

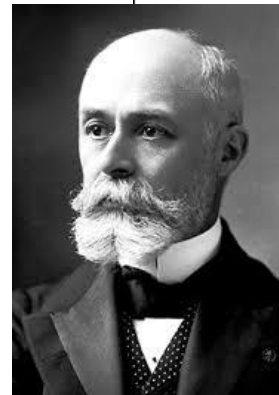
How can we study *the inside* of atom?

See what “comes out”!

- Electric current – originates within matter; can flow through matter but also...in **vacuum**!
 - Cathode rays, 1869: streams of **something travelling in straight lines** observed in vacuum tubes when voltage is applied across the evacuated tube equipped with two electrodes.
- Radioactivity (alpha, beta, gamma)
 - Henri Becquerel, 1896:
 - radioactivity was **first discovered** in uranium salts during his work on phosphorescence.
- Light (later!)



10 - 11 - 96. Sulfide Double Phosphor of the Potassium
Phosphor salt - Geiger's counter tubes -
Exposed on March 27. at the same distance to the
Nicollet's 4 1/2 mm.



Discovery of Electron

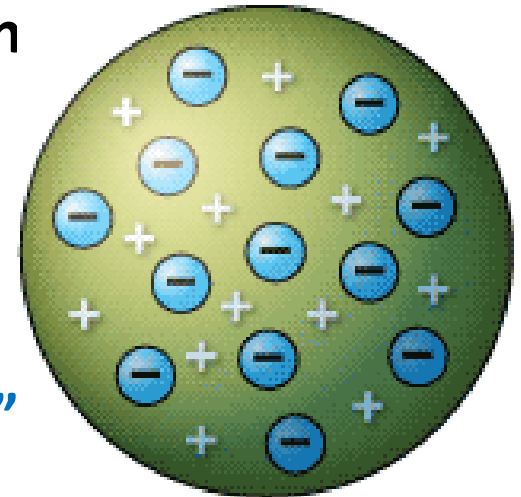


Joseph
John
Thomson



1897: Studying cathode rays, Thomson detected **charged particles** that were around **1800 times lighter than the lightest atom**, hydrogen. Therefore they were **not atoms, but a new particle**, the first subatomic particle to be discovered. Originally it was called "corpuscle" but was later named **electron**.

- many elements were shown to emit electrons...
- ...all atoms must contain **electrons as universal building blocks**
- atoms are neutral, so there must be a **balancing "cloud" of opposite charge**



Plum Pudding Model, 1904

1906 Nobel prize in Physics

Radioactivity

- Marie Sklodowska-Curie and Pierre Curie, 1898:

- conducted a **systematic study** to determine which elements and compounds emitted “mysterious radiation” that they called “radioactivity”

- isolated a new radioactive element, polonium (named in honor of Marie's home country),

- 4 years later, discovered an even more intensely radioactive substance, radium.

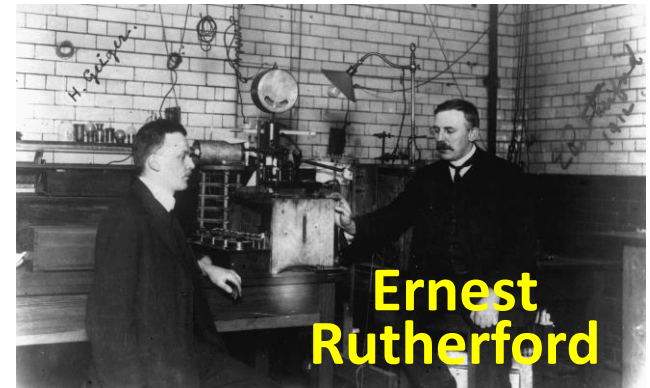


- Ernest Rutherford and Frederick Soddy, 1899-1903:

