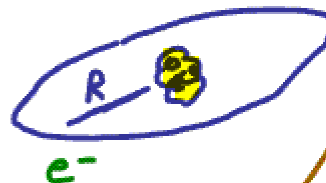
Physics 100 - February 26, 2007

- Exam - I heard it was lots of fun! ☺
  - Still being graded
  - Expect to have for you by Wednesday

Last Time



Nucleus Atom
Circular motion
Stable, discrete, fixed orbits
γ emitted/absorbed as e⁻ makes transitions between orbits

Bohr Model of the atom

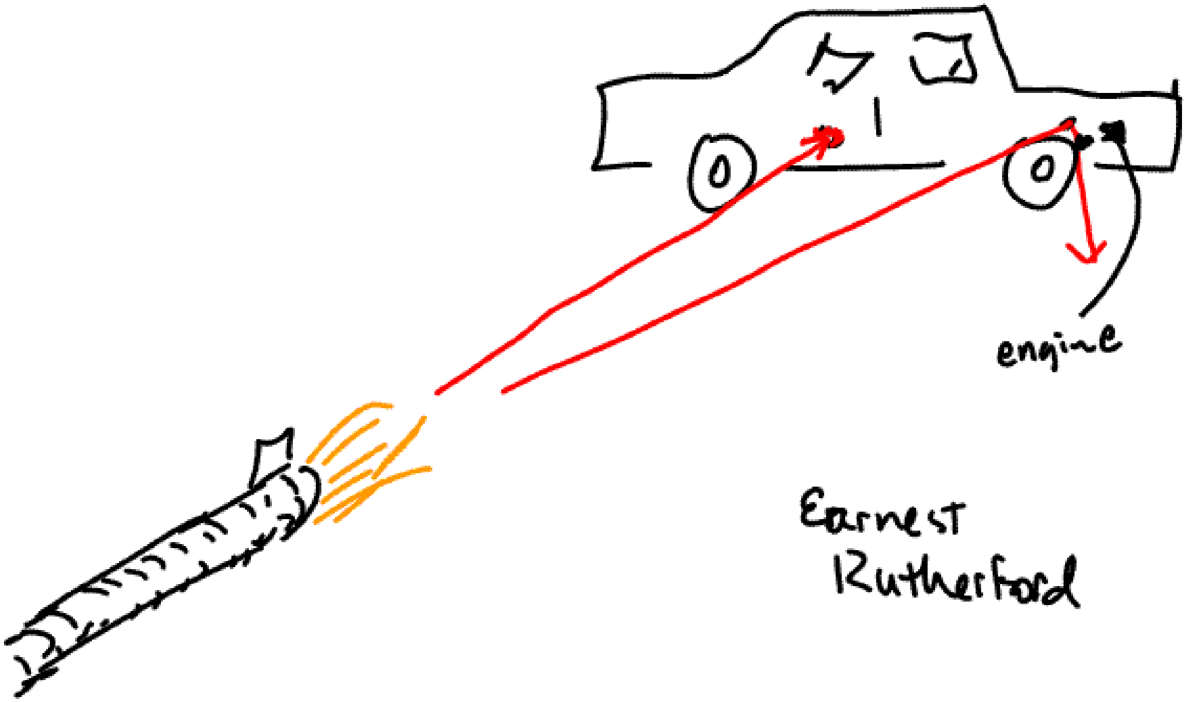
What characterizes it?

Why is it important? — 1st quantum Model of atom; explained discrete Atomic spectra

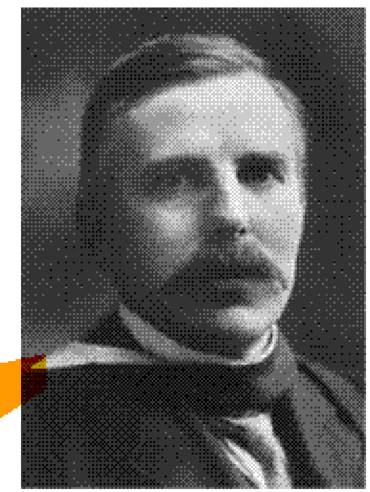
In what ways was it a successful Model?

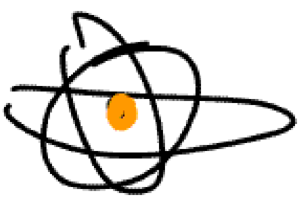
What were shortcomings? — quantization ad hoc

How did Bohr know to go with a "nuclear" atom?



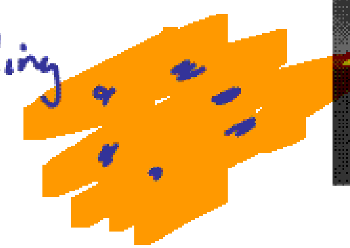
Earnest Rutherford

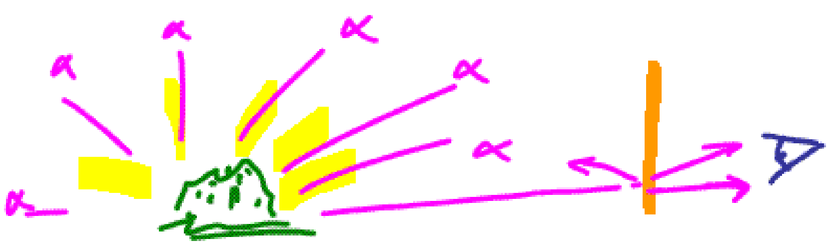




nuclear

plum pudding





Probability of scattering off thin gold foil → nucleus very small

Quantum Mechanics

Heisenberg

Schrödinger

Wave equation for matter waves

$$-\frac{\hbar^2}{2m}\frac{d^2\psi(x)}{dx^2} + V\psi(x) = E\psi(x)$$

Schrödinger's Equation

Plug in "potential" describing the physical situation

Solve for $\psi(x)$ and possible energies

Wave function

Put in e^- — p

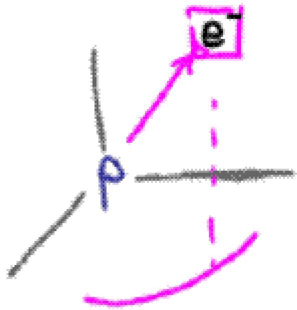
+ Coulomb

↳ get discrete allowed orbitals and energies for e^- in atom.

