Physics 294H

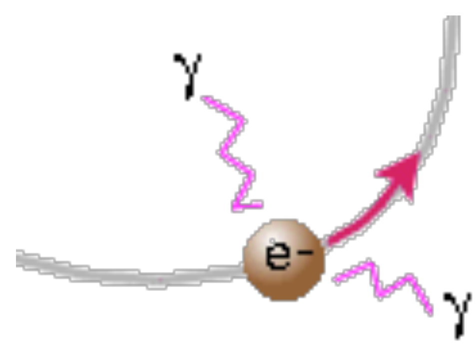
- Professor: Joey Huston
- email:huston@msu.edu
- office: BPS3230
- Homework will be with Mastering Physics (and an average of 1 hand-written problem per week)
  - **Help-room hours: 12:40-2:40 Monday (note change); 3:00-4:00 PM Friday**
- Average on 3rd exam =77/120
- **Final exam Thursday May 5 10:00 AM – 12:00 PM 1420 BPS**
  - **Are there any conflicts?**
- Course website: www.pa.msu.edu/~huston/phy294h/index.html
  - lectures will be posted frequently, mostly every day if I can remember to do so

Grading scale

- 3 hour exams: 3X120=360 points
- ~105 iclicker points: cut off at a max of 95; I'll post a PDF file with points (by iclicker number) after lecture today
- 131 Mastering Physics points; 60 points hand-in problems; total = 191; divide by a factor of 1.5 for 127 points
- Total (so far) of 582 points (final=240 points)
- >=470 4.0
- 400-470 3.5
- 350-400 3.0
- 300-350 2.5
- 250-300 2.0
- <250 1.5

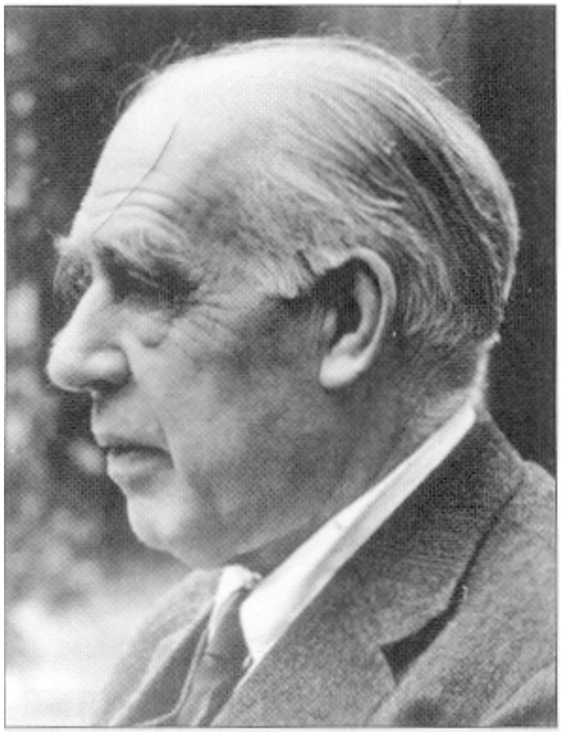
- Rutherford's model was very appealing but there were some "minor" problems that had to be solved.
- What held the nucleus together to be so small?

  AND…
- The orbiting electrons were giving off light, due to Conservation of Energy, they should eventually spiral into nucleus!

