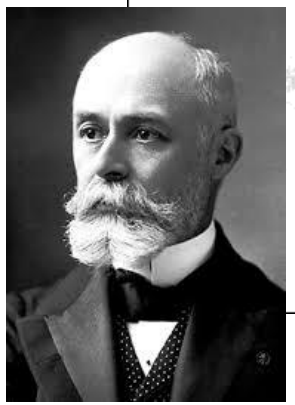
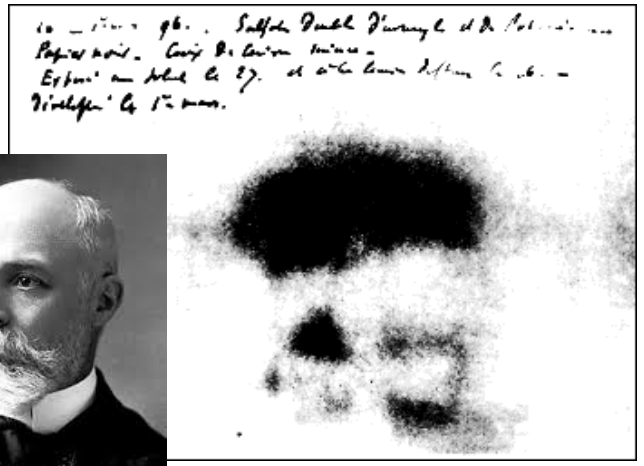
How can we study *the inside* of atom?

See what "comes out"!

- **Electric current – originates within matter; can flow through matter but also…in vacuum!**
  - **<u>Cathode rays, 1869</u>: 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)**
  - **<u>Henri Becquerel, 1896</u>:**

    - radioactivity was first discovered in uranium salts during his work on phosphorescence.
- **Light** (later!)



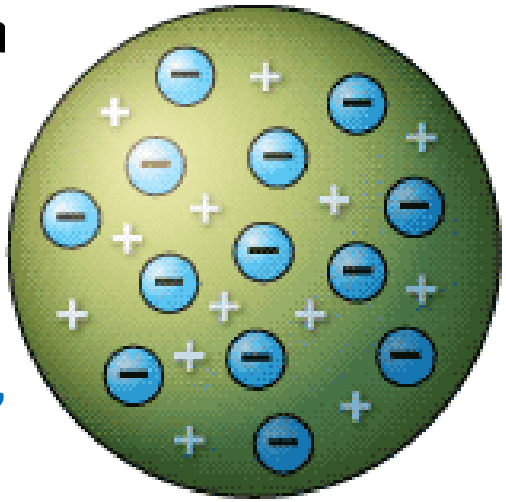


Discovery of Electron

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*.

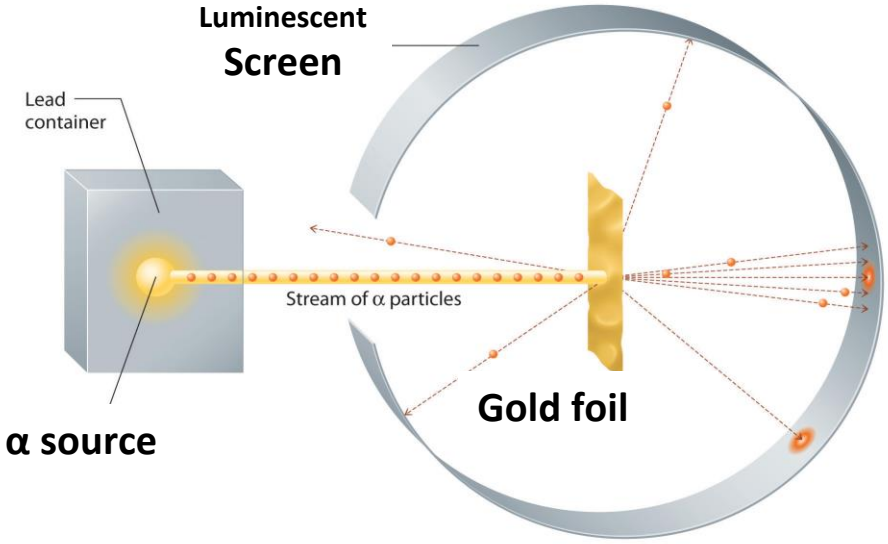
- **Ernest Rutherford and Frederick Soddy, 1899-1903:**

