

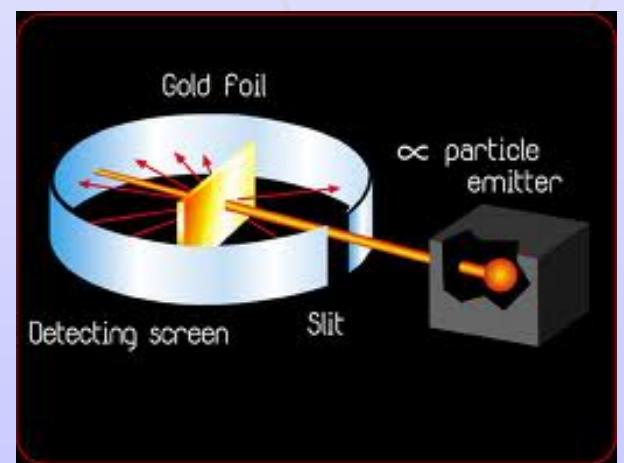
# 1911-2011: Cento anni di modello planetario dell'atomo. Cos'altro abbiamo imparato su atomi, molecole e solidi in questo secolo?



**Giovanni Carlotti**

Dipartimento di Fisica, Università di Perugia

*« Fu l'evento più incredibile mai successomi in vita mia. Era quasi incredibile quanto lo sarebbe stato sparare un proiettile da 15 pollici a un foglio di carta velina e vederlo tornare indietro e colpirti. » (Ernest Rutherford)*



## Atoms & Molecules

## History

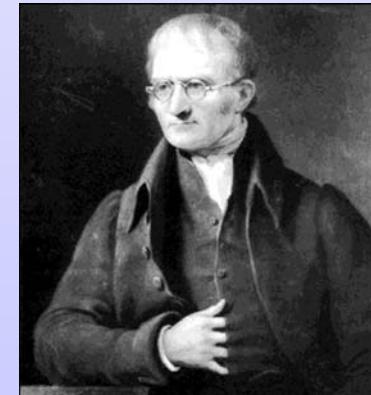
~400 BC - suggested the existence of atoms.

Democritus  
existence of

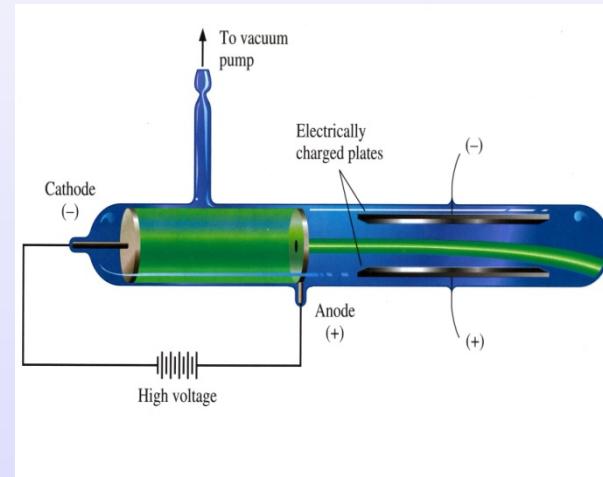
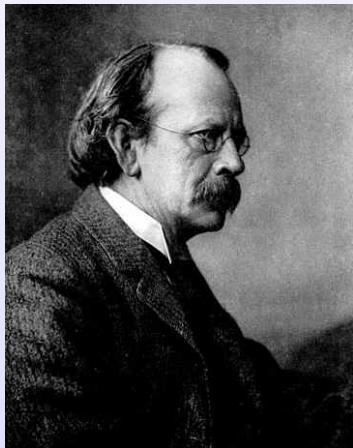
1783 - Antoine Lavoisier found that matter is not created nor destroyed in a chemical reaction. Known as "father of modern chemistry."



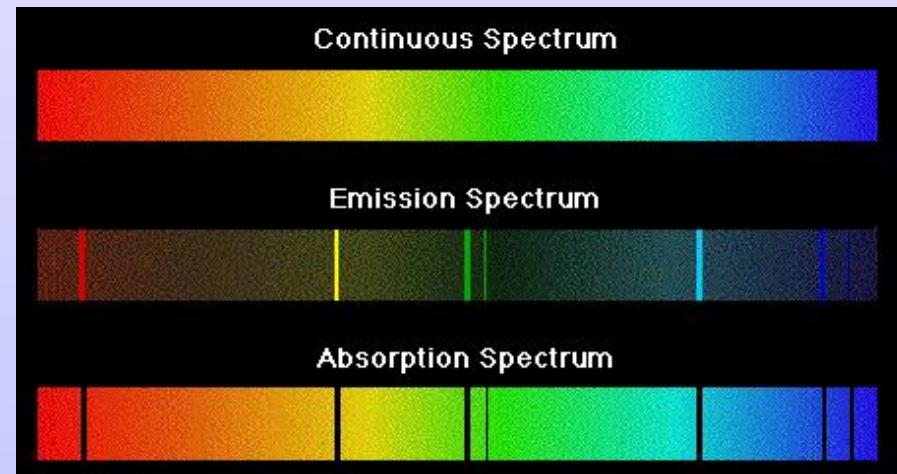
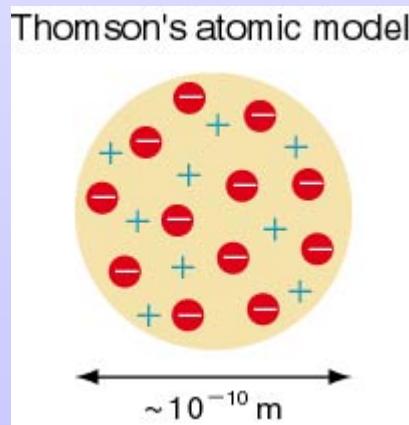
1803 - John Dalton proposed that matter is made up of tiny atoms; that atoms of the same element are alike; & that atoms combine in definite ratios to form compounds. This set aside false idea promoted by Aristotle 2000 years earlier that matter was continuous, and reaffirmed Democritus's early "atomic model."