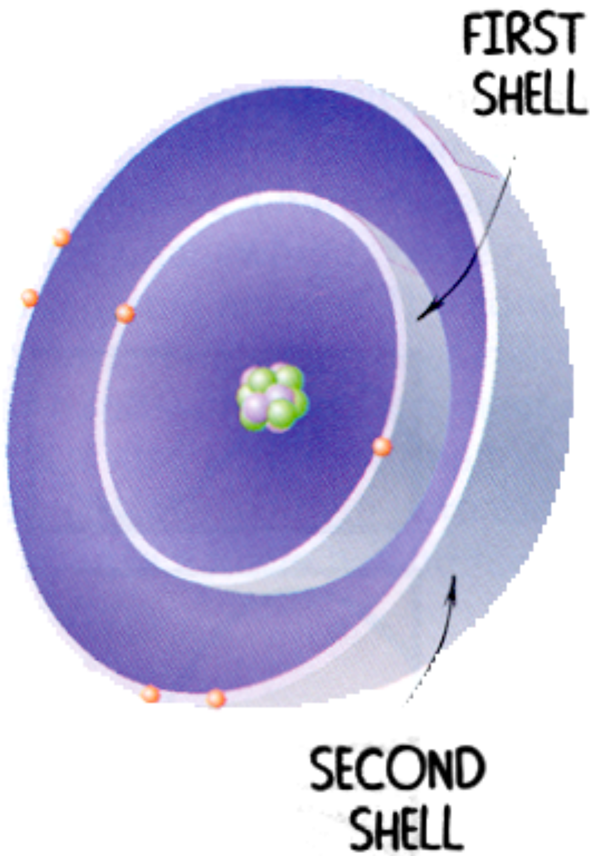


Bohr to the Rescue

- In 1905, Einstein had proposed the wave/particle duality of light with the photon.
- In 1913, Bohr used the concept in creating a quantum model of the atom.

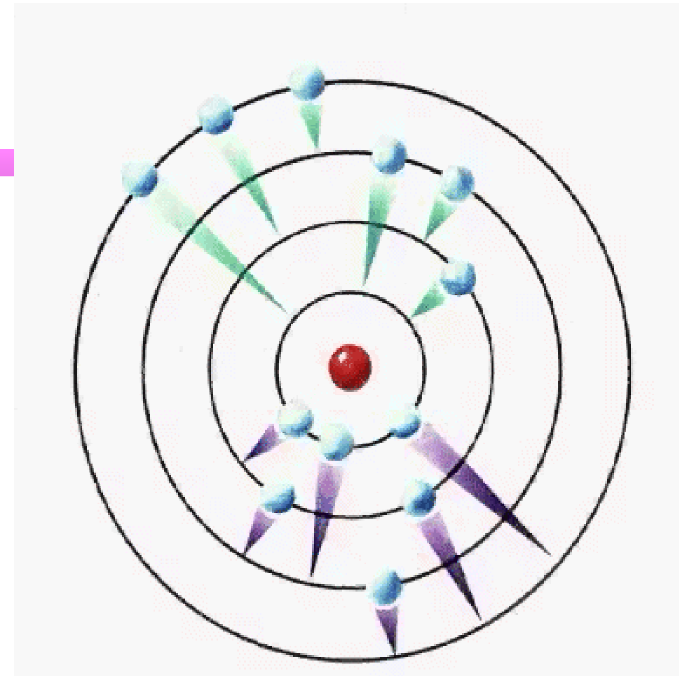


Niels Bohr, Danish physicist (1885–1962)



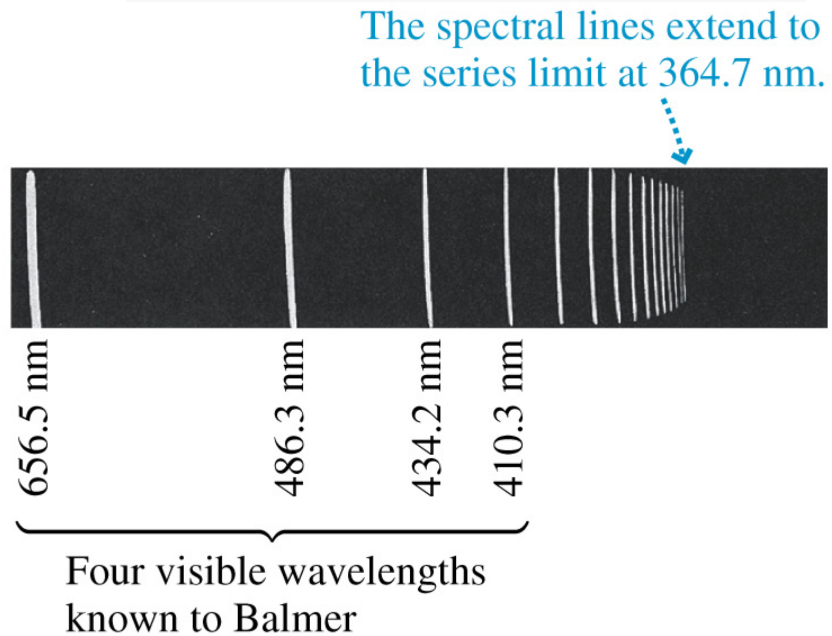
- Only certain stable orbits exists for the electrons.
- While at these orbitals, they do not give off photons.
- Don't ask any more questions.