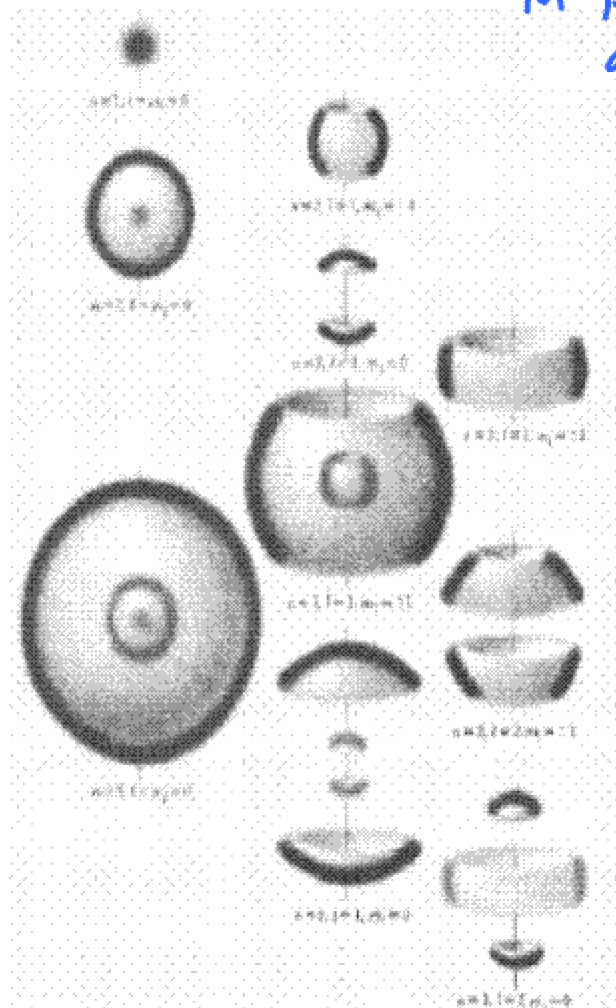
QM treatment of H atom

wave mechanics

Spherical Symmetry



Shapes of allowed electron states in Hydrogen atom



Energy or principal quantum number

n = 1, 2, 3 ...

Orbital quantum number

l = 0, 1, ... n-1

Magnetic quantum number

-l, -(l-1), ..., 0, 1, ... l-1, l

Similar to Bohr – discrete states

But orbits are not circular

* Look at Falstad's Applet on Lecture links page

Schrödinger solved p — e^- situation

$\Rightarrow$ Solves for Allowed energies and "orbitals" for the H atom

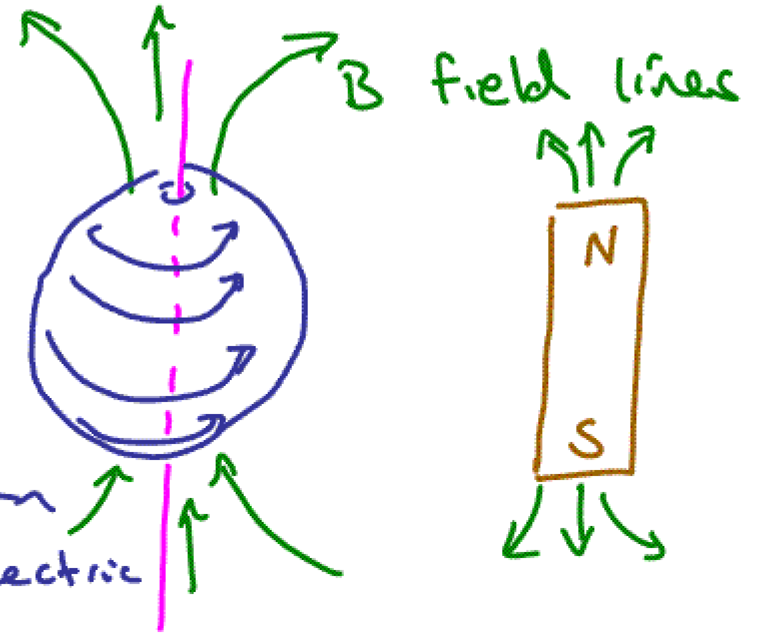
These allowed orbitals have different energies

To really understand chemistry we need to see how to put multiple electrons in a single atom.
How do electrons stack up in the orbitals??

To understand this we need to understand something of a surprise <u>discovery</u>

Electrons and other particles have **intrinsic SPIN**

Spin



Imagine that the electron is a uniform ball of electric charge that "spins"

It would be like a little current loop

current loops create magnetic fields that look like Magnetic fields coming from a bar magnet

Particles w/ spin have "magnetic Moments" and look like tiny little bar magnets

This was discovered in 1922 by Stern + Gerlach

Stern-Gerlach experiment — 1922

→ Discovery that electrons have spin

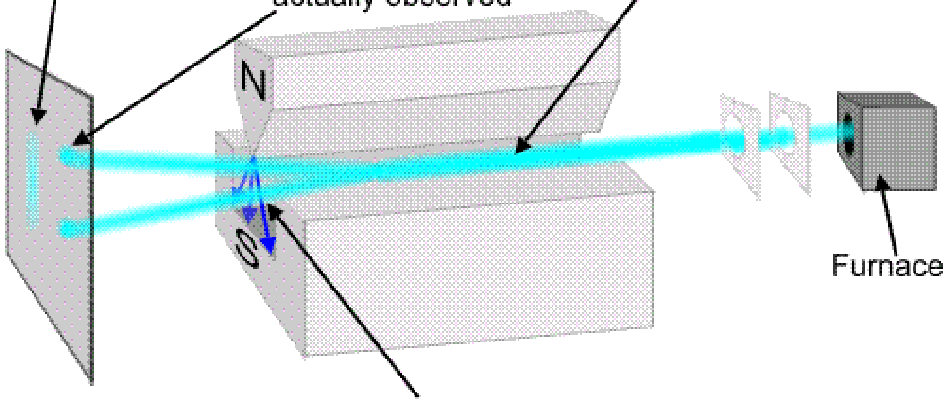


Diagram from Wikipedia

Otto Stern

-wikipedia

"If this nonsense from Bohr will prove to be right we will quit physics."
(Stern vowed in 1913)

as quoted in Phys. Today Dec 03

Walther Gerlach

from Phys Today article (Dec. 03)