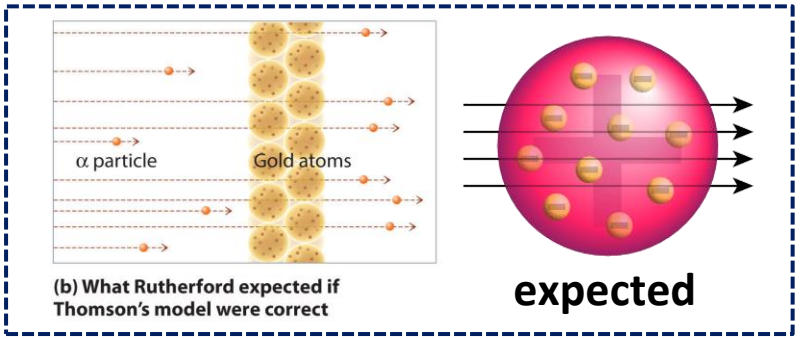
- discovered three different types of radiation "rays" with very different properties and proposed that atoms were not conserved in radioactive emissions.

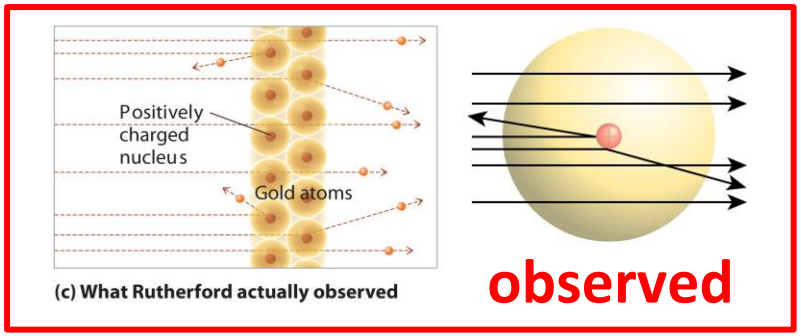
Discovery of the Nucleus

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.**

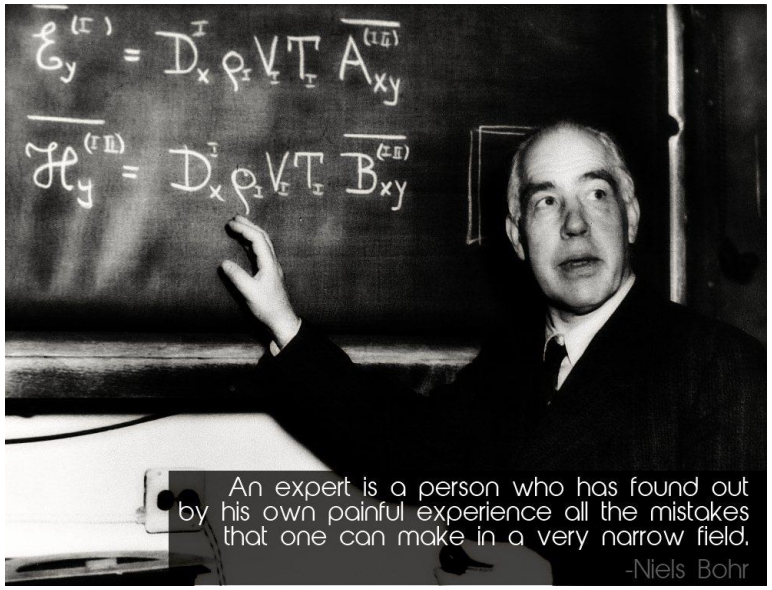






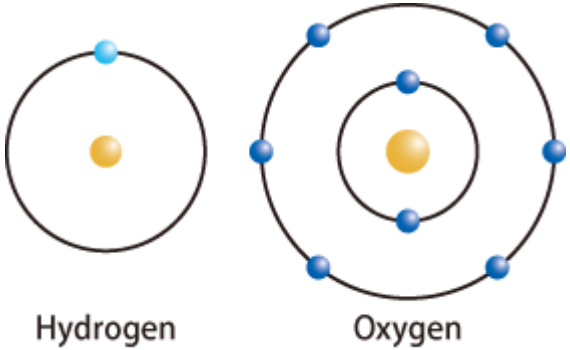
- **Rutherford's conclusion:** "the **greater part of the mass** of the atom was concentrated **in a minute nucleus**… carrying a charge".

