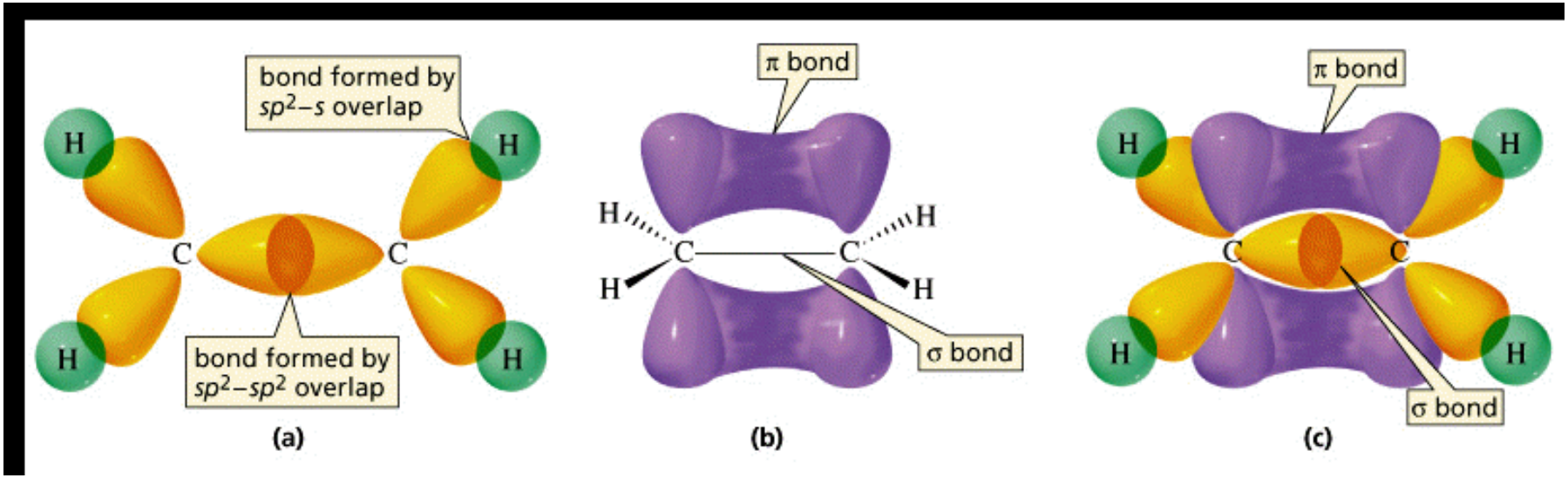


Tetraeder



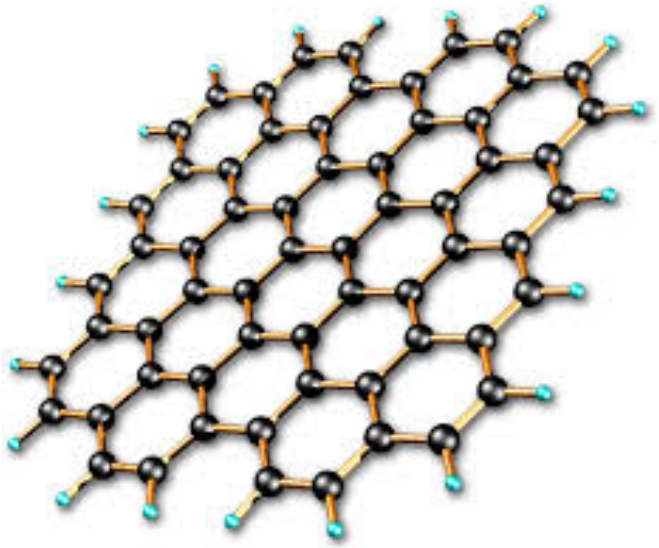


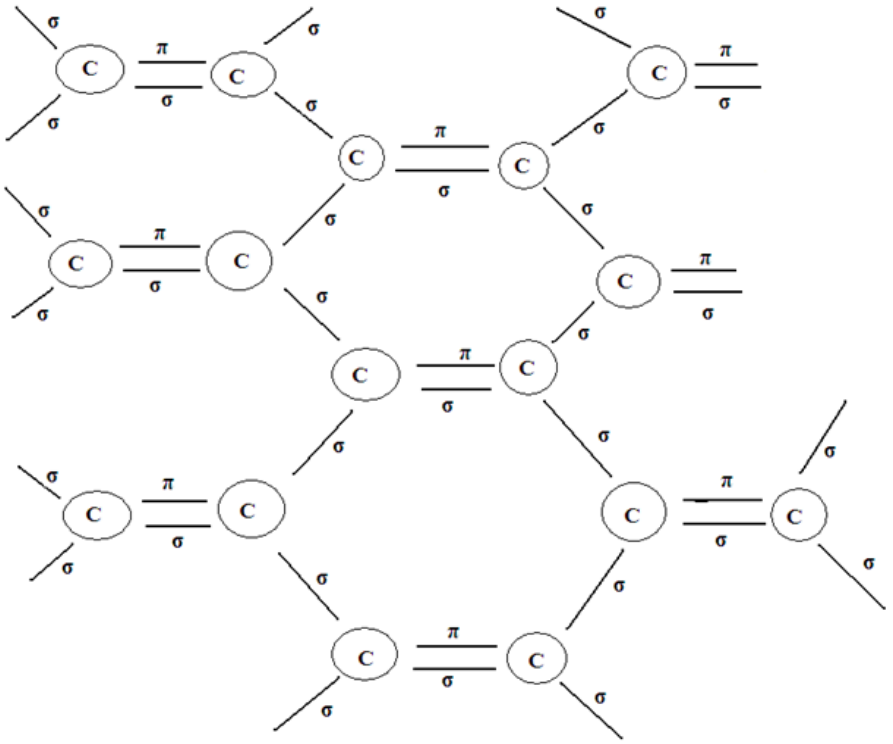
Orbital molecular theory: σ and π bonding



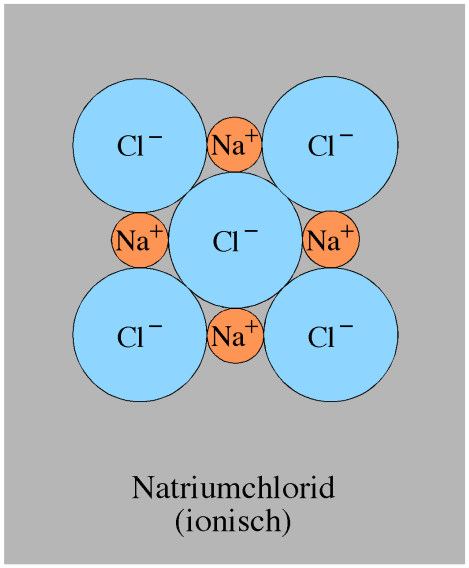