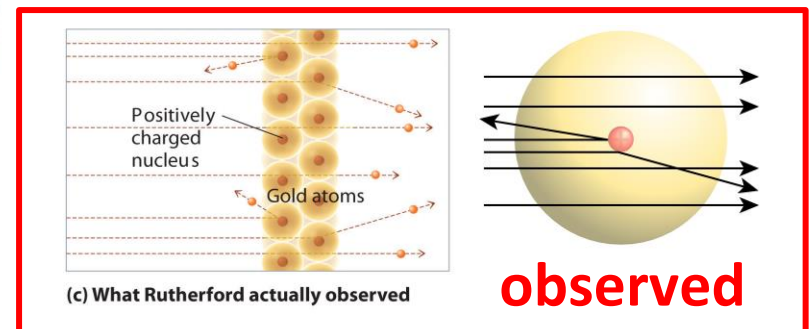
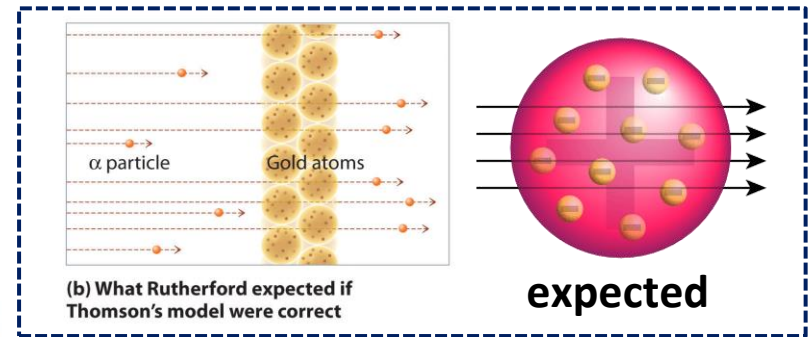
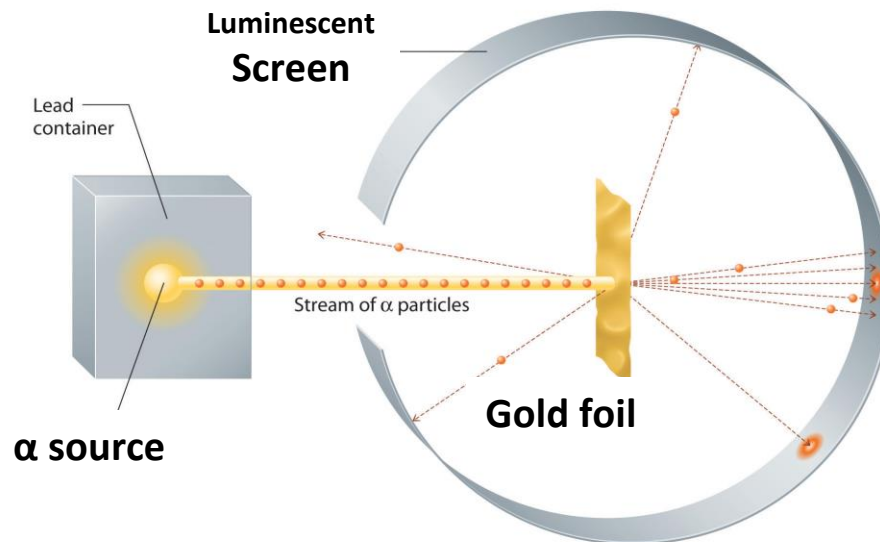
- discovered **three different types of radiation** "rays" with very different properties and **proposed that atoms were not conserved in radioactive emissions.**

Discovery of the Nucleus

Rutherford (Geiger–Marsden),
1908-1913: Gold Foil Experiment



- “Father of nuclear physics”
- Bombarded a thin metal foil with alpha particles. A majority of the particles passed through the sheet, but a **small percentage were deflected**.



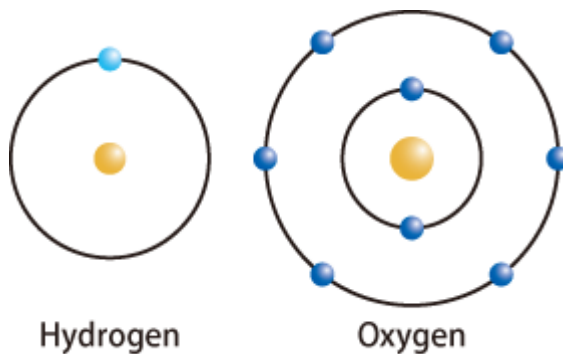
- Rutherford's conclusion: “the **greater part of the mass** of the atom was concentrated **in a minute nucleus**... carrying a charge”.