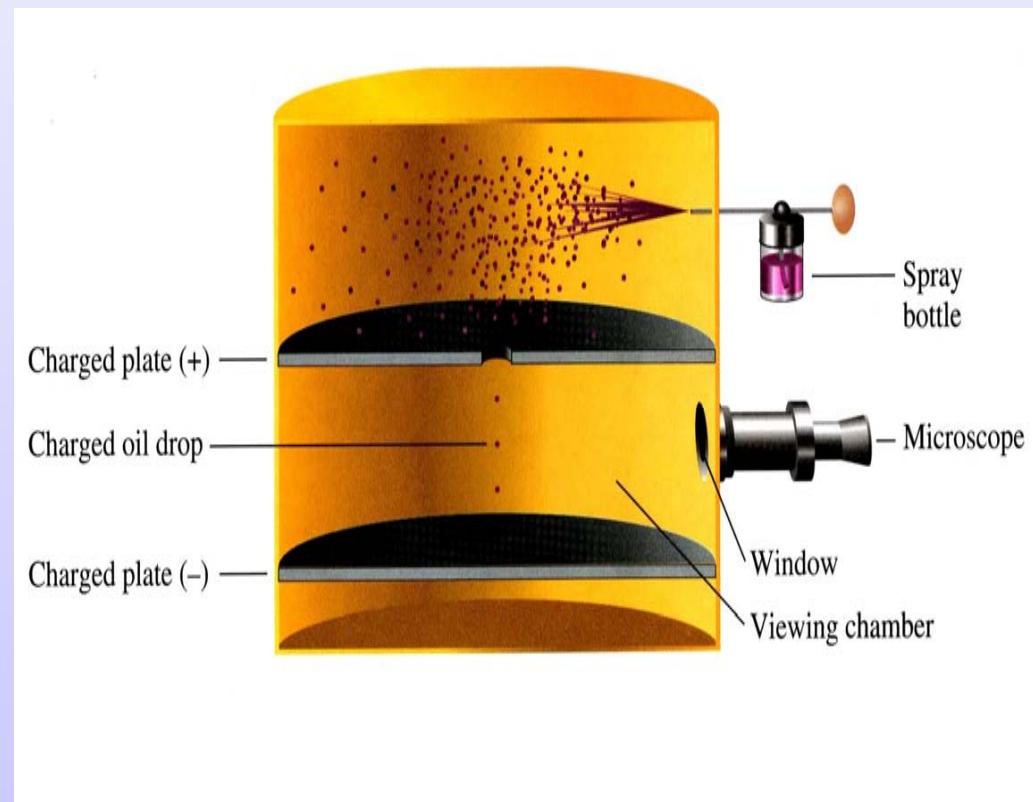
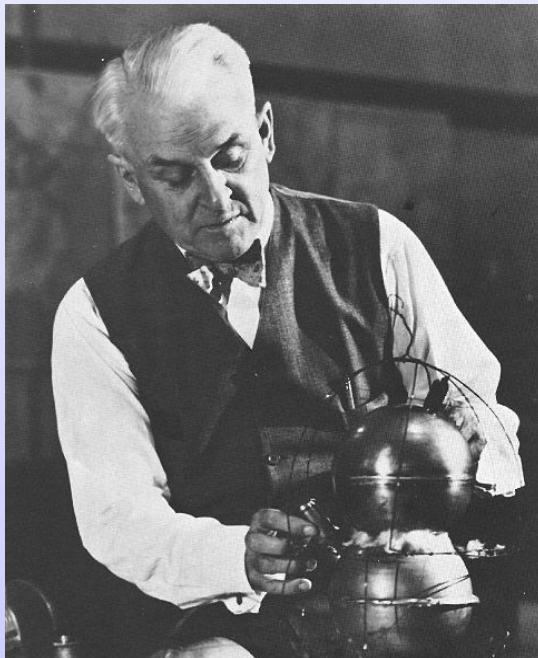
1897 – Joseph Thomson used the cathode-ray tube and discovered the electron.



