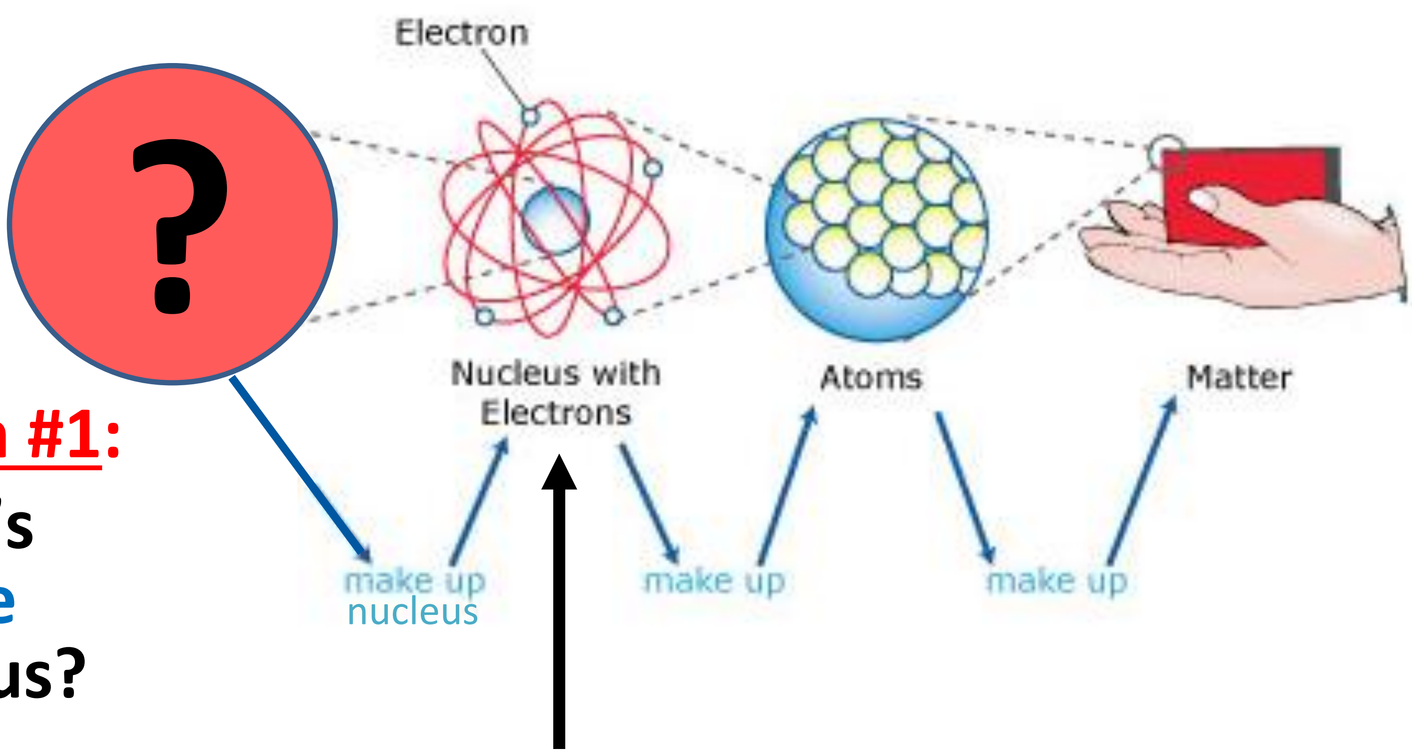
Summary: Structure of Matter



Question #1: What's inside a nucleus?

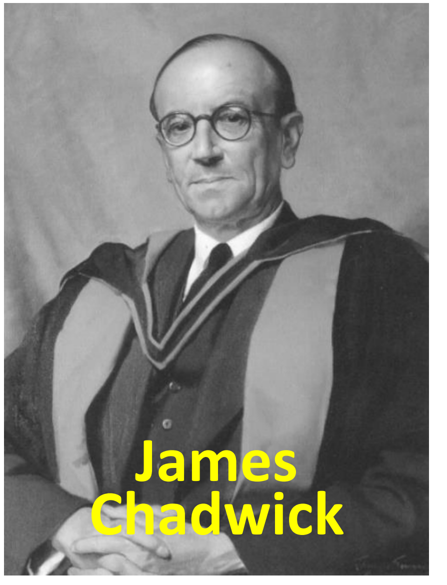
Question #2: Is planetary model of the atom *good enough* to explain all experimental observations?