Planetary Model

Niels Bohr, 1913

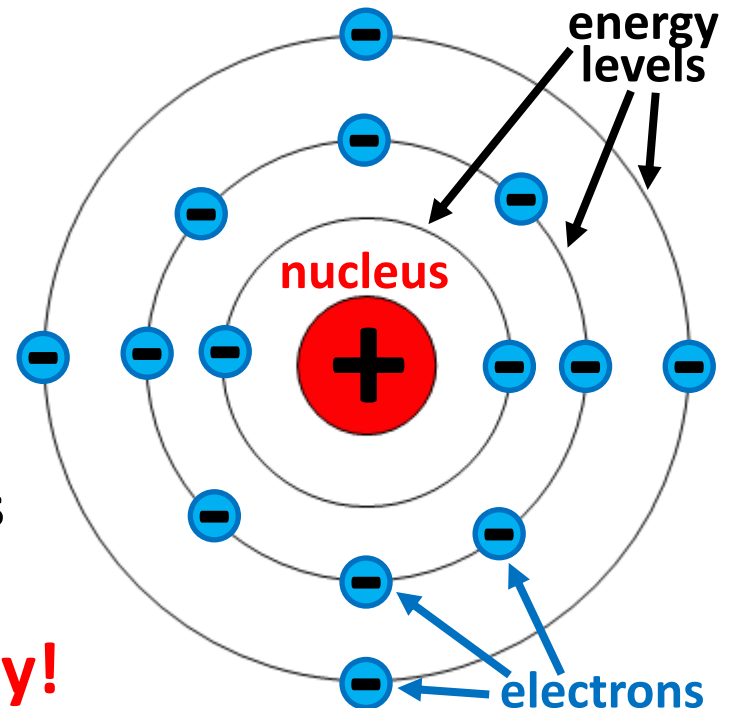
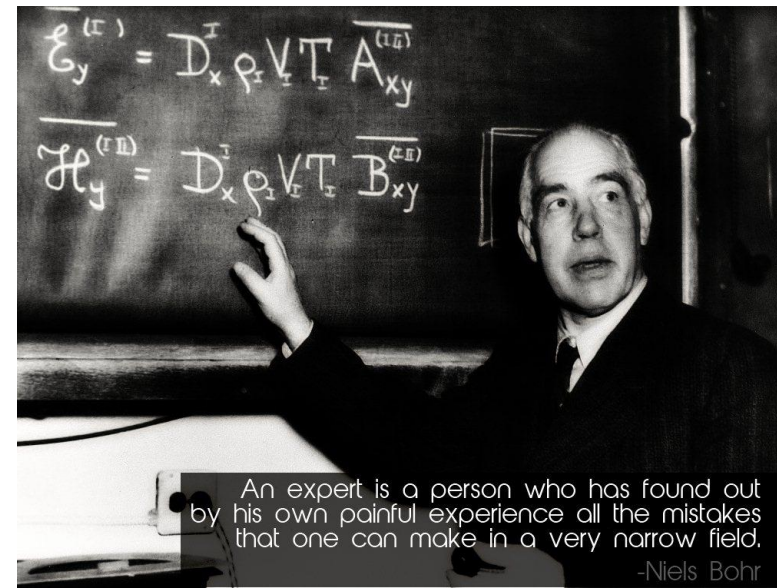
Electrons move in definite orbits around the nucleus, **much like planets circle the Sun.**

- These circular orbits, or **energy levels**, are located at certain distances from the nucleus.



- Electrons can jump between levels emitting (or absorbing) energy...