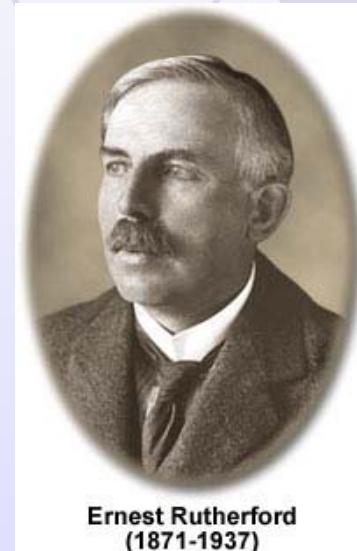
● 1904 – Thomson's atomic model



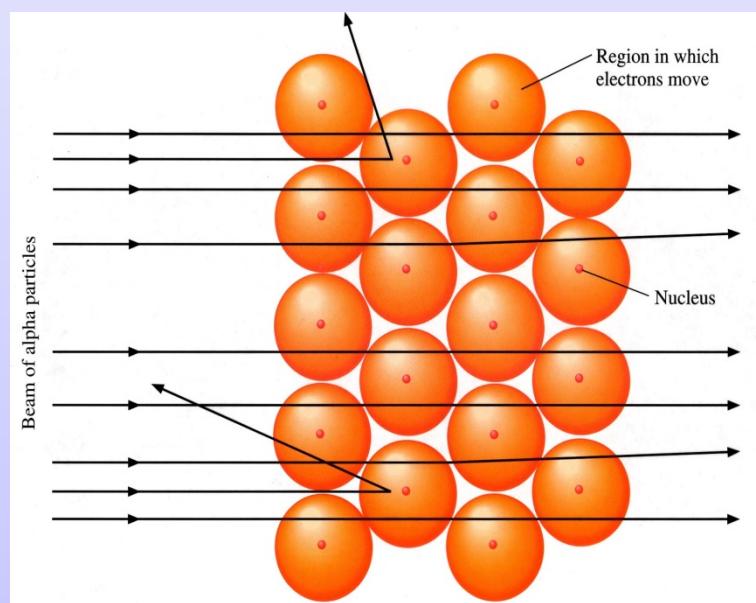
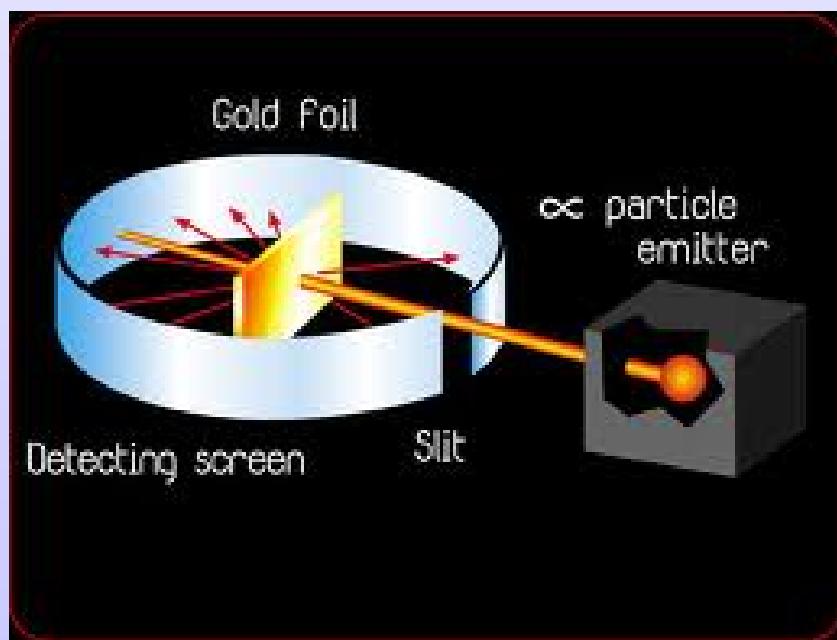
- 1886 - Eugene Goldstein demonstrated existence of + particles, protons. These particles later found to have a charge of +1 ( $1.60 \times 10^{-19}$  coulombs) and a mass of  $1.67 \times 10^{-24}$  g (a mass of 1.00 AMU).
- 1909 - Robert Millikan determined mass ( $9.11 \times 10^{-28}$  g; ~1800 less than proton) and -1 charge ( $-1.60 \times 10^{-19}$  coulombs) of an electron.



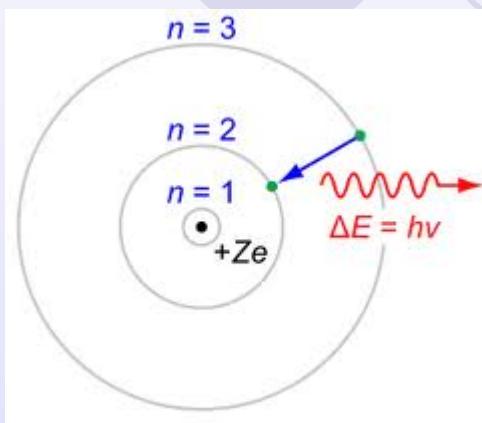
1911 - Ernest Rutherford (a New Zealand physicist) demonstrated the nuclear nature of the atom in which the empty space is 10,000 to 100,000 times larger than the size of the nucleus.