Planetary Model
Niels Bohr, 1913



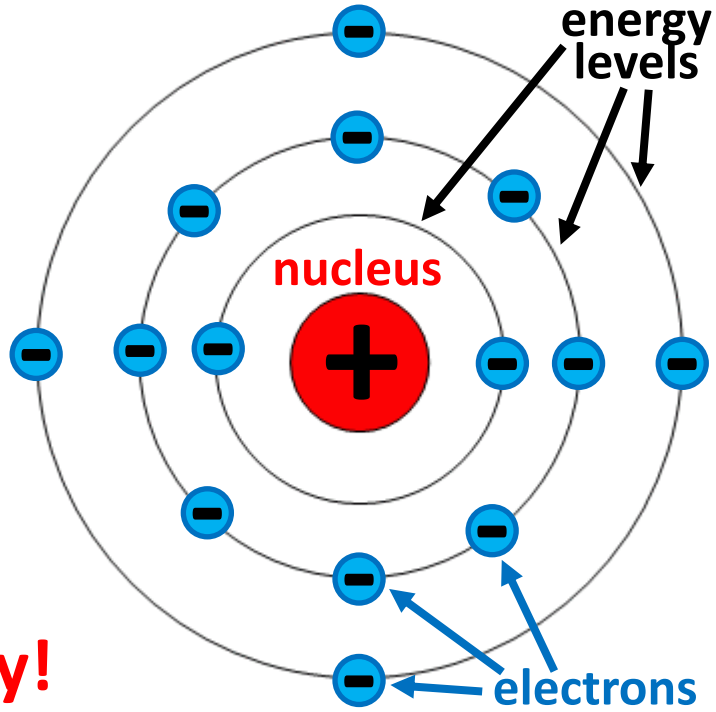
Electrons move in definite orbits around the nucleus, much like planets circle the Sun.

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



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

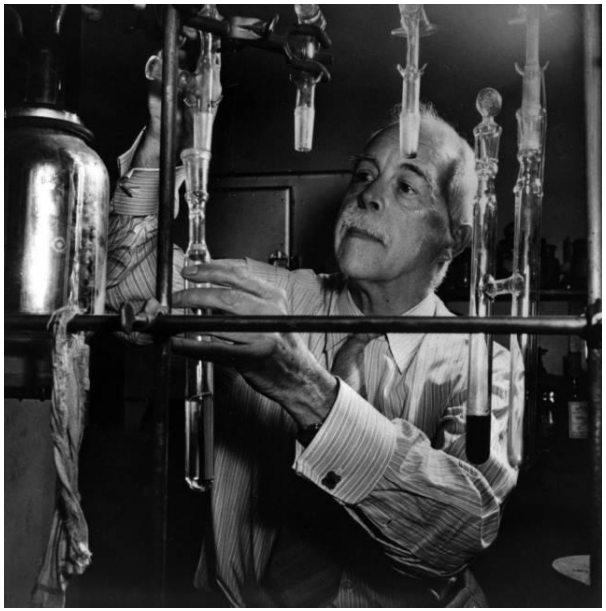
…here comes Quantum Theory!

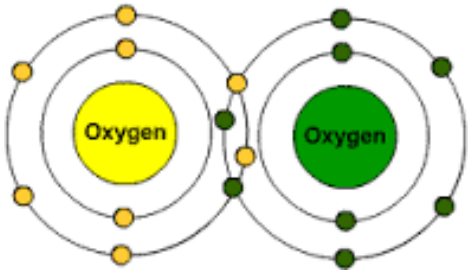


Chemical Bond Explained

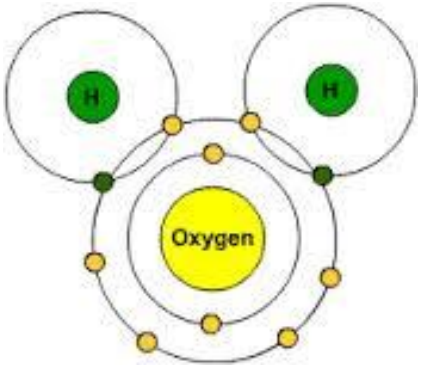
Gilbert Newton Lewis, 1916:

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

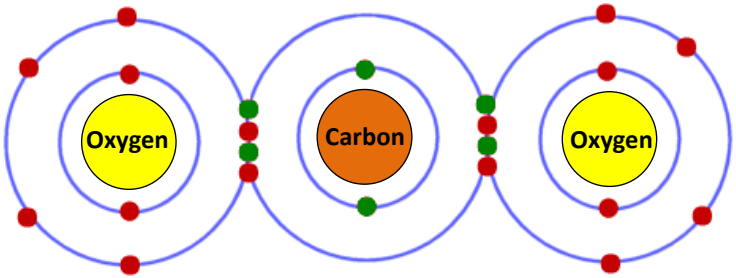




Oxygen molecule



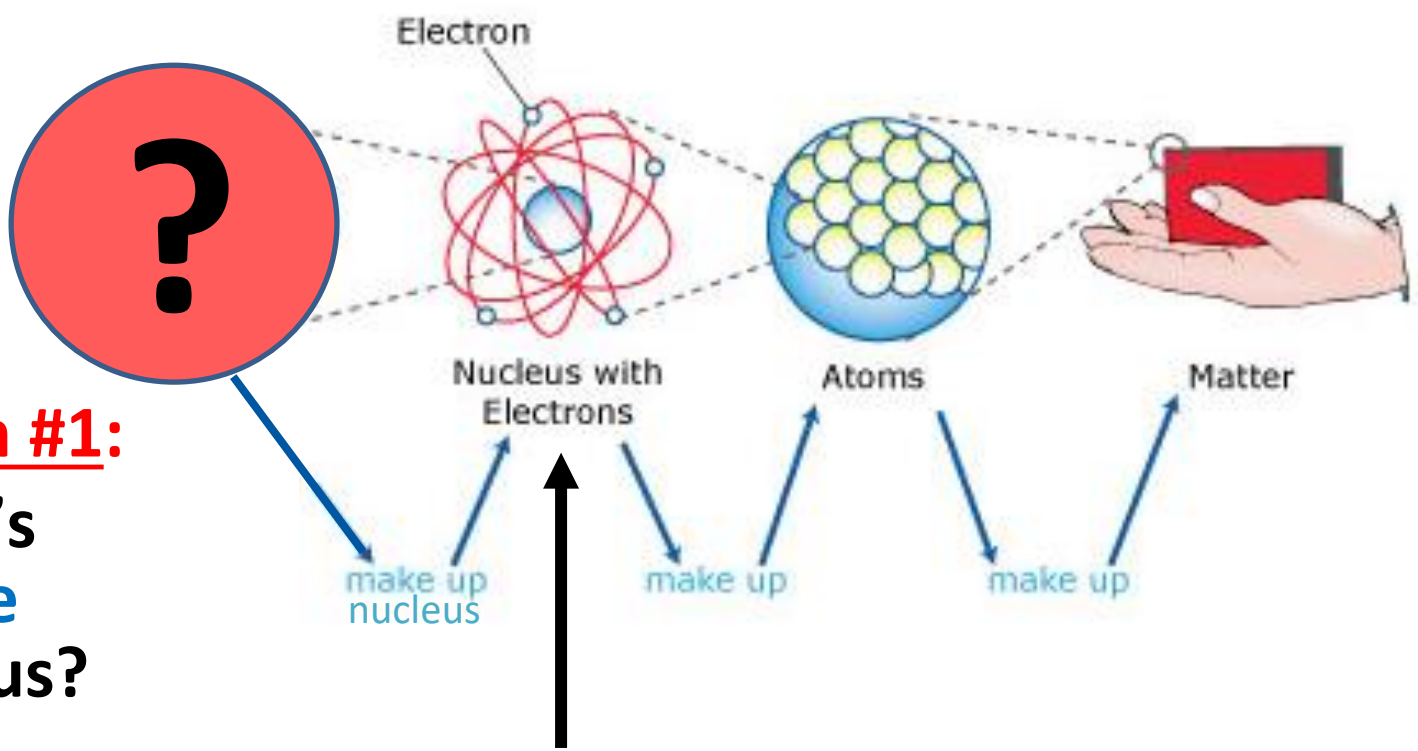
Water



Carbon dioxide

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

Summary: Structure of Matter



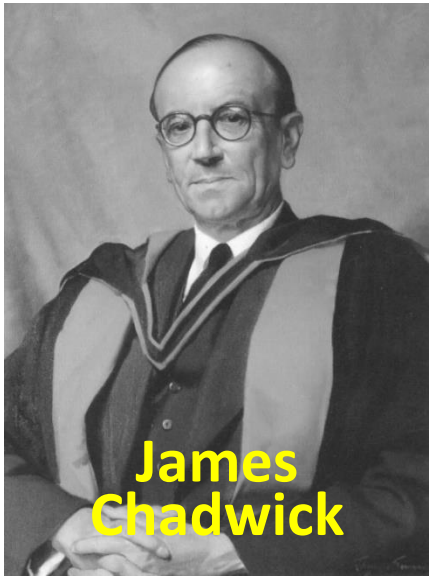
Question #1:

What's inside a nucleus?

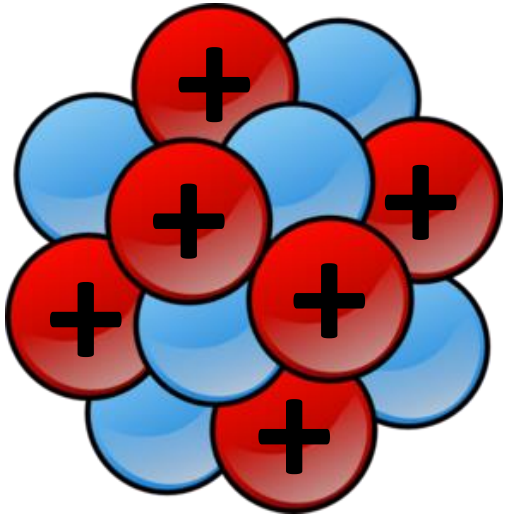
Question #2: Is planetary model of the atom *good enough* to explain all experimental observations?