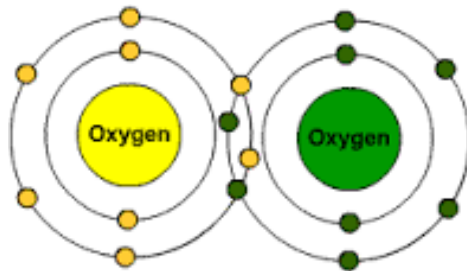
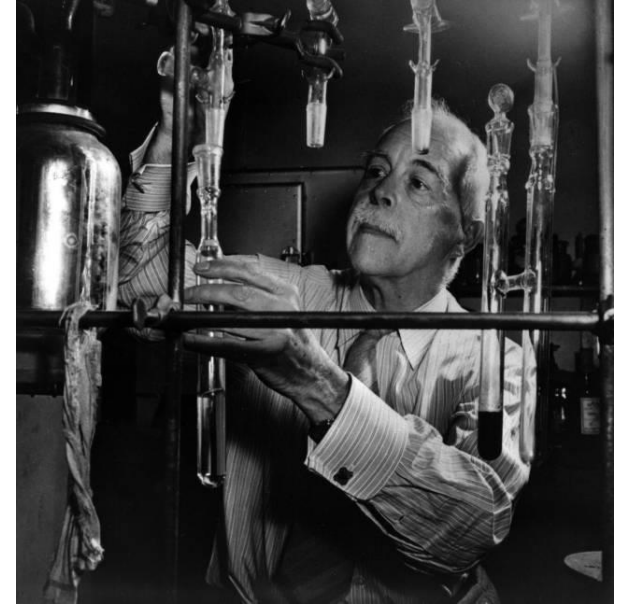
...here comes Quantum Theory!



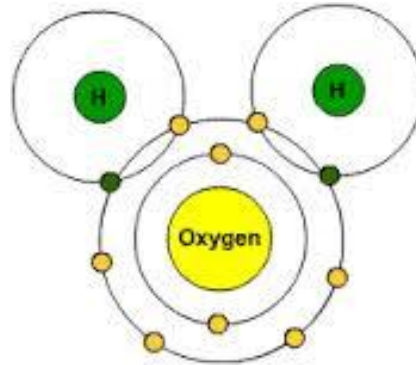
Chemical Bond Explained

Gilbert Newton Lewis, 1916:

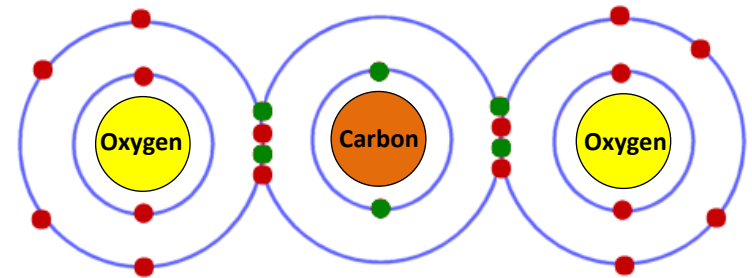
a **covalent bond** between two atoms is maintained by a **pair of electrons shared** between them.