Graphene: σ and π bonding

Graphene

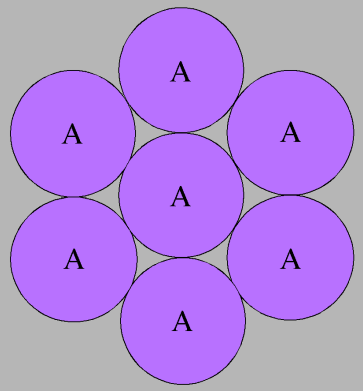




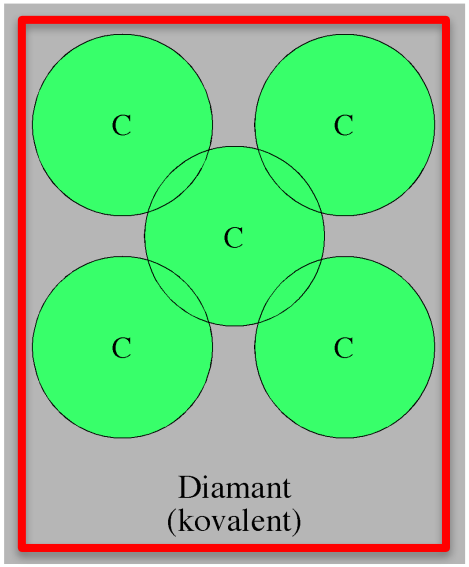
Today's lecture



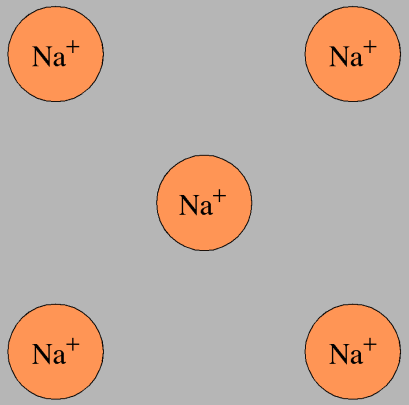
Natriumchlorid
(ionisch)