Spin is quantized

$0, \frac{1}{2}, 1, 3/2, 2 \ldots$

Integer Spin $0, 1, 2 \ldots \Rightarrow$ Boson

½-integer Spin $\frac{1}{2}, 3/2, 5/2 \ldots \Rightarrow$ Fermion

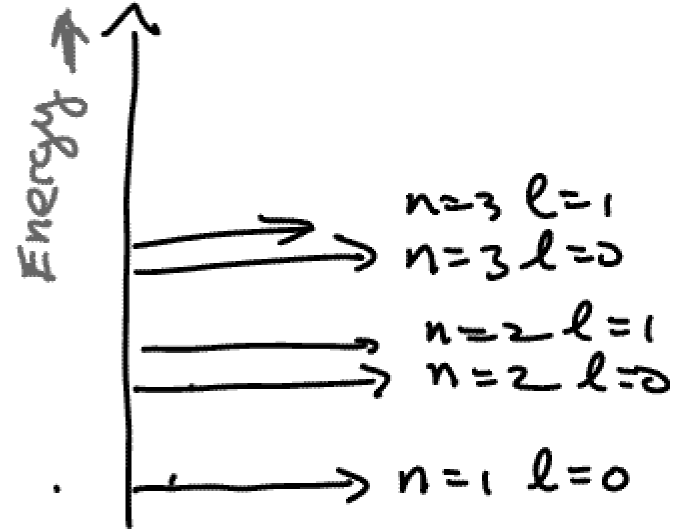
It's like you can only have bar magnets with certain discrete strengths

2 identical Fermions → cannot occupy the same quantum state

2 identical Bosons → can occupy the same quantum state

Schrödinger's eqn gives allowed energy states for e^- in atom

They vary in energy like so →



n = energy quantum number
l = orbital angular momentum quantum number

→ These characterize the state ... determine the orbital

Z ↓	ATOM ↓	n = 1, l = 0	n = 2, l = 0	n = 2, l = 1			n = 3, l = 0
1	H	↑	—	—	—	—	—
2	He	↑↓	—	—	—	—	—
3	Li	↑↓	↑	—	—	—	—
4	Be	↑↓	↑↓	—	—	—	—
5	B	↑↓	↑↓	↑	—	—	—
⋮							
11	Na	↑↓	↑↓	↑↓	↑↓	↑↓	↑

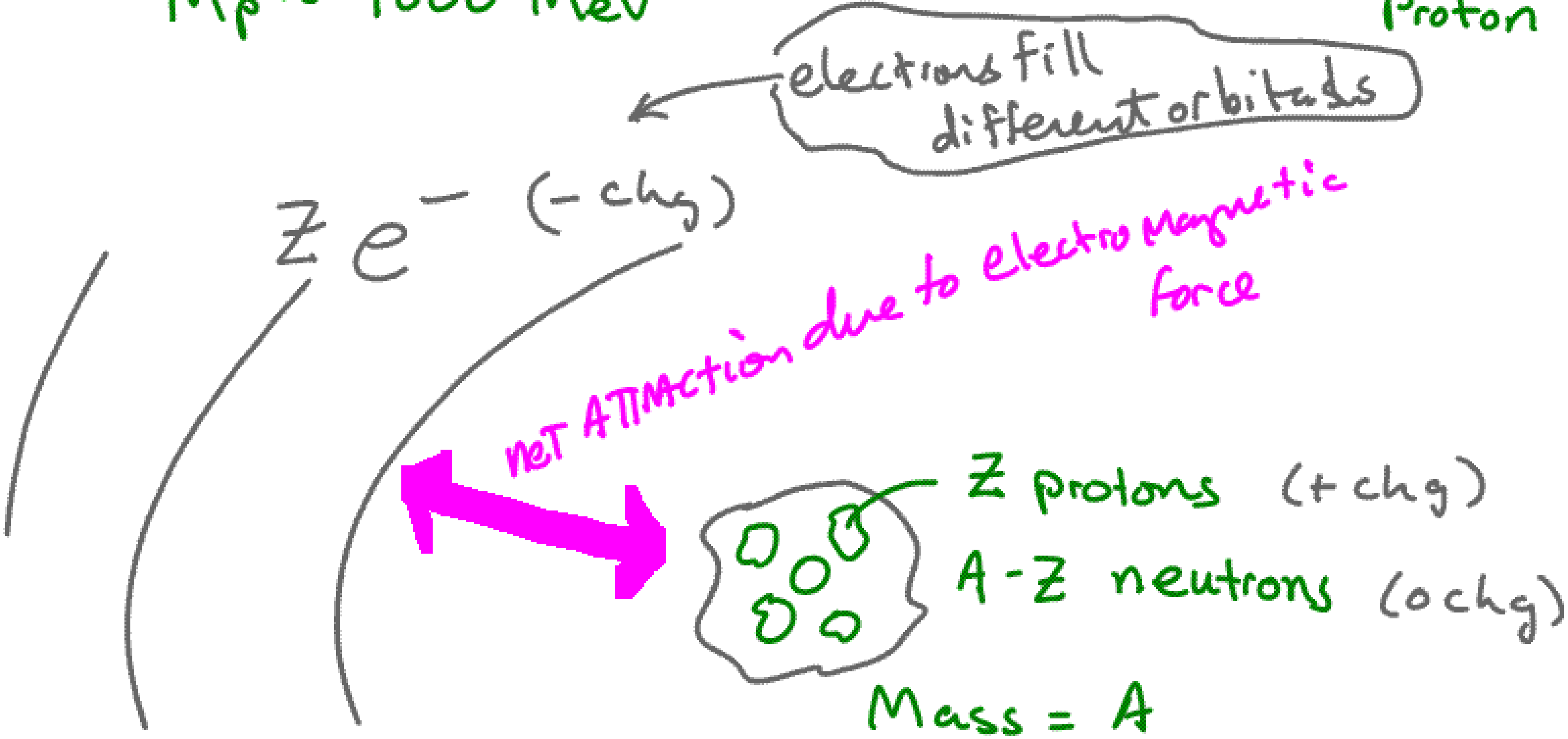
Electrons fill levels lowest energy to highest

They do NOT all crowd into lowest level because they are <u>Fermions</u>

$M_e = .5\ MeV/c^2$

$M_p \sim 1000\ MeV$

Mass of 1 A = Mass of Proton



The Atom

The way in which the orbitals are filled means there is Periodicity in ATomic characteristics as Z increases