- Electrons can only move from orbital to another orbital by gaining or releasing photons (a quanta of energy, E=hf).



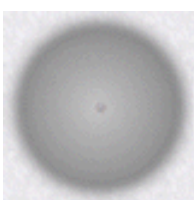
$$\lambda = \frac{91.18nm}{\left(\frac{1}{m^2} - \frac{1}{n^2}\right)}$$

- m=1 Lyman series (UV)
- m=2 Balmer series (visible)
- m=3 Paschen series (IR)



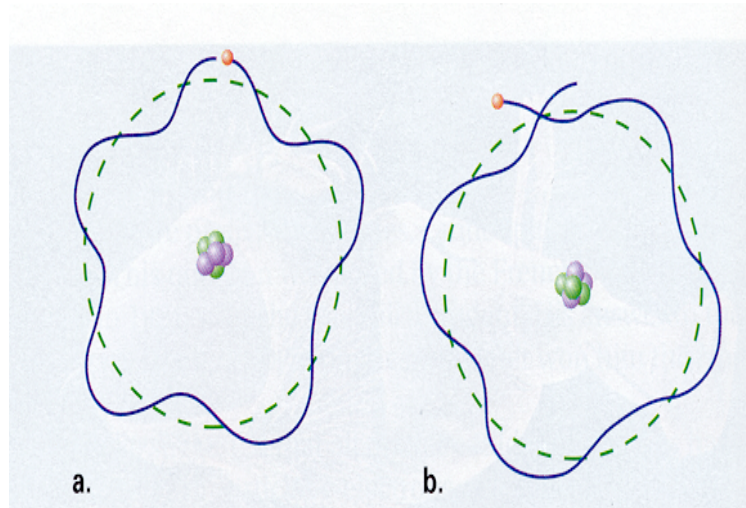
Enter De Broglie

- Bohr's model worked but it lacked a satisfactory reason why.
- De Broglie suggested that all particles have a wave nature.



$\lambda = h/p$

h=Planck's constant



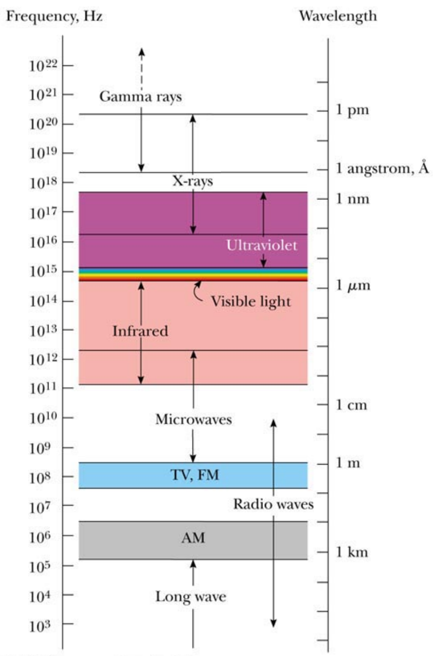
It was the Wave Nature of the electron that determined the nature of the orbits.

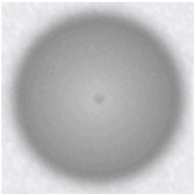
Have to be able to fit an integral number of wavelengths in an orbital.

Wave-particle duality

- Light has a particle nature
- De Broglie suggested that all particles have a wave nature.