Kristallines Argon
(van der Waals)



Diamant
(kovalent)

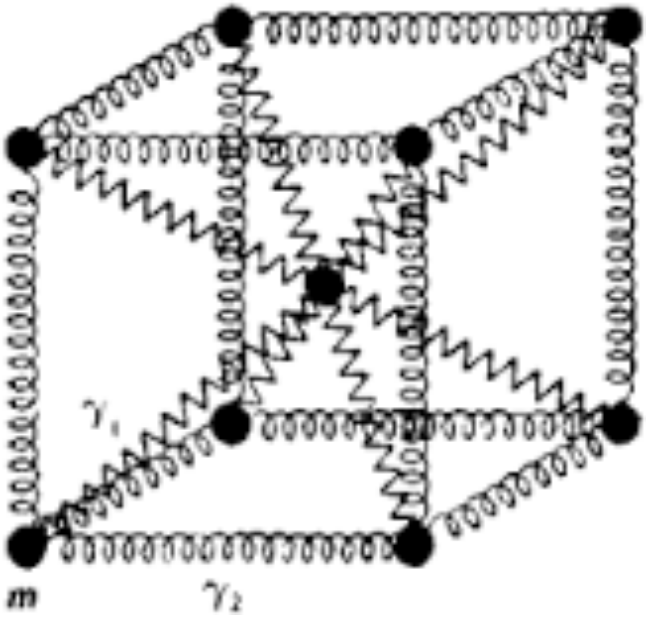


Natrium
(metallisch)

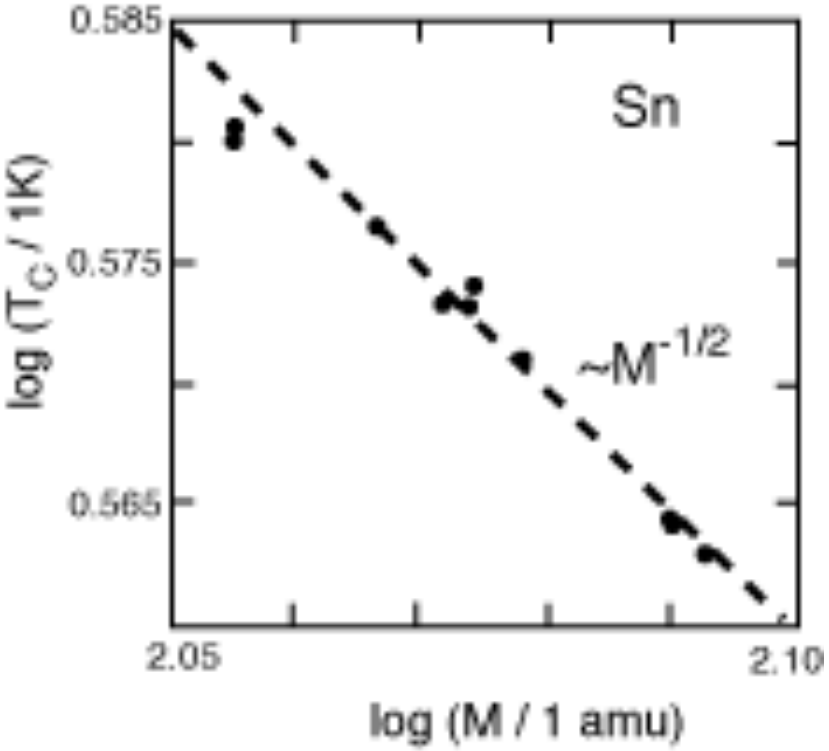
Summary

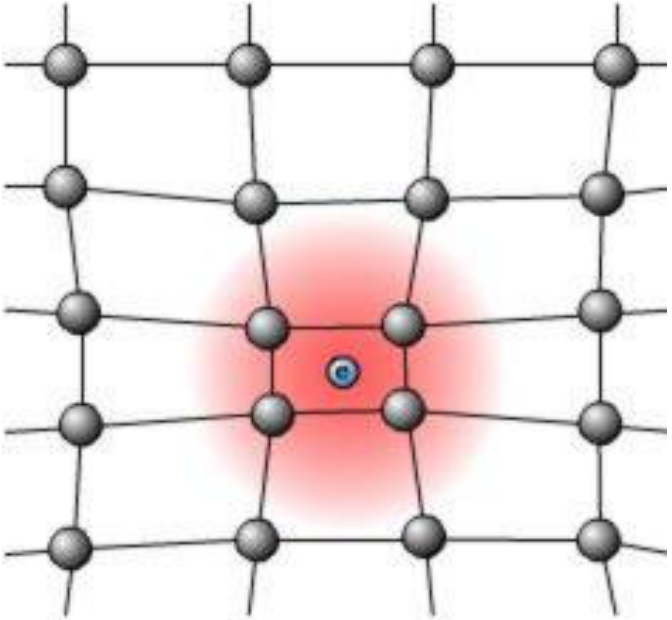
Bindungstyp	Beispiel	Bindungsenergie (eV)
Ionisch	NaCl LiF	8.23 10.92
Van-der-Waals	Ar Kr	0.080 0.116
Kovalent	Diamant Si	7.36 4.64
Metallisch	Na Fe W	1.13 4.29 8.66
Wasserstoff-Brücken	H_2O HF	0.52 0.30