Ernest Rutherford  
(1871-1937)



## 1913. Bohr's atom



$$\Delta E = E_2 - E_1 = h\nu ,$$

$$L = n \frac{h}{2\pi} = n\hbar$$



$$E_2 - E_1 = E_0 \left( \frac{1}{n_2^2} - \frac{1}{n_1^2} \right)$$

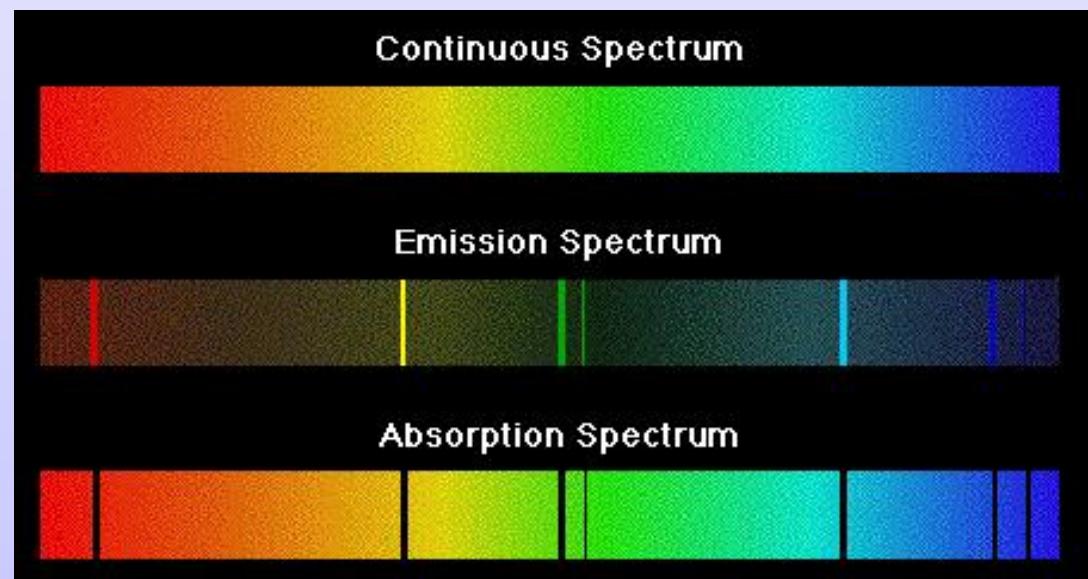
$$ma \quad E_2 - E_1 = h\nu = \frac{hc}{\lambda}$$

$$\frac{1}{\lambda} = \frac{E_0}{hc} \left( \frac{1}{n_2^2} - \frac{1}{n_1^2} \right)$$

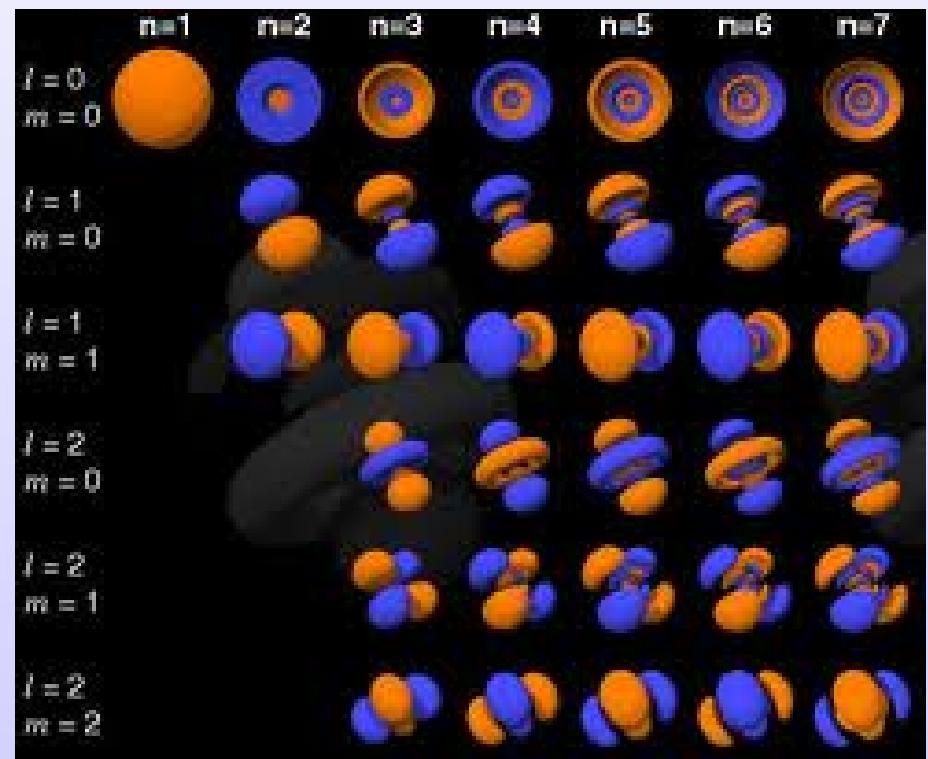
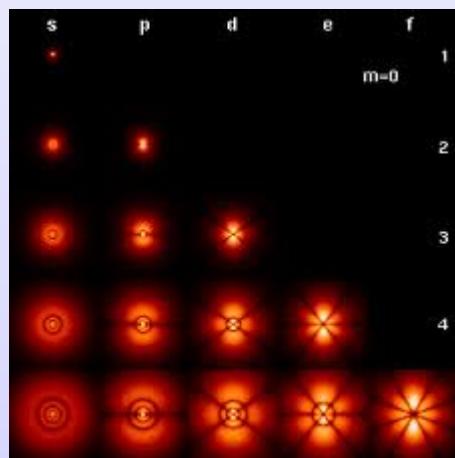
$$\frac{1}{\lambda} = R \left( \frac{1}{n_2^2} - \frac{1}{n_1^2} \right)$$