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).**



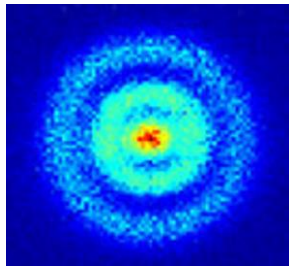
Atomic Nucleus Structure



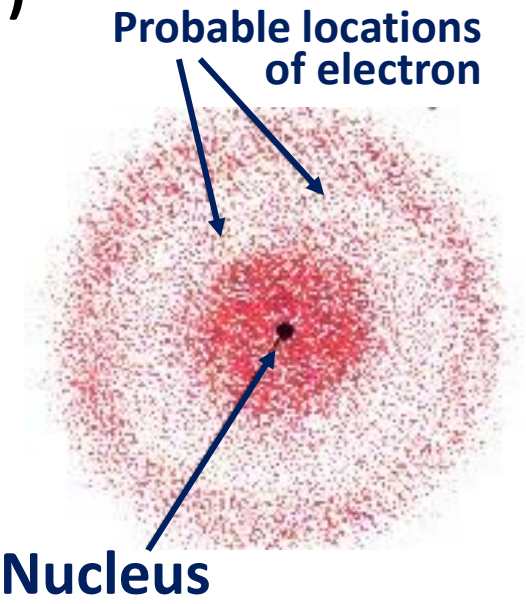
Atom ~10^{-10}m

Nucleus ~10^{-14}m
Proton ~10^{-15}m
Neutron ~10^{-15}m

Wave Model of the Atom (contemporary model)

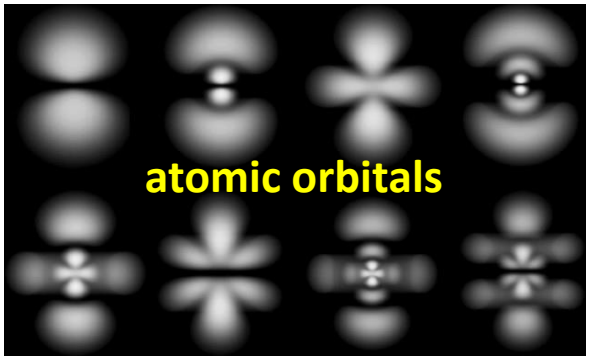


Atom has a small positively charged nucleus surrounded by a large region (*"electron cloud"*) in which there are enough electrons to make an atom neutral.