**Oxygen
molecule**



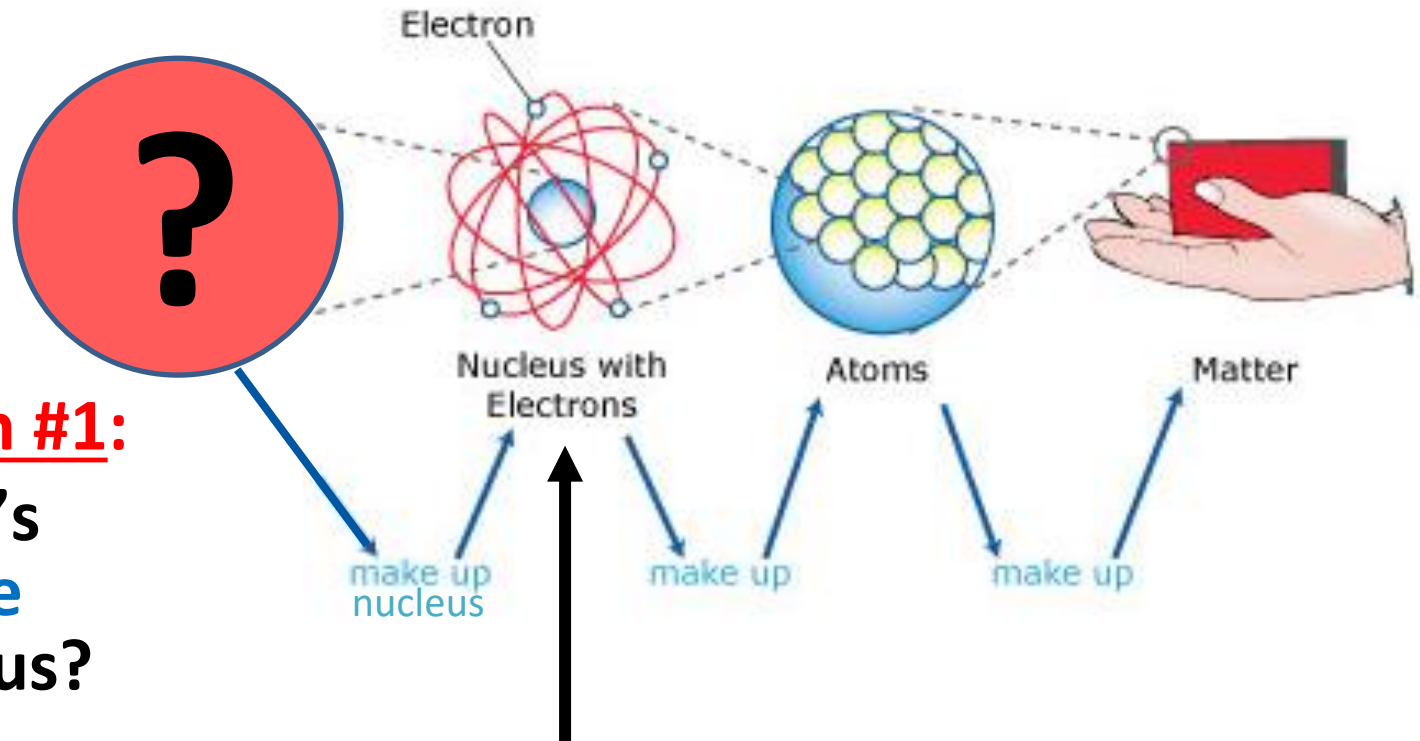
Water



**Carbon
dioxide**

Although nominated 35 times (!), Lewis *never won* the Nobel Prize in Chemistry...

Summary: Structure of Matter



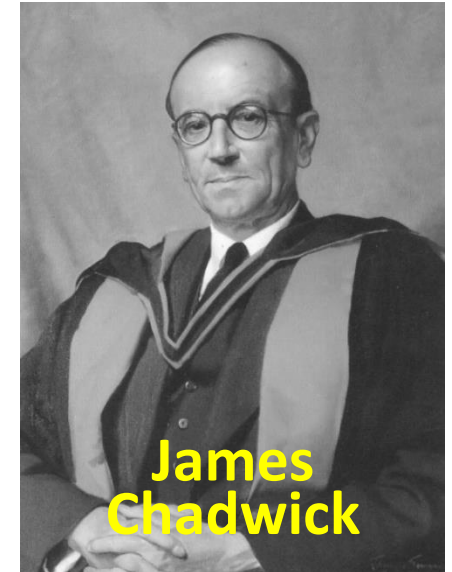
Question #1:

What's
inside
a nucleus?

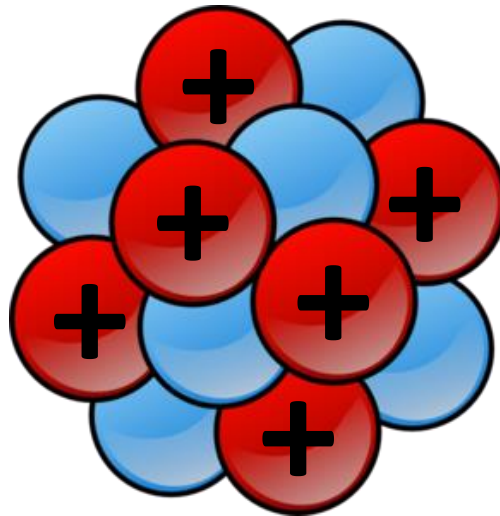
Question #2: Is **planetary model** of the atom *good enough* to explain all experimental observations?

