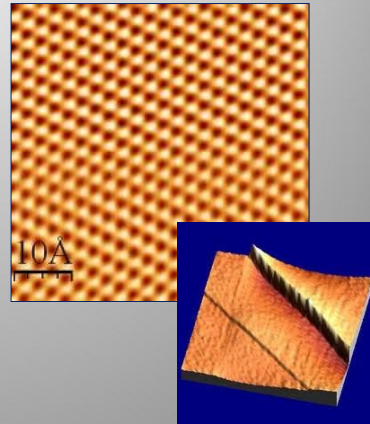


PHYS485

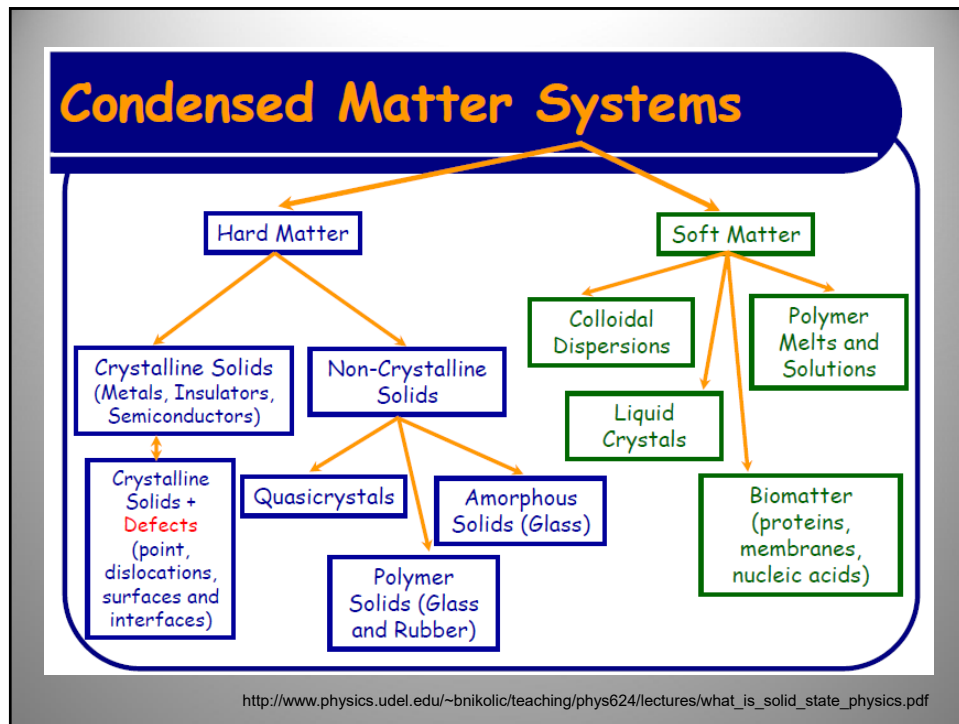
Materials Physics

Dr. Gregory W. Clark
Manchester University



Materials Physics

- **Condensed matter physics**
 - Solid state – crystalline vs. amorphous; strong interatomic/molecular interactions
 - Liquid state - no long range order; weak interatomic/molecular interactions
 - Exotic phases: e.g., superfluids, superconductors
- **Macroscopic & micro/nanoscale properties**
 - Bulk vs. surface/interface
 - Electrical, mechanical, thermal, magnetic



tentative!

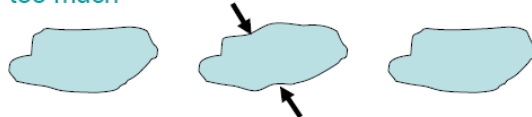
Outline for the First Half-Semester

- Bonding in Solids
- Static Structure of Crystals
- Dynamic Structure of Crystals
- Mechanical Properties
- Electrons in Solids

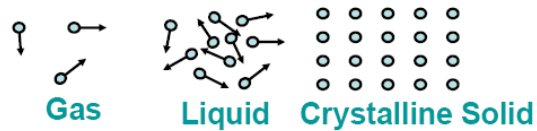
vibrational
behaviour

What is a solid?