Periodic Table of the elements

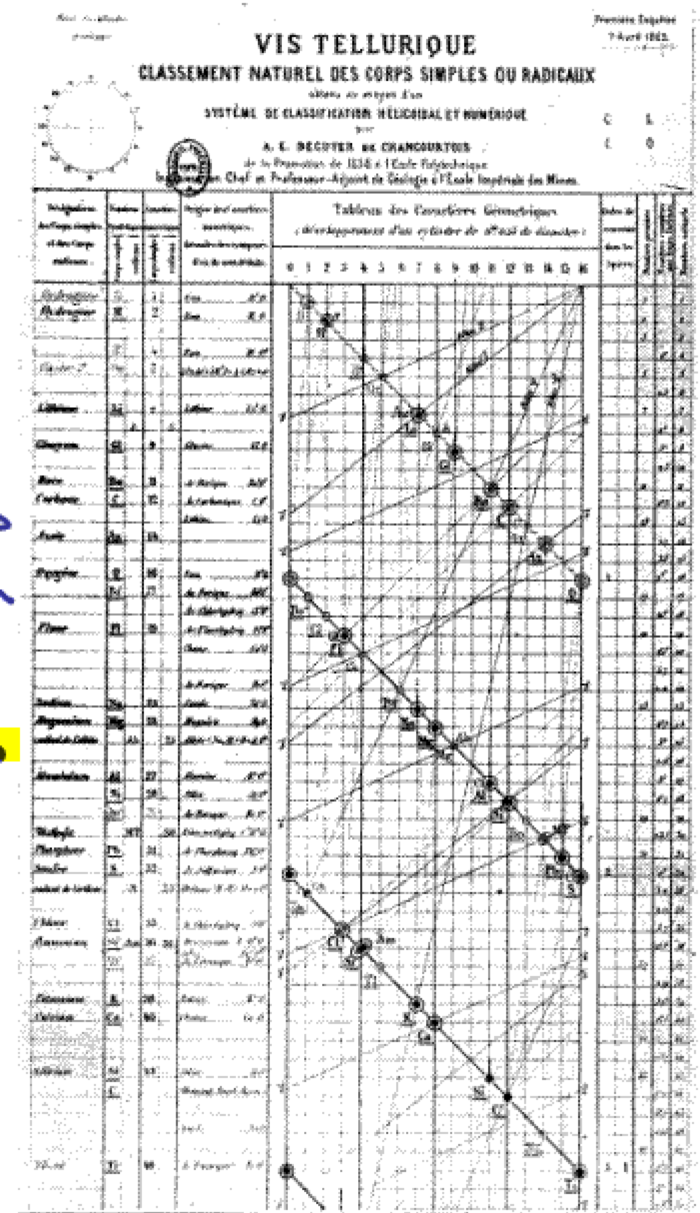
John Newlands - English analytical chemist
(1837-1898) ... Arranged table of elements
by ATOMIC Masses

Antoine Lavoisier
France (1743-1794)

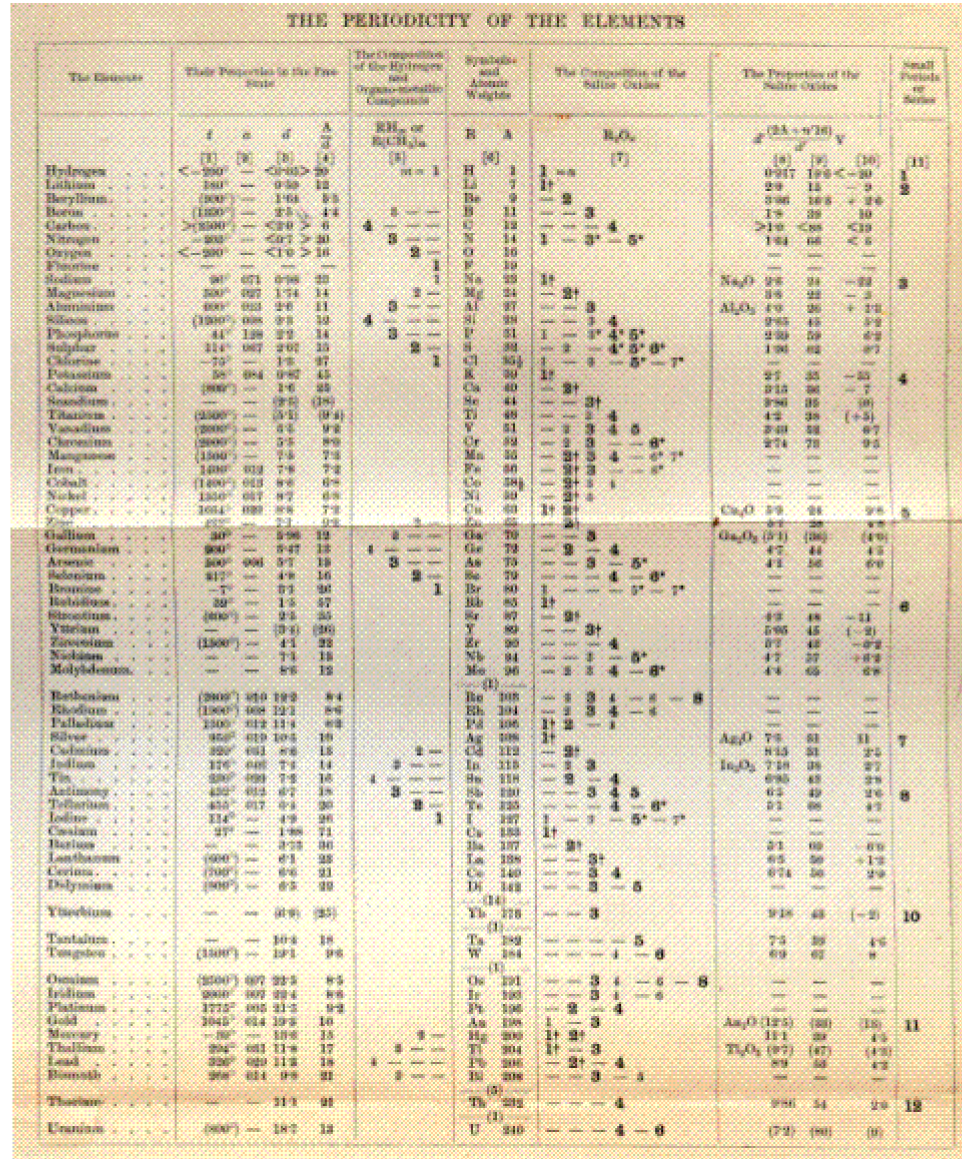
"Father of Modern
Chemistry"
quantitative Analysis