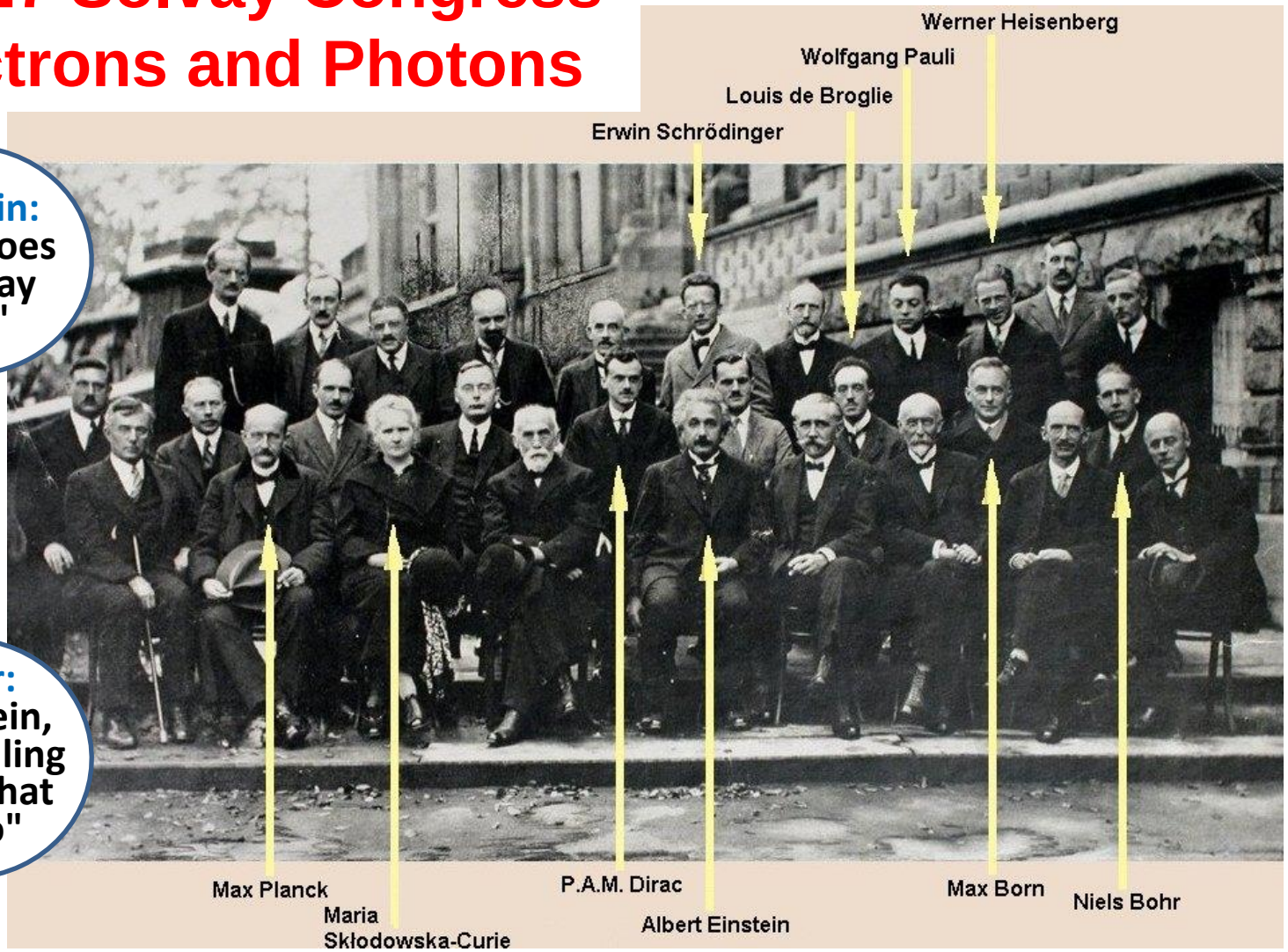


Quantum Theory states that the electrons inside an atom possess both particle- and wave-like properties:

- **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.**



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.