Inside a Nucleus

- Rutherford, 1920: discovery of a **proton** (Greek: “first”), a **positively charged** subatomic particle.
- 1920-1932: search for a *neutral* particle.
- Chadwick, 1932: detected **zero charged** particles with about the same mass as the proton, eventually called **neutron** (**1935 Nobel Prize in Physics**).



**Atomic
Nucleus
Structure**



Atom $\sim 10^{-10}\text{m}$

Nucleus $\sim 10^{-14}\text{m}$

Proton $\sim 10^{-15}\text{m}$

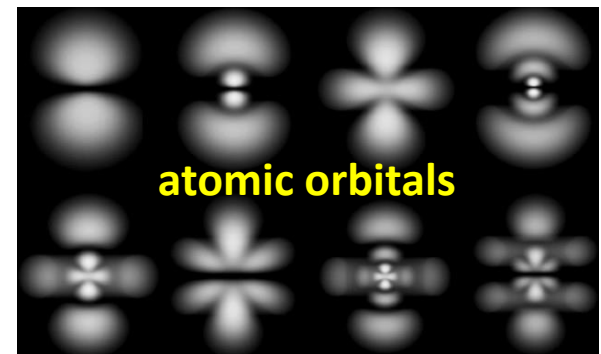
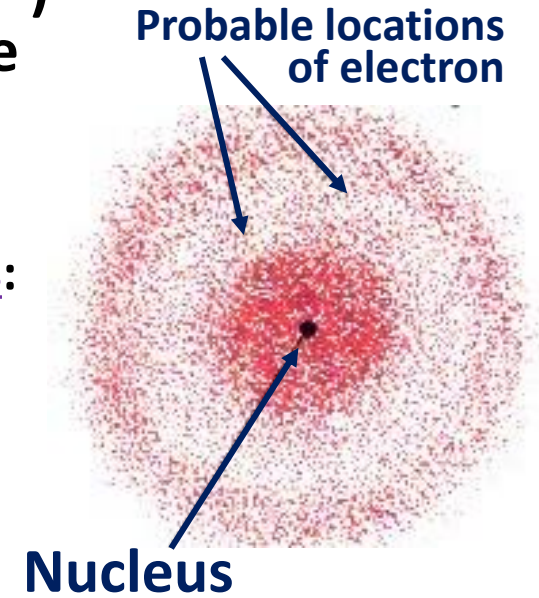
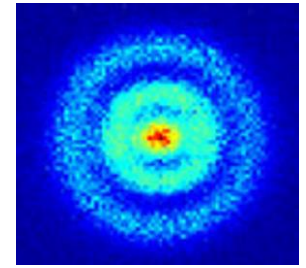
Neutron $\sim 10^{-15}\text{m}$

Wave Model of the Atom (contemporary model)

Atom has a small positively charged nucleus surrounded by a large region (“*electron cloud*”) in which there are enough electrons to make an atom neutral.

Quantum Theory states that the electrons inside an atom possess both particle- and wave-like properties:

- There is always an **integer number of electrons** orbiting the nucleus.
- It is **impossible to determine the exact location** of an electron. Electrons do not have a definite path around the nucleus. The **probable location of an electron** is based on how much energy it has.
- The modern term “**atomic orbital**” refers to the **physical region or space where the electron can be calculated to be present**.
- Electrons whirl about the nucleus billions of times in one second and can **jump between orbitals in a particle-like fashion**, losing or gaining energy.