Rutherford Transmutation Experiments

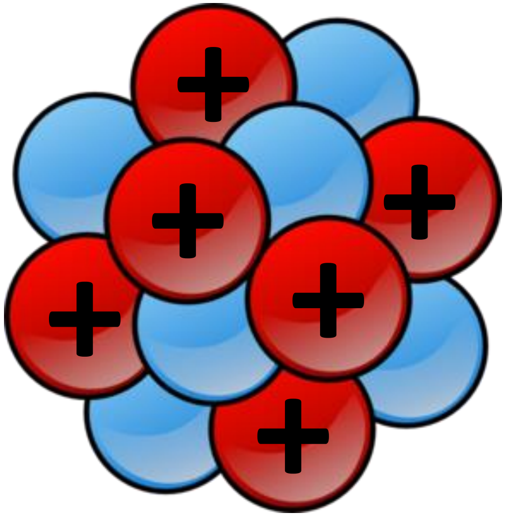
- **<u>1919</u>: "splitting the atom" - it is possible to change one element into another by striking it with energetic alpha particles.**
- **<u>Early 1920's</u>: a number of experiments, *transmuting* one atom into another (ex. Nitrogen into Oxygen)**
  - **Observation #1: in every case, hydrogen nuclei were emitted in the process.**
  - **Therefore hydrogen nucleus must play a fundamental role in atomic structure.**
  - **Observation #2: the positive charge of any nucleus could be accounted for by an integer number of hydrogen nuclei.**
  - **Observation #3: the total mass of any given atomic nucleus IS LARGER than the total mass of the number of hydrogen nuclei corresponding to its charge.**
  - **Therefore the nucleus must also contain a neutral particle.**

Inside a Nucleus

- **<u>Rutherford, 1920</u>: 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).**



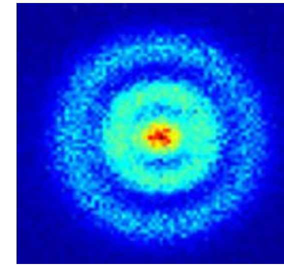
Atomic Nucleus Structure



Atom ~10^{-10}m

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

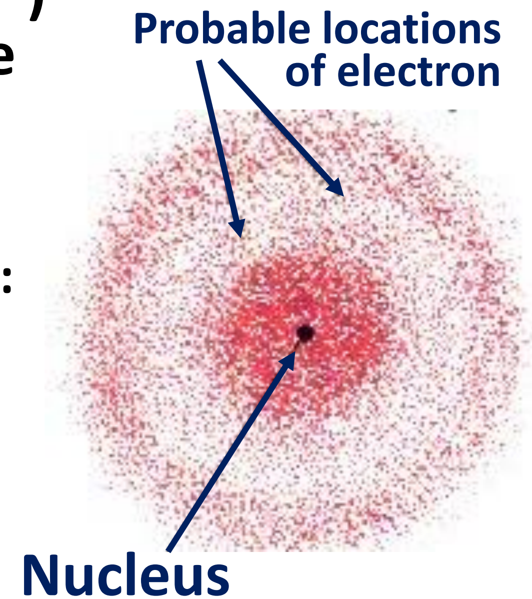
Wave Model of the Atom
(contemporary model)

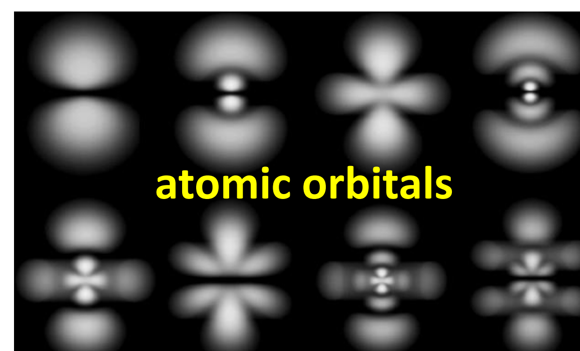


Atom has a small positively charged nucleus surrounded by a large region (*"electron cloud"*) in which there are enough electrons to make an atom neutral.