guillotined during French Revolution

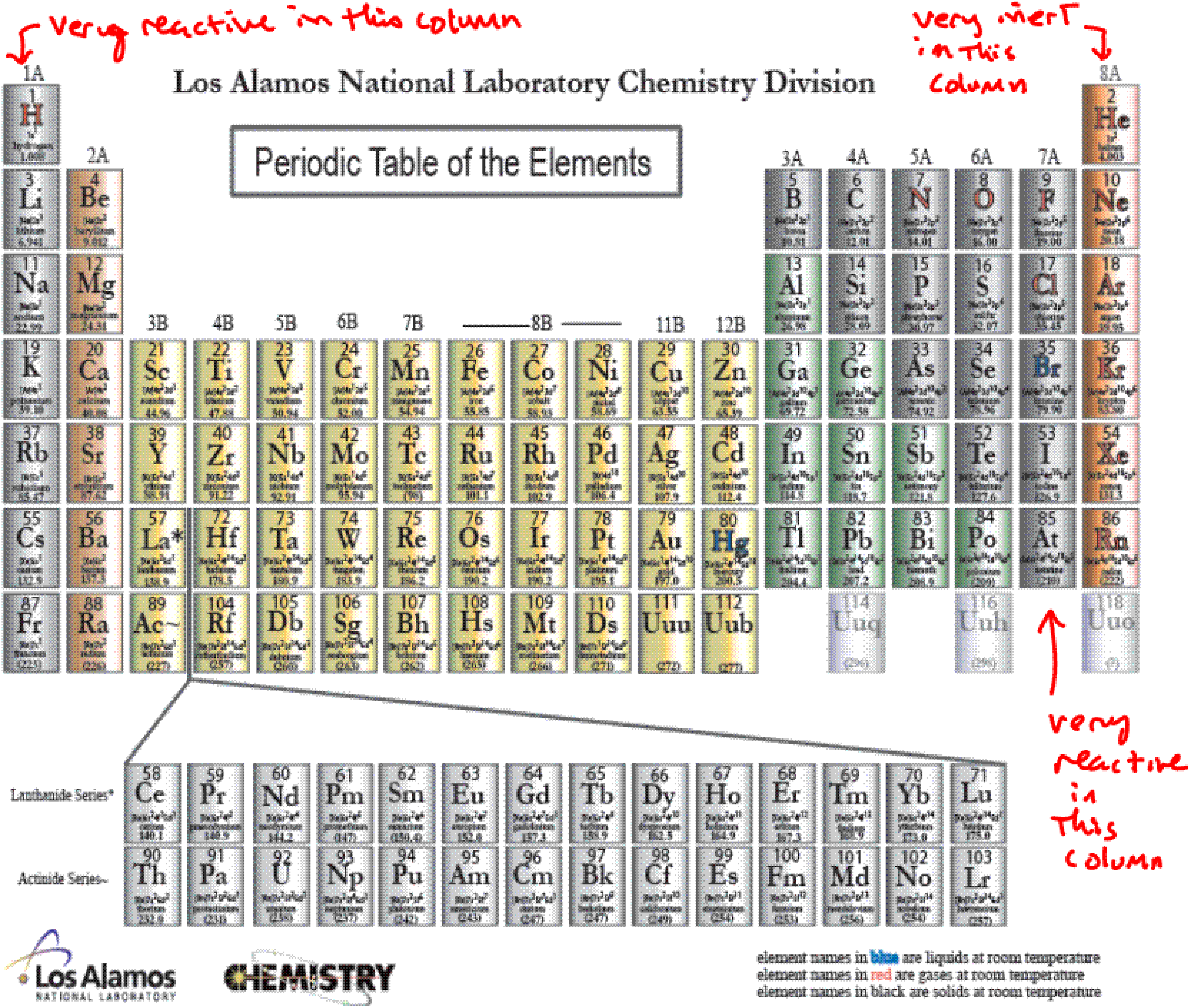
Alexandre-Emile
Béguyer de Chancourtois
France (1820-1886)



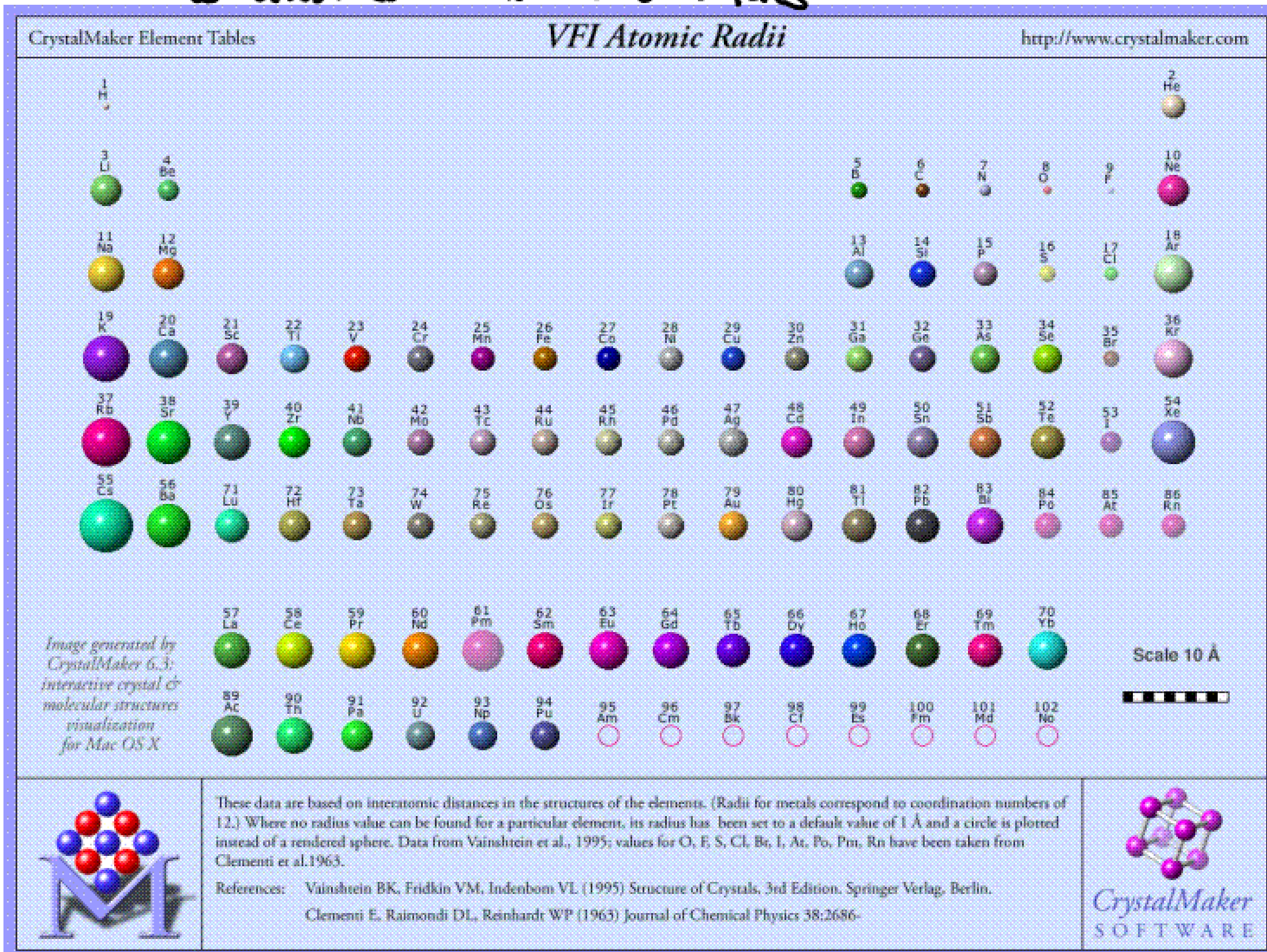
Dmitri Mendeleev
Russian (1834-1907)