## Atomic spectra



# Electronic orbitals and wavefunction: probabilistic interpretation



## We can now “see” atoms

$H^+ \sim 10^{-15} \text{ m diam.}$

$H^\circ \sim 10^{-10} \text{ m diam.}$

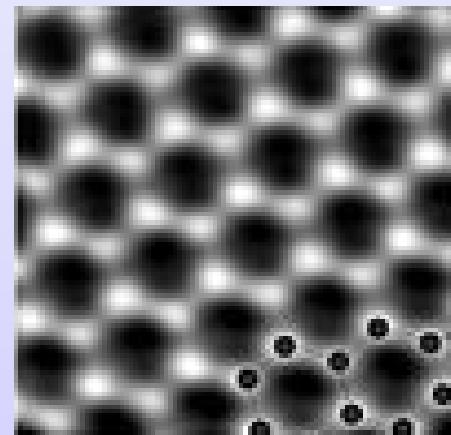
Mass  $H = 1.67 \times 10^{-27} \text{ kg}$

Note:  $6.02 \times 10^{23} = \text{Avogadro's Number}$

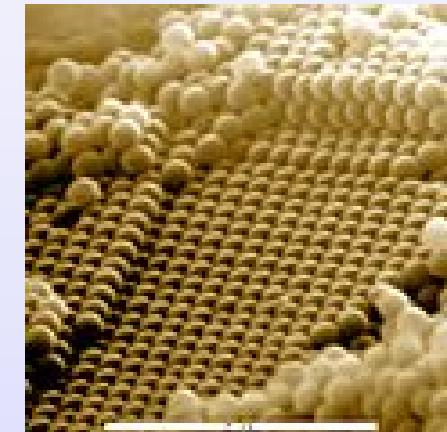
$$(6.02 \times 10^{23}) \times (1.67 \times 10^{-24} \text{ g}) = 1.00 \text{ g}$$

- The following are images of

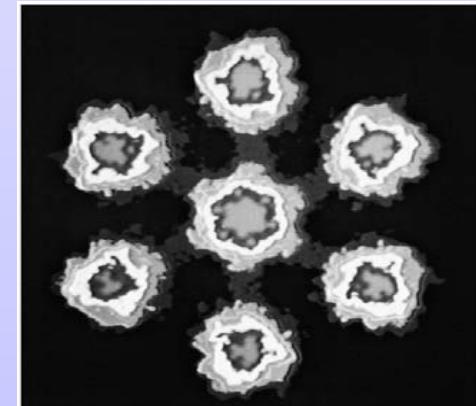
- 1) Latex Molecules



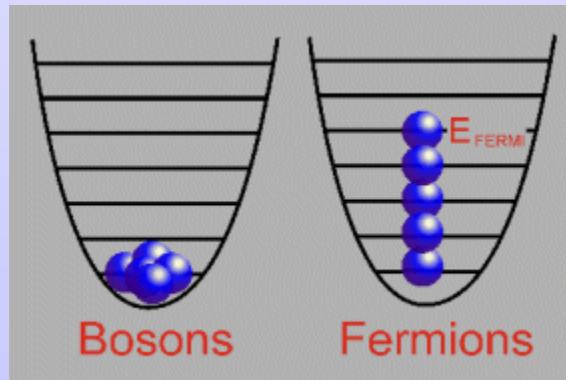
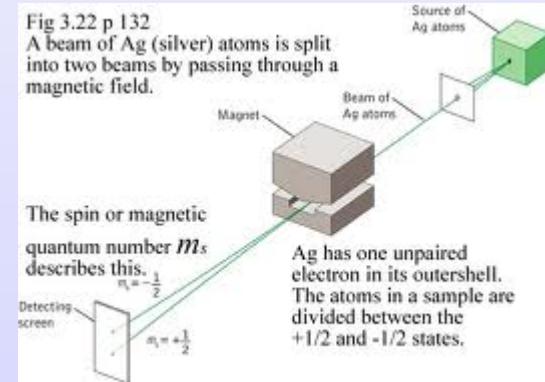
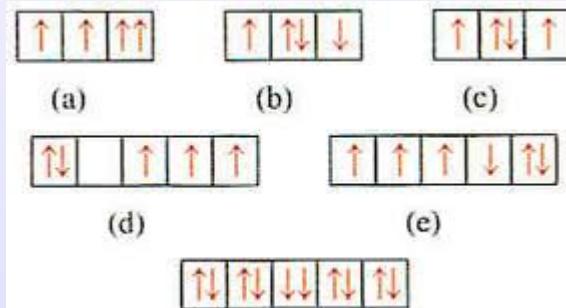
- 2) C in Graphene