Phonon – Lattice Vibrations



Phonons can make superconductivity

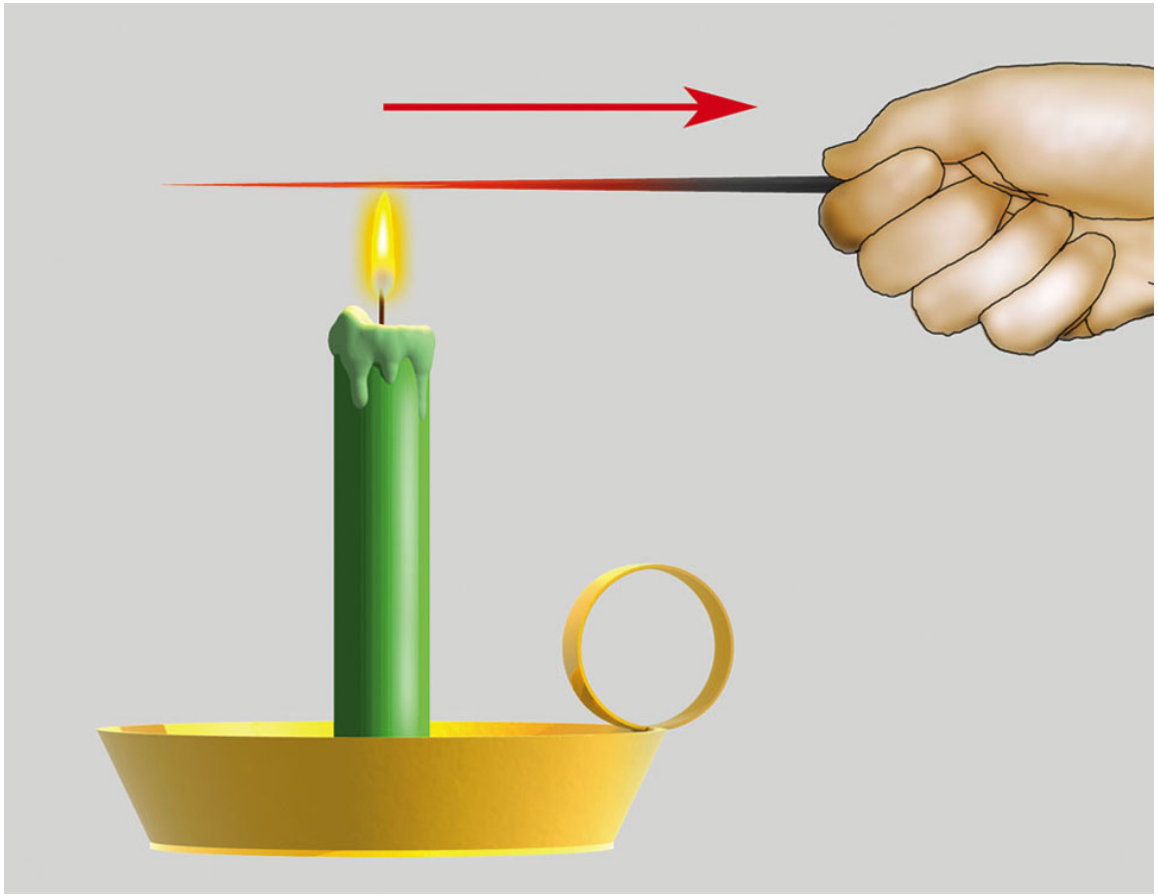




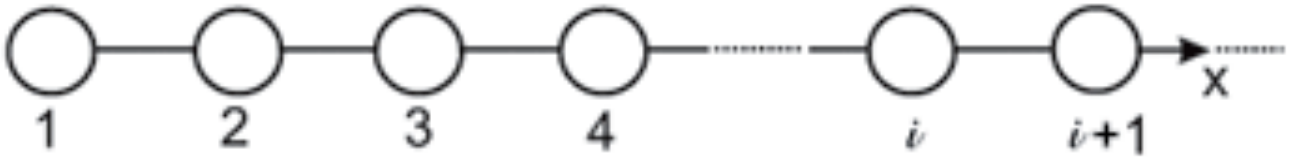
E. Maxwell, Phys. Rev. **86**, 235 (1952) and
B. Serin et al., Phys. Rev. B **86** 162 (1952))