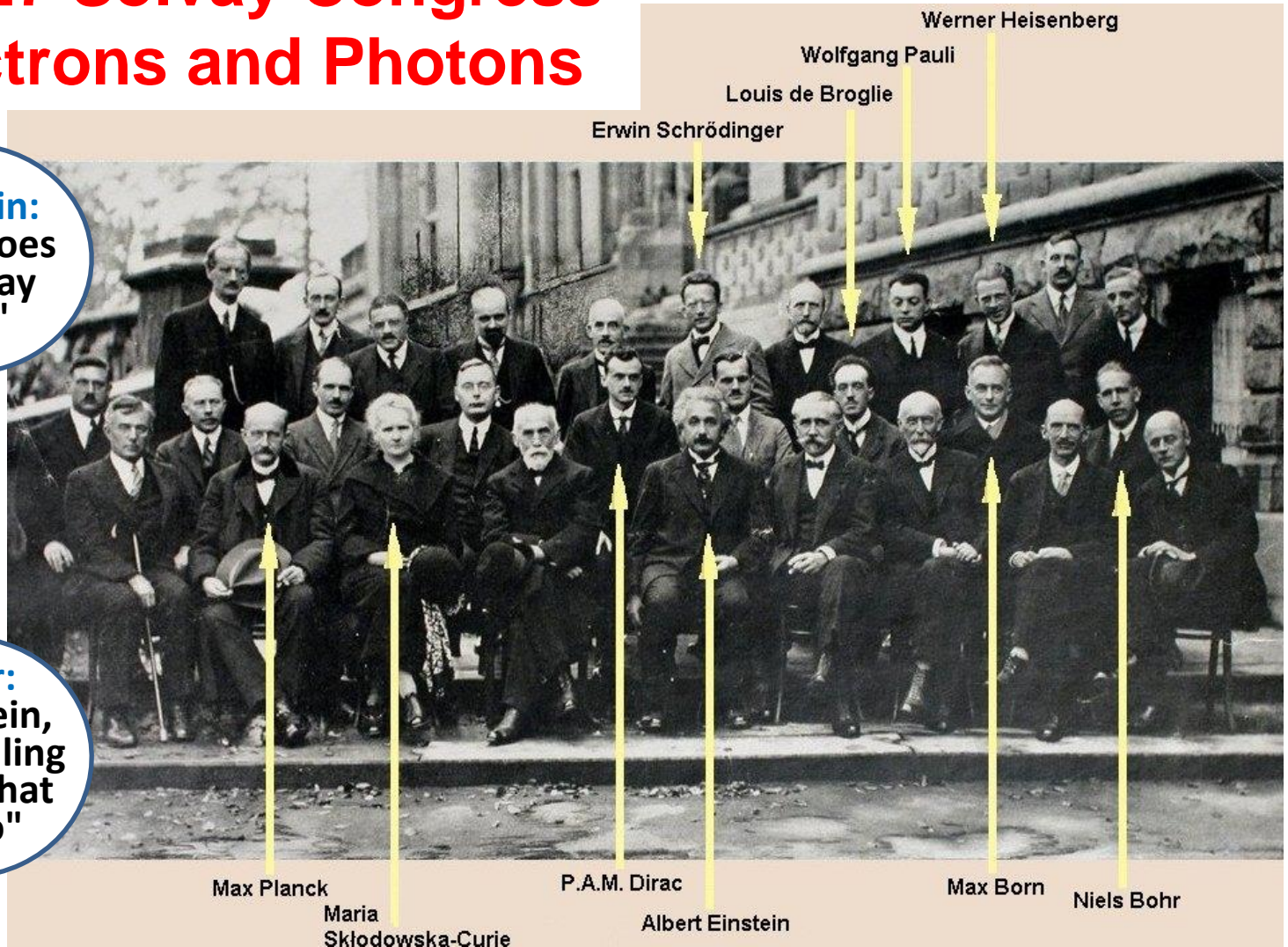


atomic orbitals

The 1927 Solvay Congress on Electrons and Photons

Einstein:
"God does not play dice"

Bohr:
"Einstein, stop telling God what to do"



In October 1927, the world's most notable physicists met to discuss the newly formulated quantum theory and subatomic makeup. **17 of the 29 attendees were or later became Nobel Prize winners.**