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.**

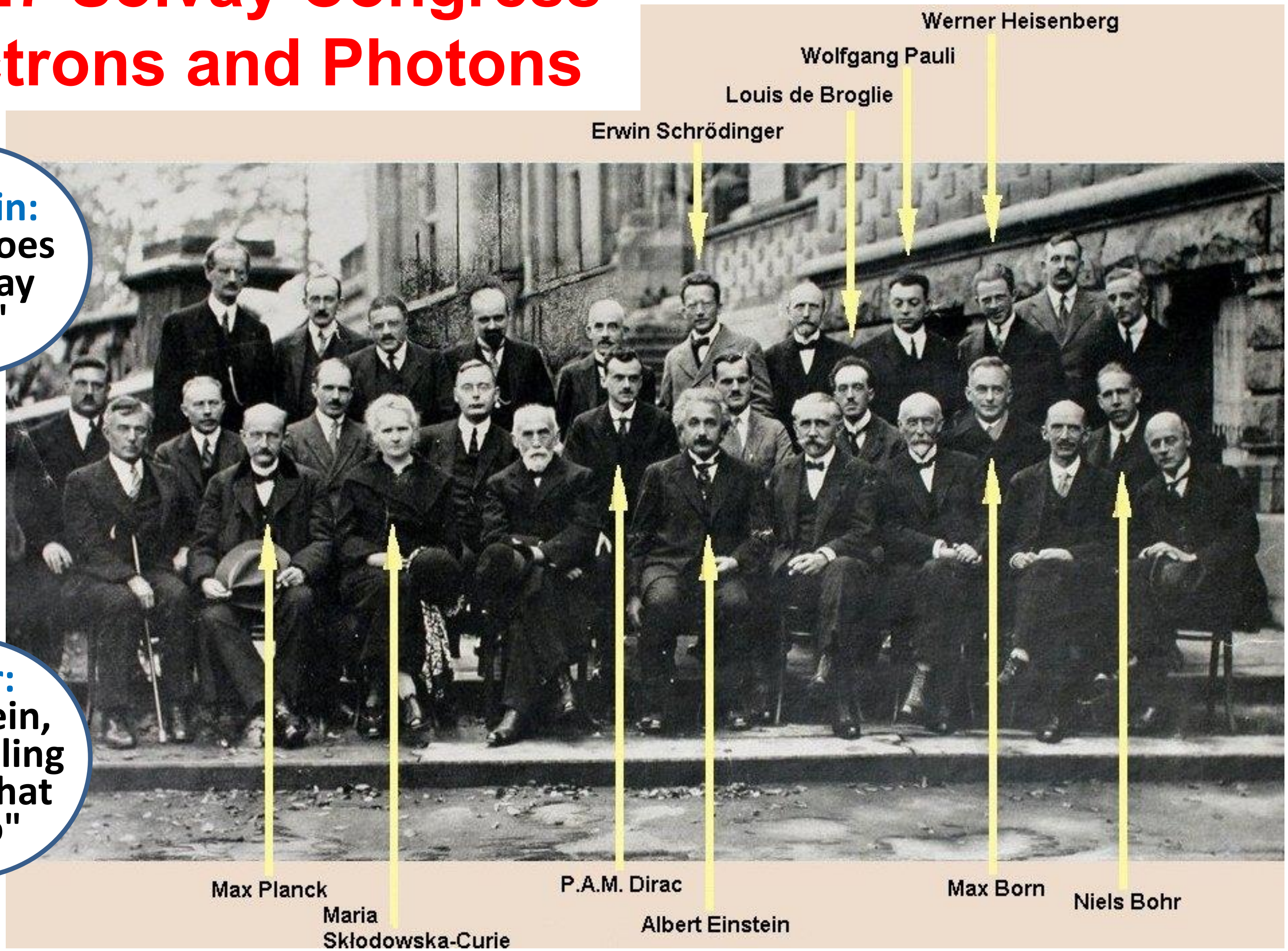




The 1927 Solvay Congress on Electrons and Photons

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.