- A material that keeps its shape
 - Can be deformed by stress
 - Returns to original shape **if it is not strained too much**



- Solid structure is defined by the atoms



<http://www.phys.psu.edu/~ralbert/phys412/chapter1.pdf>

Phenomena and Principles in **Materials Physics**

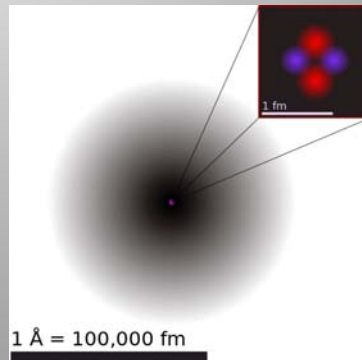
- | | | |
|---|---|--|
| <ul style="list-style-type: none"> • Mechanical <ul style="list-style-type: none"> – Structures – Strength | | <ul style="list-style-type: none"> • Newton's Laws |
| <ul style="list-style-type: none"> • Thermal <ul style="list-style-type: none"> – Heat capacity – Heat conduction – Phase transitions | | <ul style="list-style-type: none"> • Maxwell's Equations |
| <ul style="list-style-type: none"> • Electrical <ul style="list-style-type: none"> – Insulators – Metals – Semiconductors – Superconductors | ↔ | <ul style="list-style-type: none"> • Thermodynamics and Statistical Mechanics |
| <ul style="list-style-type: none"> • Magnetic <ul style="list-style-type: none"> – Ferromagnetism | | <ul style="list-style-type: none"> • Quantum Mechanics <ul style="list-style-type: none"> – Schrodinger's Equation – Pauli exclusion principle |
| <ul style="list-style-type: none"> • Optical <ul style="list-style-type: none"> – Reflection, refraction – Colors | | <ul style="list-style-type: none"> • Order and Symmetry |

<http://www.phys.psu.edu/~ralbert/phys412/chapter1.pdf>

Atoms

- An **atom** is a stable, electrically neutral unit of matter consisting of neutrons, protons, and electrons held together by electromagnetic and strong nuclear interactions.
- The central part of the an atom is its nucleus, containing n's and p's.
- Z = **atomic number**, specifies the number of p's and indicates the corresponding element
- $A = N + Z$, **atomic mass number**, specifies the **isotope** and the total number of nucleons in the nucleus (N = # neutrons)
- A_r = **atomic weight** (relative A), weighted average of naturally occurring isotopes