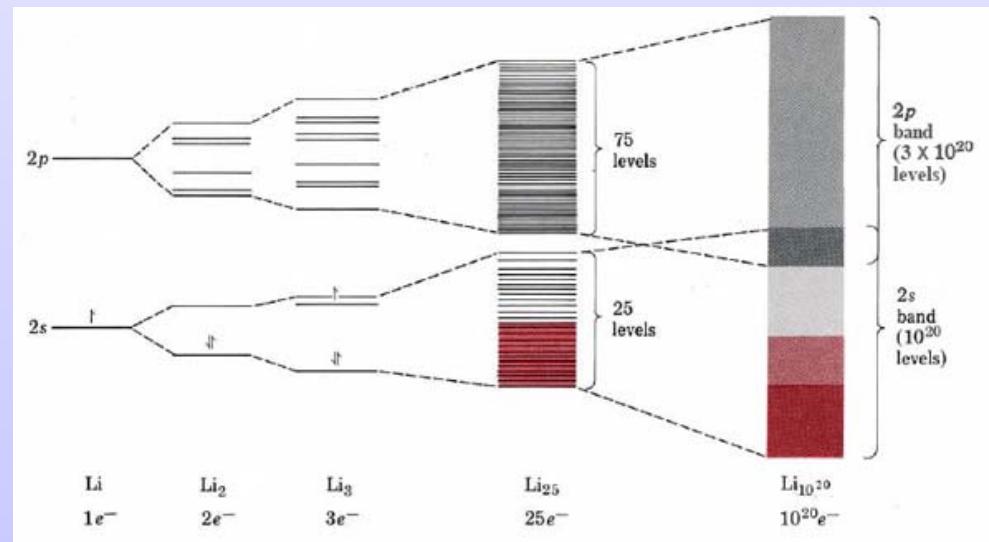
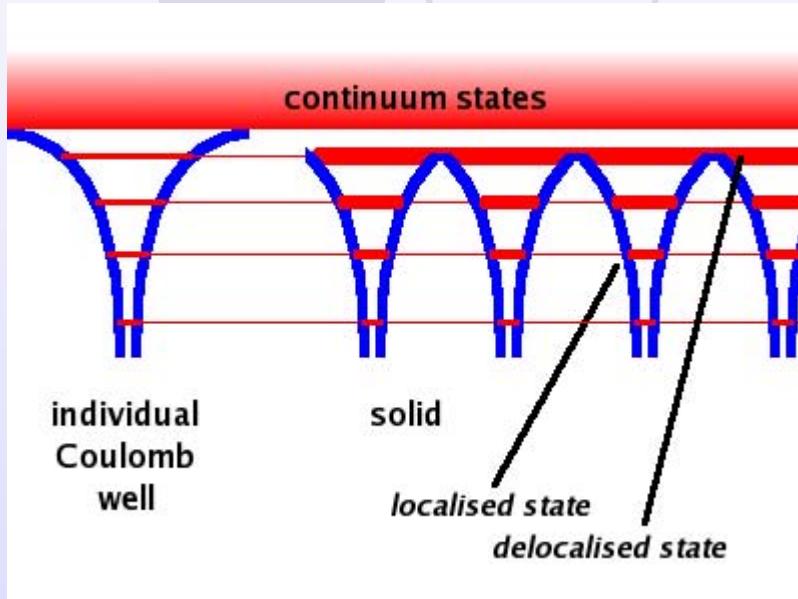
- 3) U atoms



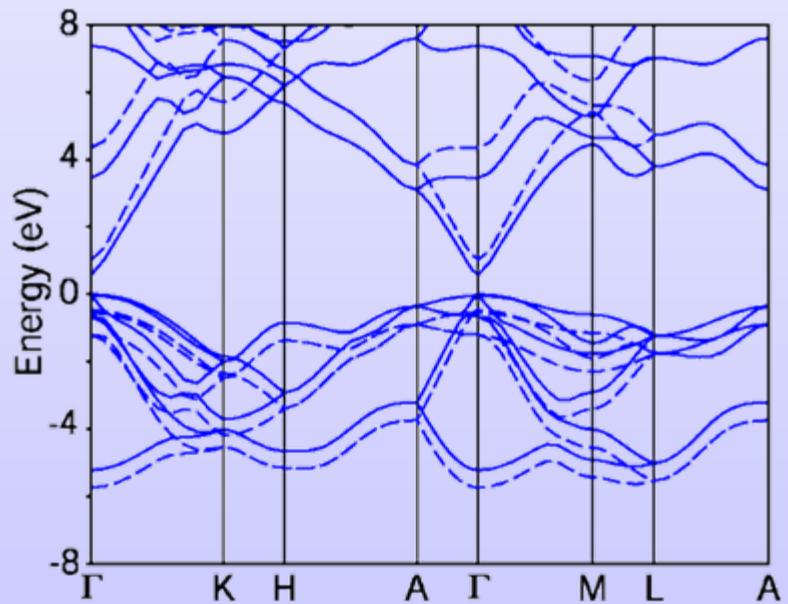
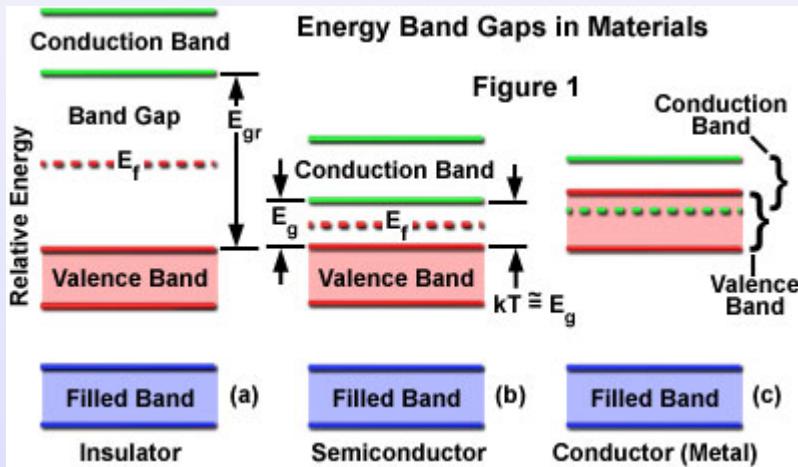
# Pauli exclusion principle: fermions