THE PERIODICITY OF THE ELEMENTS

when elements arranged by mass - see a certain periodicity in their chemical properties.

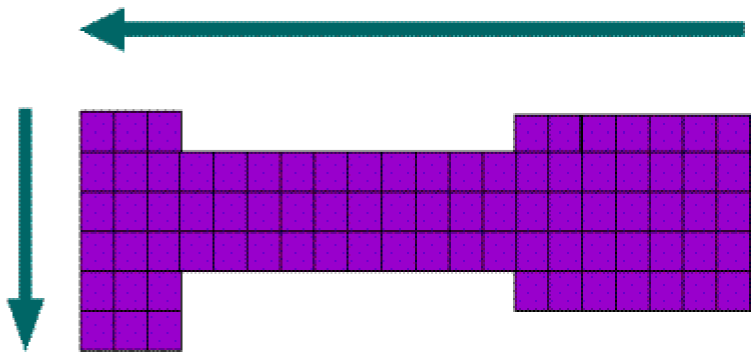

very reactive in this column
very inert in this column
very reactive in this column
Los Alamos National Laboratory Chemistry Division
Periodic Table of the Elements
1A
2A
3B
4B
5B
6B
7B
8B
11B
12B
3A
4A
5A
6A
7A
8A
Lanthanide Series*
Actinide Series~
Los Alamos NATIONAL LABORATORY
CHEMISTRY
element names in blue are liquids at room temperature
element names in red are gases at room temperature
element names in black are solids at room temperature

variations in things like atomic sizes and ionization energies and chemical reactivity can be understood by how electrons fill the allowed atomic orbitals



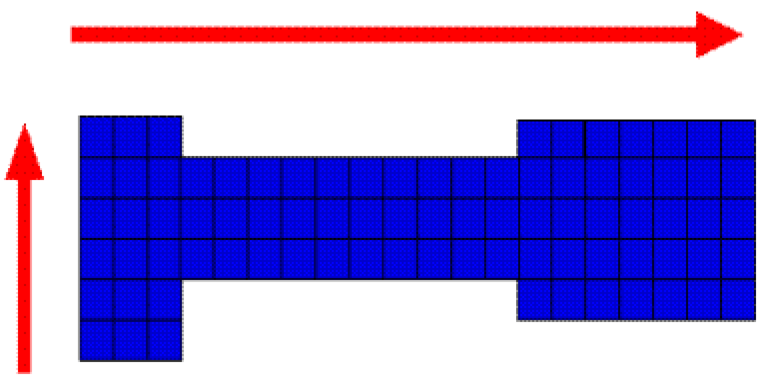
Figures from –
http://www.shodor.org/chemviz/ionization/students/background.html