Recall that $q_p = -q_e = 1.602 \times 10^{-19} \text{ C}$



Periodic Table of the Elements

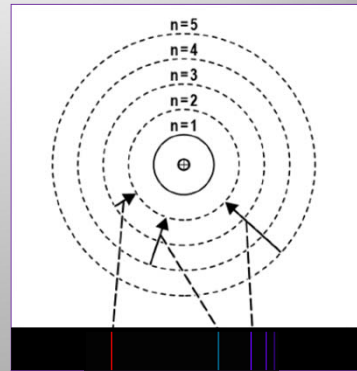
1 1A H Hydrogen 1.00794																	13 3A B Boron 10.811	14 4A C Carbon 12.011	15 5A N Nitrogen 14.007	16 6A O Oxygen 15.999	17 7A F Fluorine 18.998	18 8A Ne Neon 20.180	
3 Li Lithium 6.941	4 Be Beryllium 9.01218																	5 Al Aluminum 26.98154	6 Si Silicon 28.0855	7 P Phosphorus 30.97376	8 S Sulfur 32.06	9 Cl Chlorine 35.453	10 Ar Argon 39.948
11 Na Sodium 22.98976	12 Mg Magnesium 24.304	3 Sc Scandium 44.95591	4 Ti Titanium 47.88	5 V Vanadium 50.9415	6 Cr Chromium 51.9961	7 Mn Manganese 54.938	8 Fe Iron 55.845	9 Co Cobalt 58.9332	10 Ni Nickel 58.6934	11 Cu Copper 63.546	12 Zn Zinc 65.38	13 Ga Gallium 69.723	14 Ge Germanium 72.64	15 As Arsenic 74.9216	16 Se Selenium 78.96	17 Br Bromine 79.904	18 Kr Krypton 83.80						
37 Rb Rubidium 85.4678	38 Sr Strontium 87.62	39 Y Yttrium 88.90584	40 Zr Zirconium 91.224	41 Nb Niobium 92.90638	42 Mo Molybdenum 95.94	43 Tc Technetium 98.9062	44 Ru Ruthenium 101.07	45 Rh Rhodium 101.07	46 Pd Palladium 106.42	47 Ag Silver 107.8682	48 Cd Cadmium 112.411	49 In Indium 114.818	50 Sn Tin 118.71	51 Sb Antimony 121.757	52 Te Tellurium 127.6	53 I Iodine 126.90447	54 Xe Xenon 131.29						
55 Cs Cesium 132.90545	56 Ba Barium 137.327	57-71 Lanthanide Series		72 Hf Hafnium 178.49	73 Ta Tantalum 180.9479	74 W Tungsten 183.85	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.9665	80 Hg Mercury 200.59	81 Tl Thallium 204.3833	82 Pb Lead 207.2	83 Bi Bismuth 208.98037	84 Po Polonium 209	85 At Astatine 210	86 Rn Radon 222.0175					
87 Fr Francium 223	88 Ra Radium 226	89-103 Actinide Series		104 Rf Rutherfordium 261	105 Db Dubnium 262	106 Sg Seaborgium 266	107 Bh Bohrium 264	108 Hs Hassium 277	109 Mt Meitnerium 268	110 Ds Darmstadtium 271	111 Rg Roentgenium 272	112 Cn Copernicium 285	113 Uut Ununtrium 284	114 Uuq Ununquadium 289	115 Uup Ununpentium 288	116 Uuh Ununhexium 289	117 Uus Ununseptium 286	118 Uuo Ununoctium 294					
				57 La Lanthanum 138.90548	58 Ce Cerium 140.116	59 Pr Praseodymium 140.90766	60 Nd Neodymium 144.24	61 Pm Promethium 144.9127	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92534	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93032	68 Er Erbium 167.26	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.04	71 Lu Lutetium 174.967					
				89 Ac Actinium 227	90 Th Thorium 232.0377	91 Pa Protactinium 231.03688	92 U Uranium 238.02891	93 Np Neptunium 237.04817	94 Pu Plutonium 244.0642	95 Am Americium 243.06136	96 Cm Curium 247.07645	97 Bk Berkelium 247.06715	98 Cf Californium 251.0832	99 Es Einsteinium 252.083	100 Fm Fermium 257.10	101 Md Mendelevium 258.10	102 No Nobelium 259.10	103 Lr Lawrencium 260.10					
				<div style="display: flex; justify-content: space-around; align-items: center;"><div style="text-align: center;">Alkali Metal</div><div style="text-align: center;">Alkaline Earth</div><div style="text-align: center;">Transition Metal</div><div style="text-align: center;">Basic Metal</div><div style="text-align: center;">Semimetals</div><div style="text-align: center;">Nonmetals</div><div style="text-align: center;">Halogens</div><div style="text-align: center;">Noble Gas</div><div style="text-align: center;">Lanthanides</div><div style="text-align: center;">Actinides</div></div>																			
<div style="display: flex; justify-content: space-around; align-items: center;"><div style="text-align: center;">↑ groups ↓</div><div style="text-align: center;">← periods →</div></div>																							

Atomic Structure: Emission Spectra

- For example: **Hydrogen!**
- As excited electrons relax to lower energy levels, photons are emitted of energy $E = h \nu = h c / \lambda$.

$$(h = 6.63 \times 10^{-34} \text{ Js})$$

- 1885, **Balmer**: $\lambda = 364.56 \text{ nm} \left(\frac{m^2}{m^2 - 2^2} \right)$
(for visible lines, empirically)
($m = \text{integer} > 2$)
- 1888, **Rydberg**: $\lambda^{-1} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$
($n_1 < n_2 = \text{integers}$)
($R_H = 1.097 \times 10^7 \text{ m}^{-1}$)



- 1911, **Bohr**: causal explanation for these observations!



Atomic Structure

- Atomic orbitals/electron shells**: energy levels or energy states that electrons can occupy
- These energy levels are quantized.
- Each denoted by **principle quantum number, n**