http://www.chm.bris.ac.uk/webprojects2000/igrant/theory.html

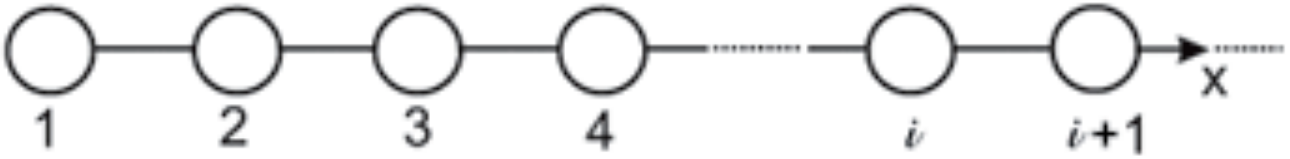
Phonons can conduct heat



Linear chain -Models

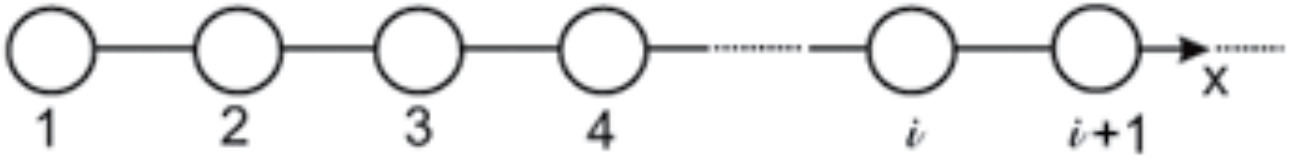


Structure factor: S = $\sum_i e^{-iqr_i}$



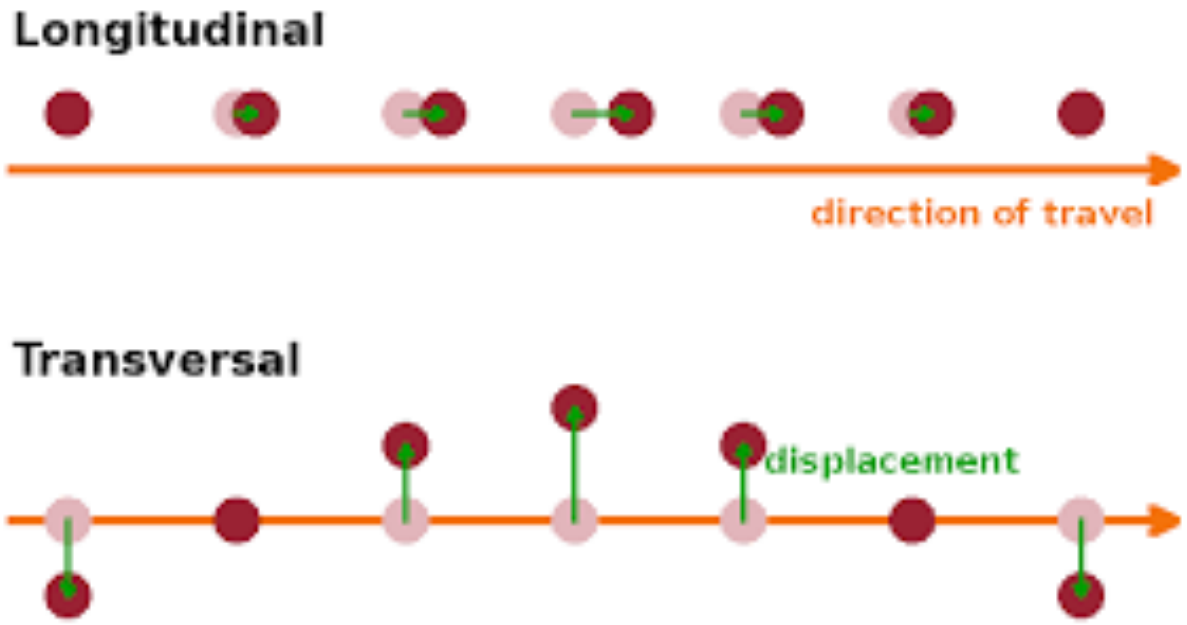
Madelungs constant: $\alpha = 2\ ln(2)$

Distortion Energy : $E = 0.5 * constant * \delta^2$



Phonon dispersion: $\omega =$

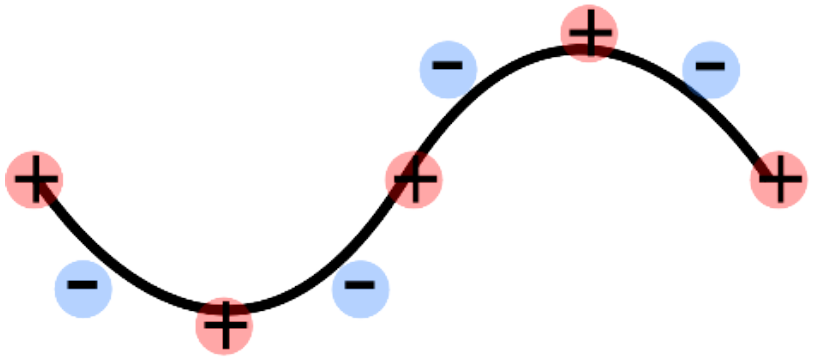