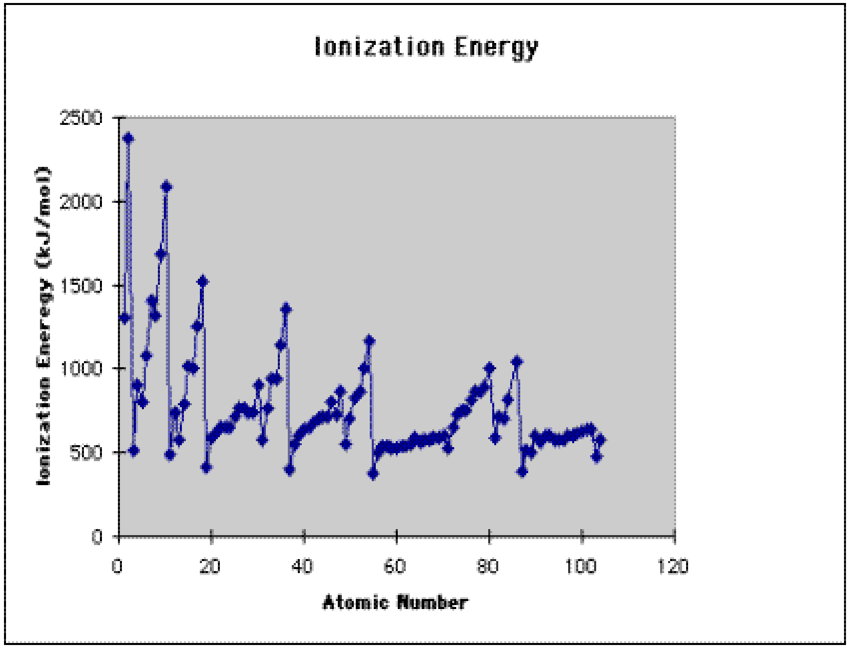
Atomic Size Increases With Arrows



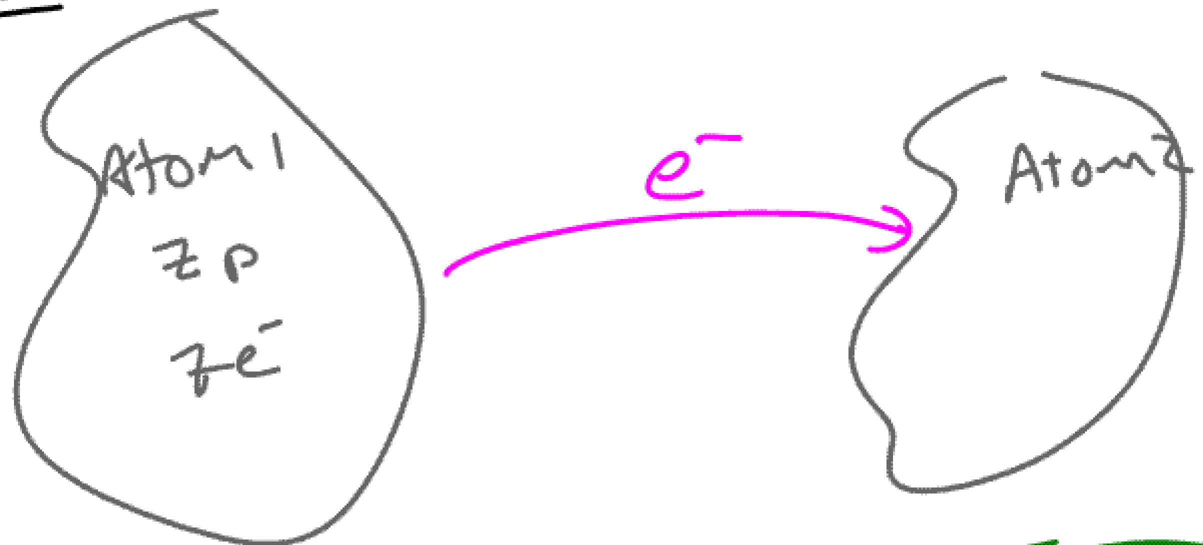
ionization Energy
energy to
remove an
electron

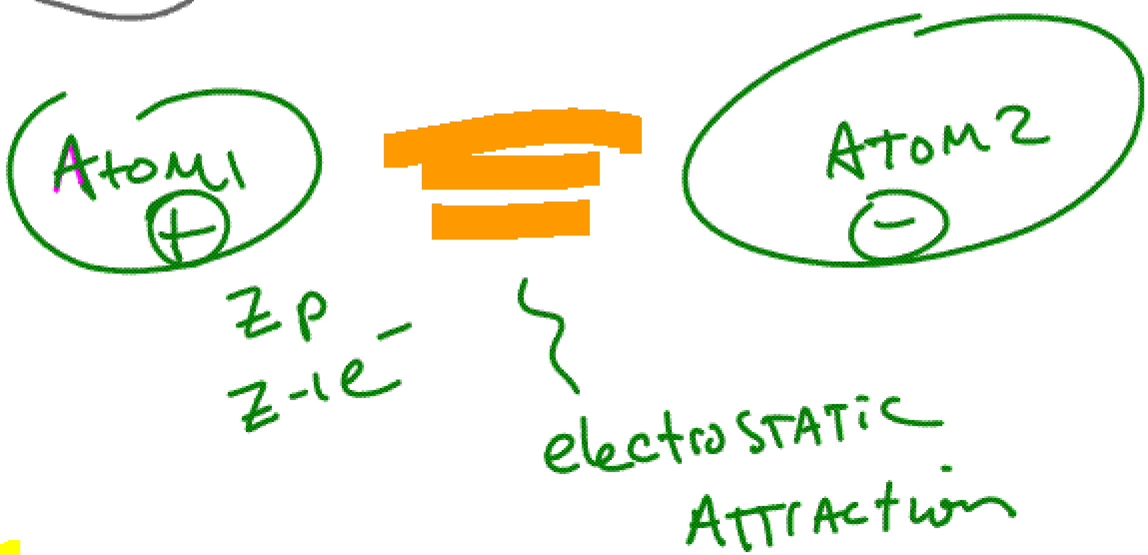
Ionization Energy Increases With Arrows





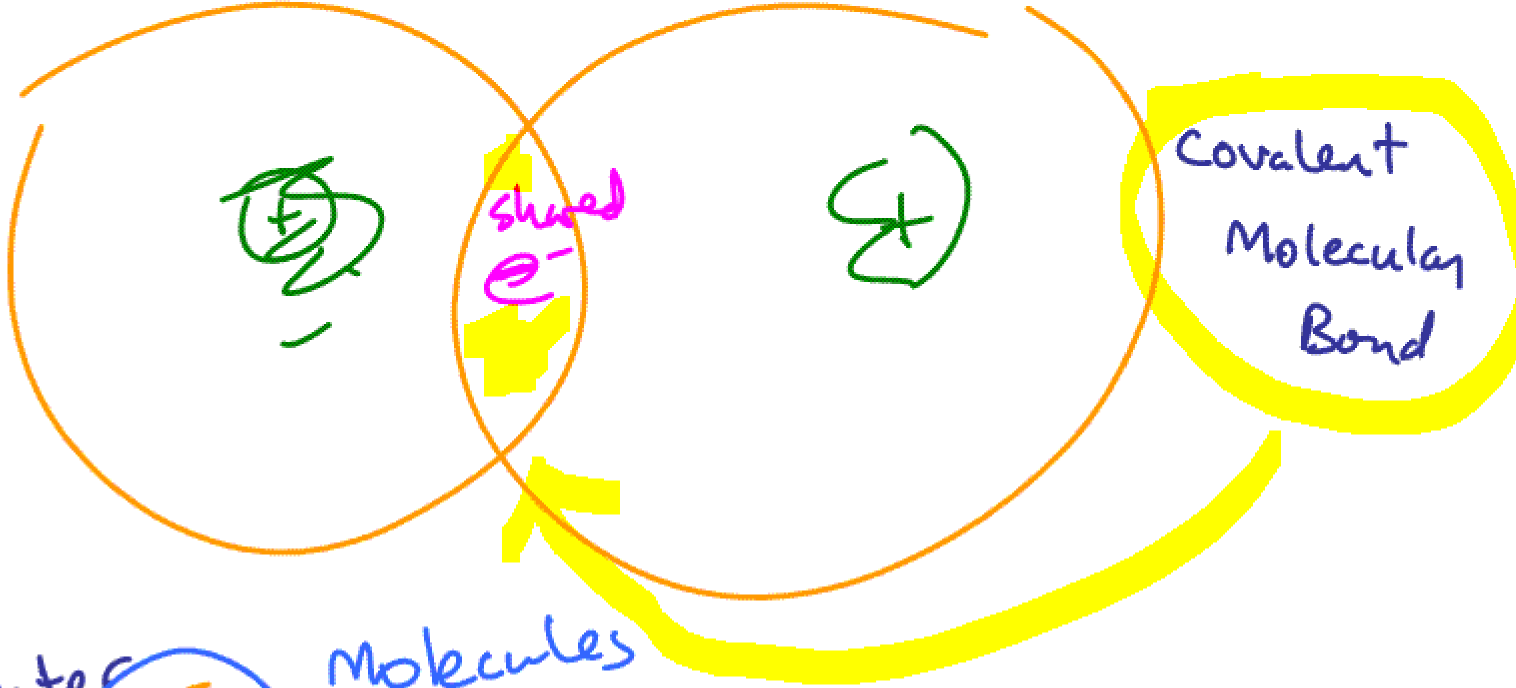
Chemistry – how Atoms interact with each other