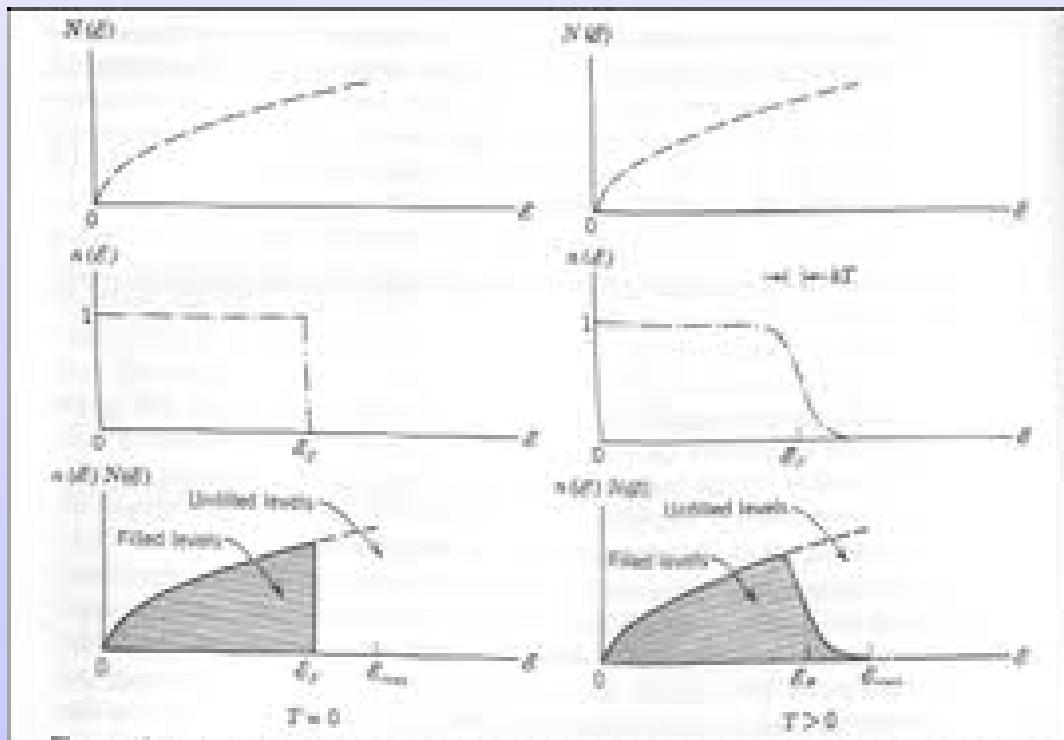
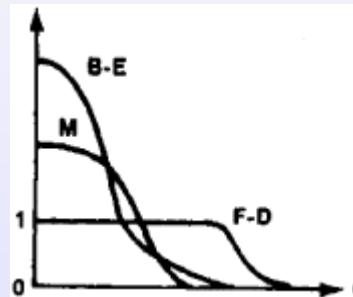
# From single atoms, to molecules and solids



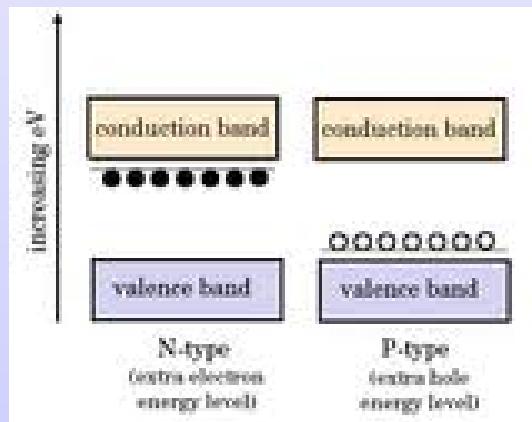
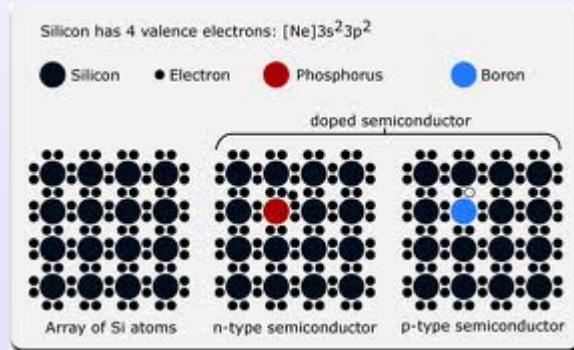
# Energy bands in different materials