Longitudinal and Transverse Phonons



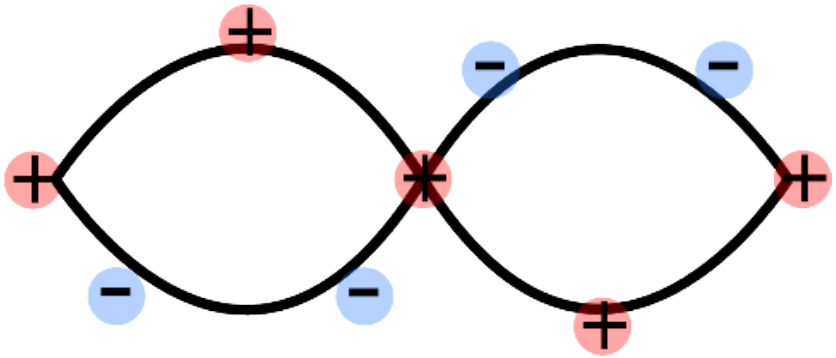
LA = Longitudinal Acoustic
LO = Longitudinal Optical
TA = Transversal Acoustic
TO = Transversal Optical

Acoustic and optical modes

Acoustical Mode



Optical Mode



LA = Longitudinal Acoustic
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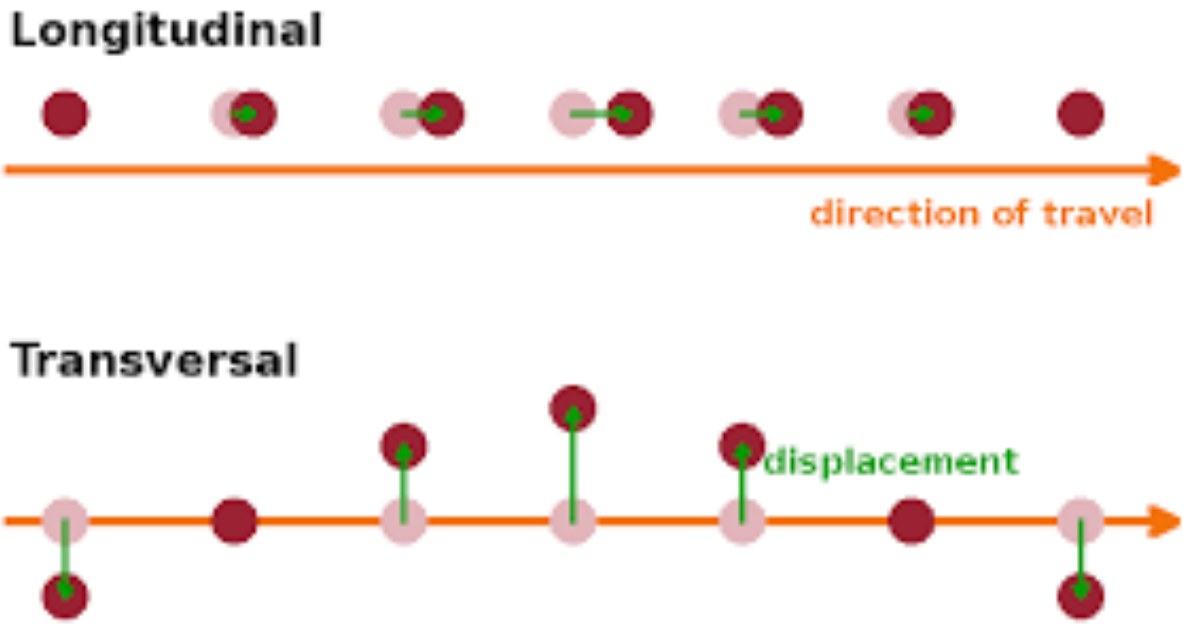
https://www2.warwick.ac.uk/fac/sci/physics/current/postgraduate/regs/mpags/ex5/phonons/