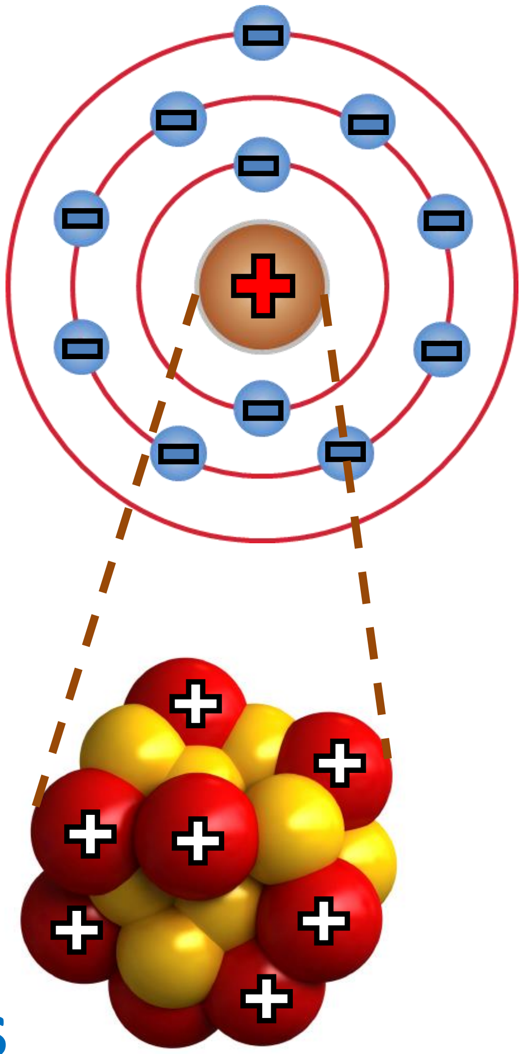
Atomic Structure Summary

- **All atoms have:**
  - a positively charged nucleus
  - and negatively charged electrons moving around within atomic orbitals

- **Atomic nucleus consists of:**
  - positively charged protons
  - and neutrons that have no electric charge

- **Atoms are neutral:**

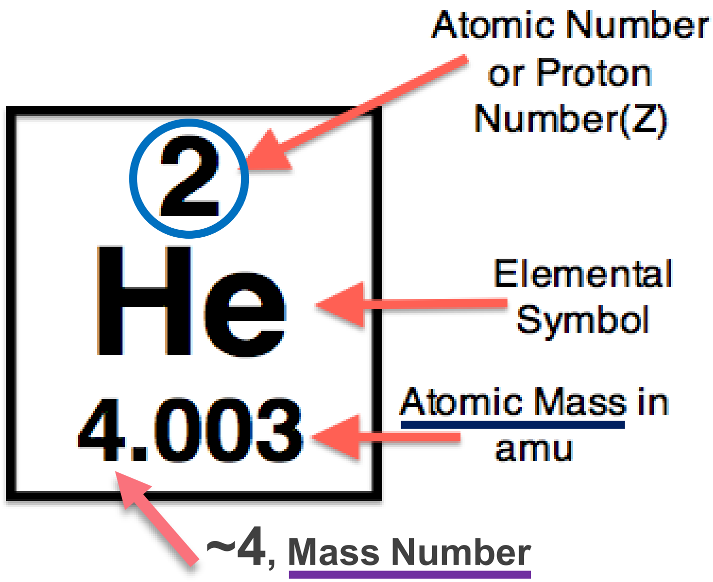
  # of protons = # of electrons



Understanding Elements

The number of protons and neutrons in the nucleus give the atoms their specific characteristics.

- **All atoms of the same chemical element contain the same number of protons, defined by a unique atomic number of that element.**
- **For example, all helium atoms, and only helium atoms, contain two protons and have an atomic number of 2.**



- **Atoms are also characterized by:**
  - **atomic mass**, "relative isotopic mass“ in *unified atomic mass units*, which is roughly (within 1%) equal to the whole mass number (since the mass of a proton and the mass of a neutron are almost the same and the mass of the atom’s electrons is negligibly small)
  - **mass number**, which is a sum of the number of protons and the number of neutrons in the nucleus (number of *nucleons*)

Periodic Table of Elements
is arranged in order of increasing atomic number

(shown *color-coded* according to discovery timeline from antiquity to 2012)