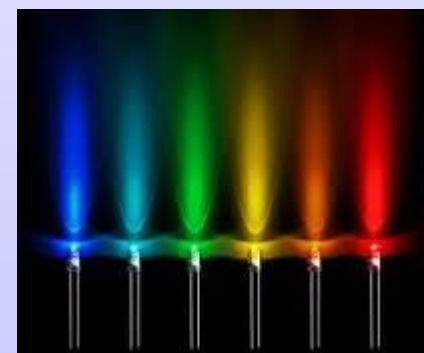
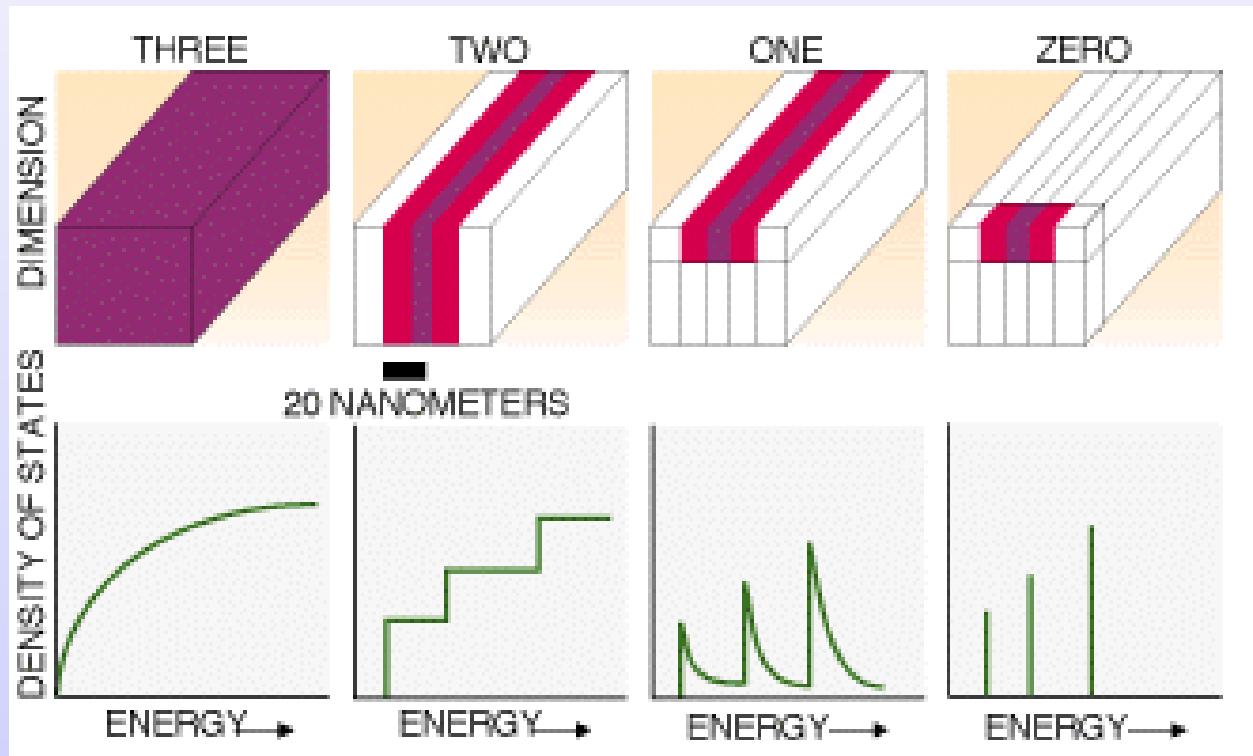
# Conductors and «quantum novelty»

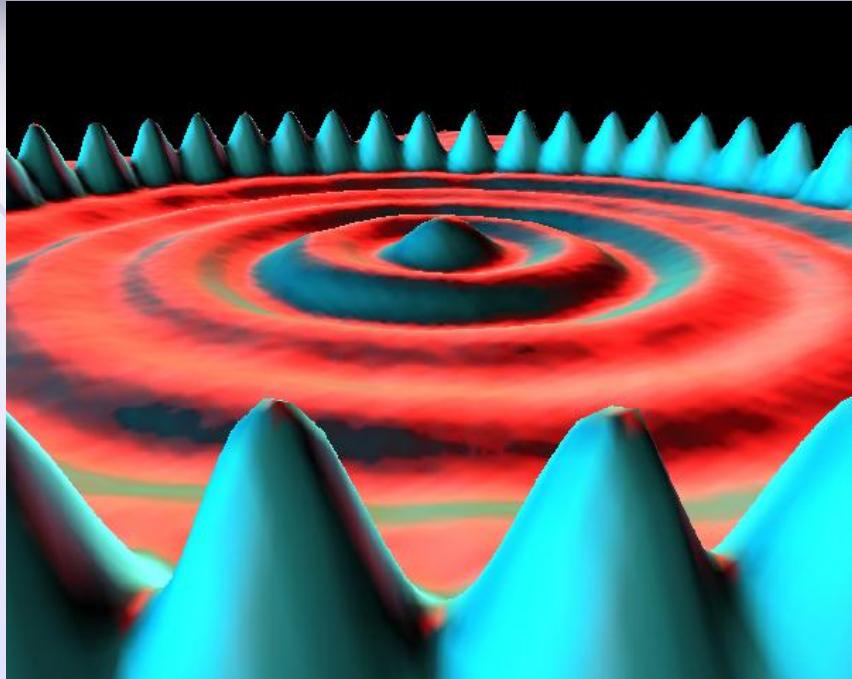


# Doped semiconductors and electronic devices



# Artificial atoms?





The corral is an artificial structure created from 48 iron atoms (the sharp peaks) on a copper surface. The wave patterns in this scanning tunneling microscope image are formed by copper electrons confined by the iron atoms. Don Eigler and colleagues created this structure in 1993 by using the tip of a low-temperature scanning tunneling microscope (STM) to position iron atoms on a copper surface, creating an electron-trapping barrier. This was the first successful attempt at manipulating individual atoms and led to the development of new techniques for nanoscale construction.



**THE END**