Number of phonon branches

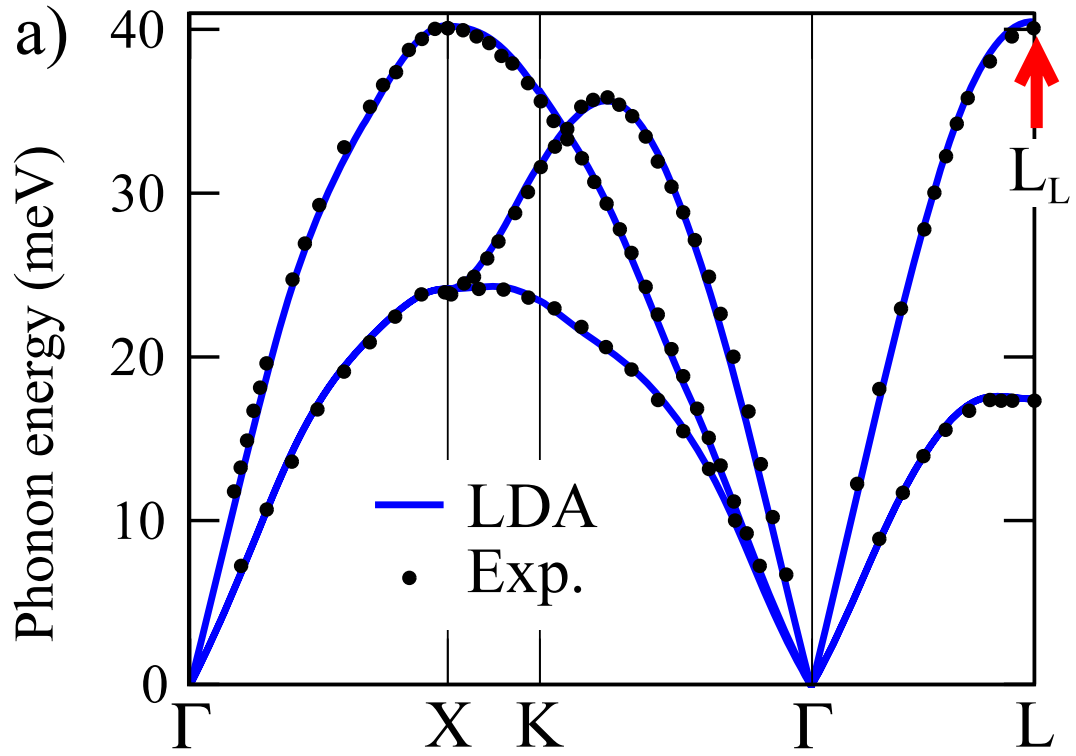


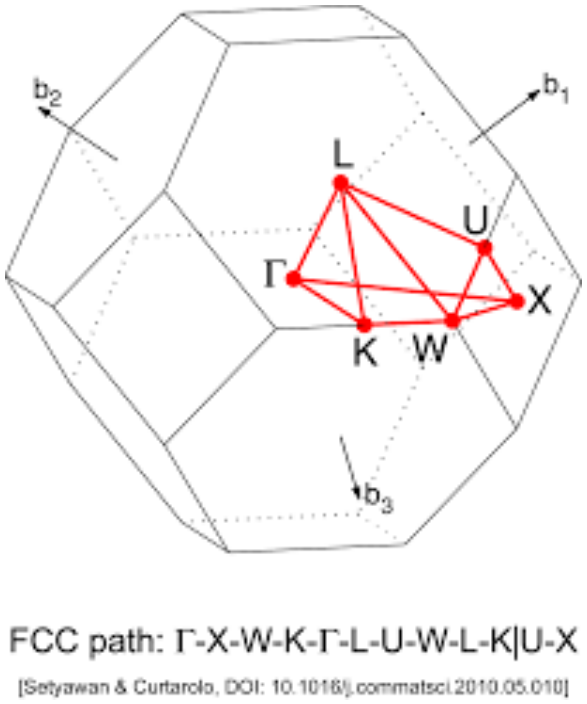
LA = Longitudinal Acoustic
LO = Longitudinal Optical
TA = Transversal Acoustic
TO = Transversal Optical