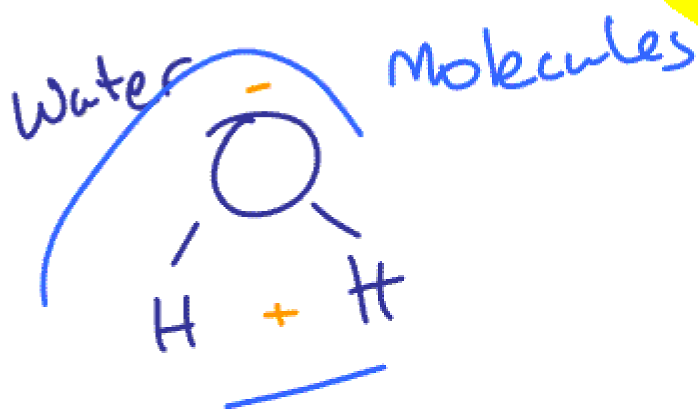


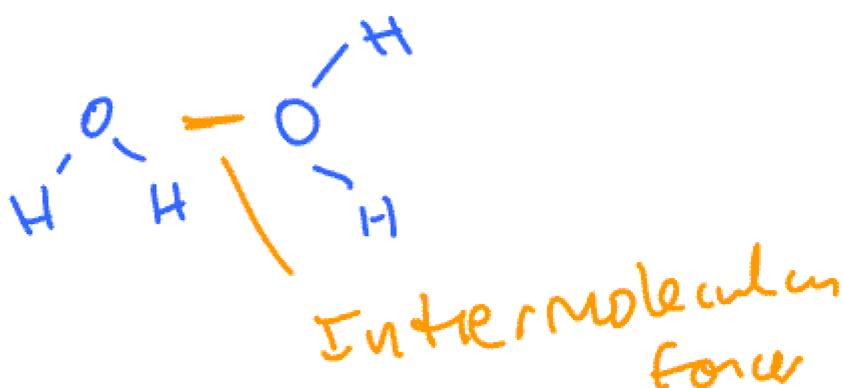


Ionic
Bond

Na^+ Cl^-

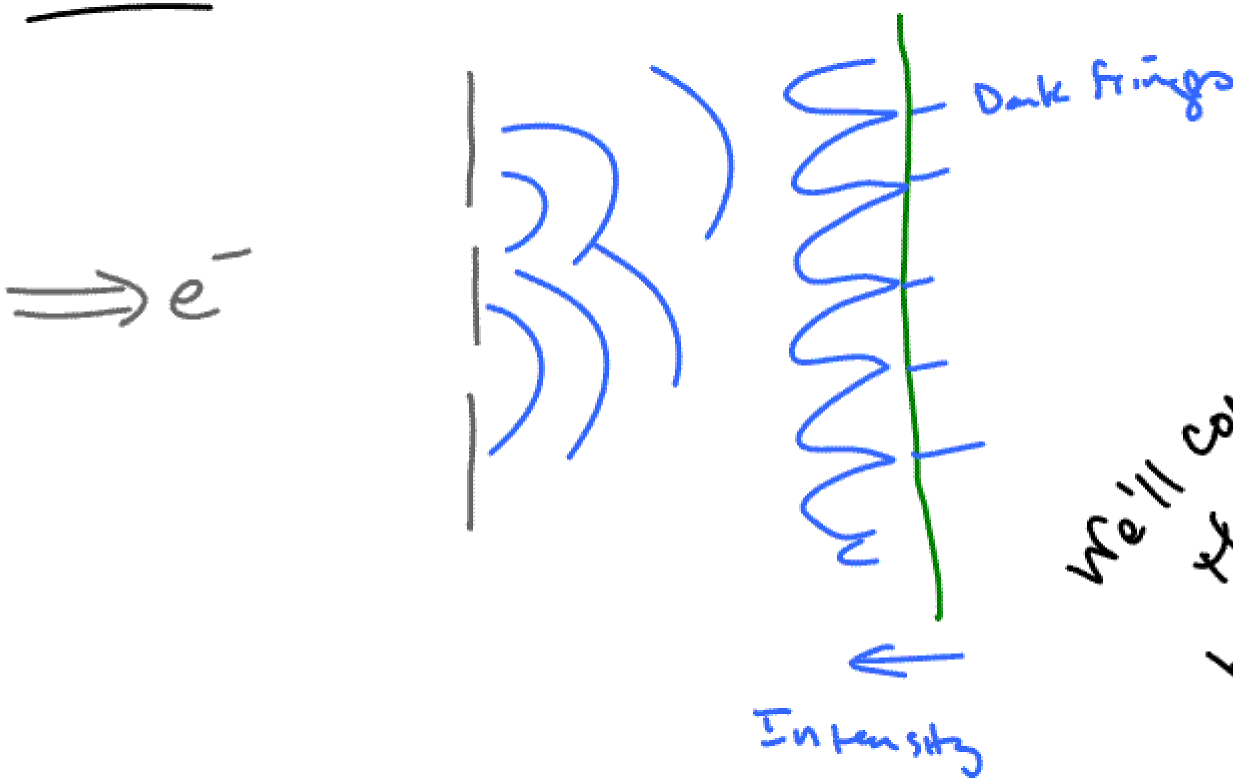

shared
e⁻
Covalent
Molecular
Bond


Water
Molecules
O
H
H


H
O
H
O
H
H
Intermolecular
force

$\psi(x)$

what is $\psi(x)$?



We'll come back to this — so I won't bother making notes better for now.

$\Delta x \, \Delta p \sim h$

Uncertainty Principle