p = number of atoms in the primitive cell

3 acoustic branches
3p-3 optical branches
Total 3p phonon branches

Phonons in aluminium



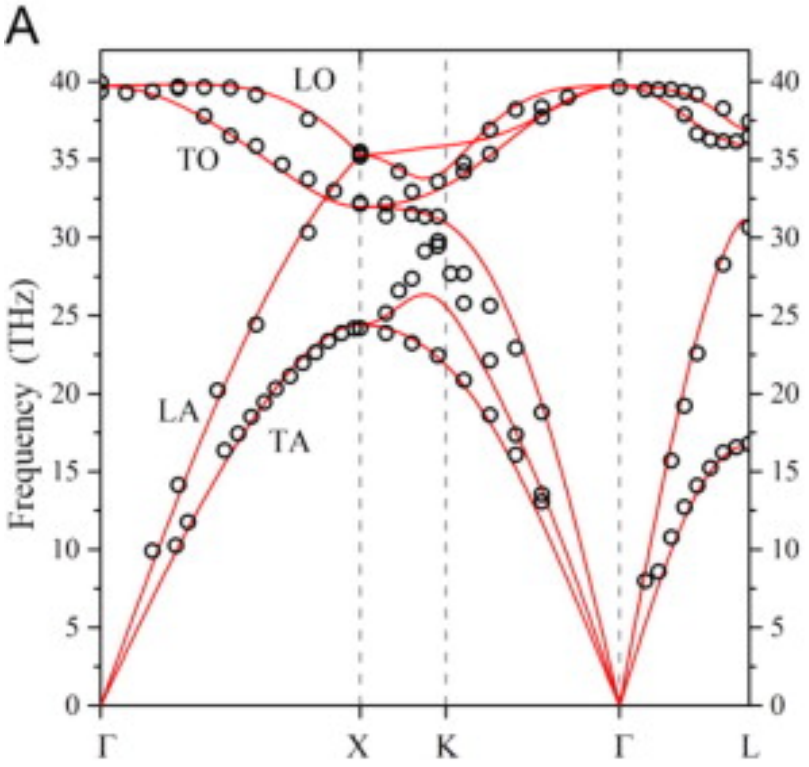


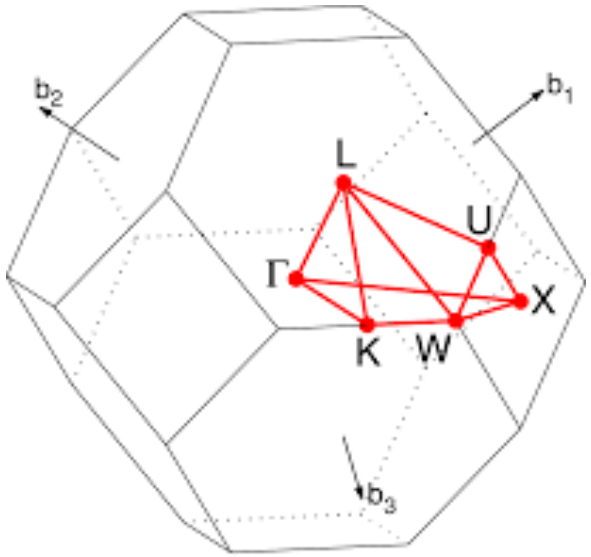
FCC path: Γ-X-W-K-Γ-L-U-W-L-K|U-X

[Setyawan & Curtarolo, DOI: 10.1016/j.commatsci.2010.05.010]

http://iopscience.iop.org/article/10.1088/0953-8984/24/5/053202

Phonons in diamond





FCC path: Γ-X-W-K-Γ-L-U-W-L-K|U-X

[Setyawan & Curtarolo, DOI: 10.1016/j.commatsci.2010.05.010]

1 THz = 4.14… meV