$E=hf$
$\lambda=c/f$
$\lambda=hc/E$
$\lambda=h/p$





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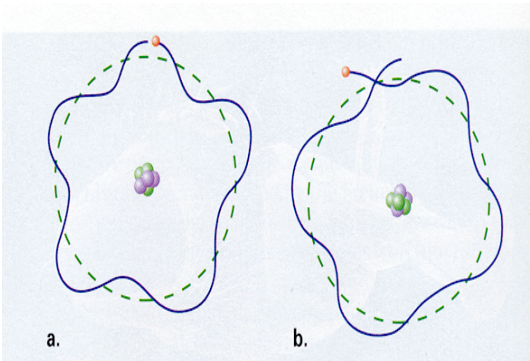
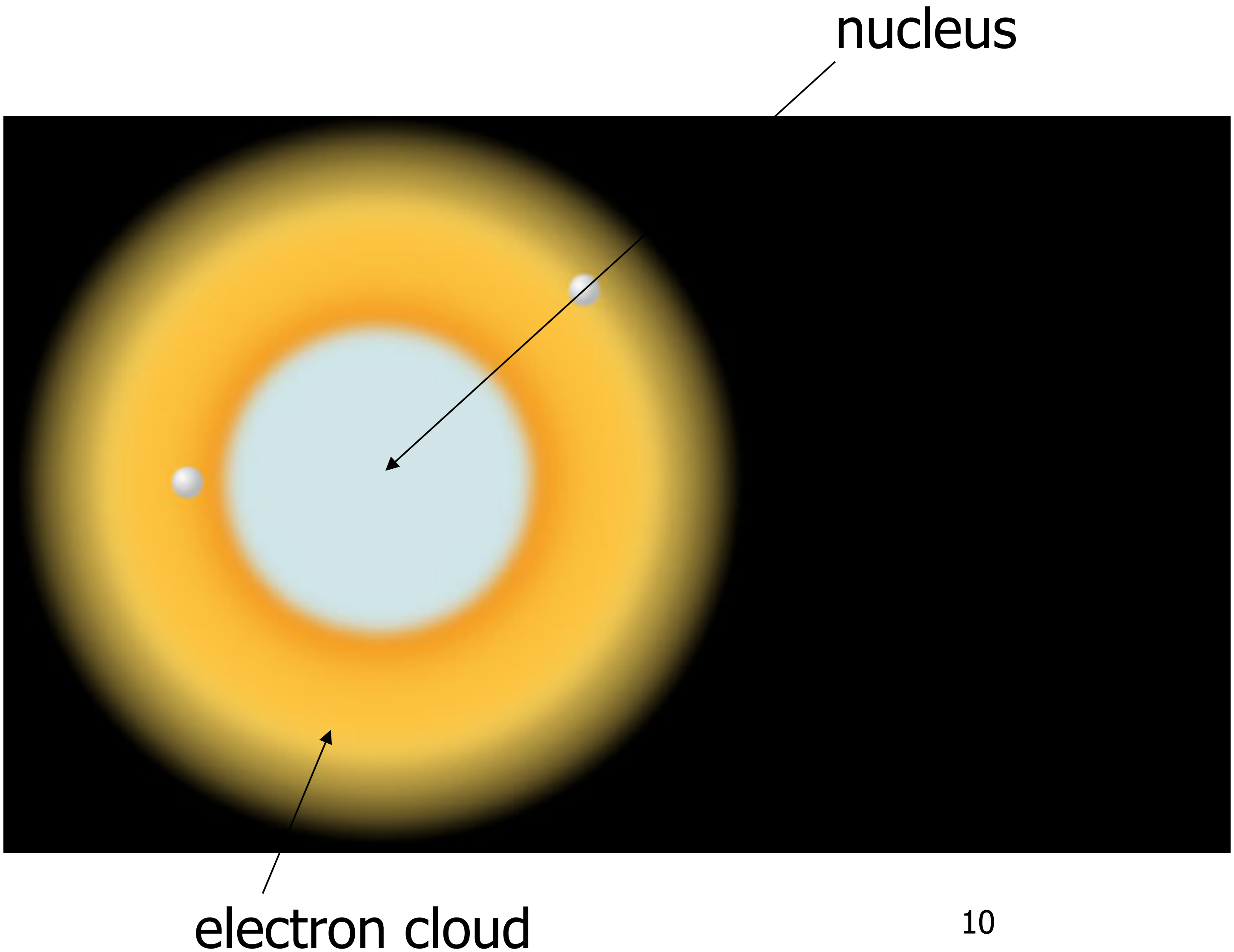


Quantum Model

- Eventually, Pauli, Schrodinger, and others develop the modern view of the atom and the electron clouds that surround the nucleus.
- That is, it’s not a miniature solar system after all
- The electrons aren’t really orbiting

Simple Atom 1920s



Back to the Nucleus

- In 1919, Rutherford starts to collect the first data indicating that there is another structure within the nucleus- the proton.
- Two years later, James Chadwick and E.S. Bieler conclude that some strong force holds the nucleus together.

1930

- In the Hunt, the picture seems to have gotten pretty simple:
- There were three fundamental particles- electron, proton, and photon.
- There were three fundamental forces- gravity, electromagnetic, and the strong nuclear force.

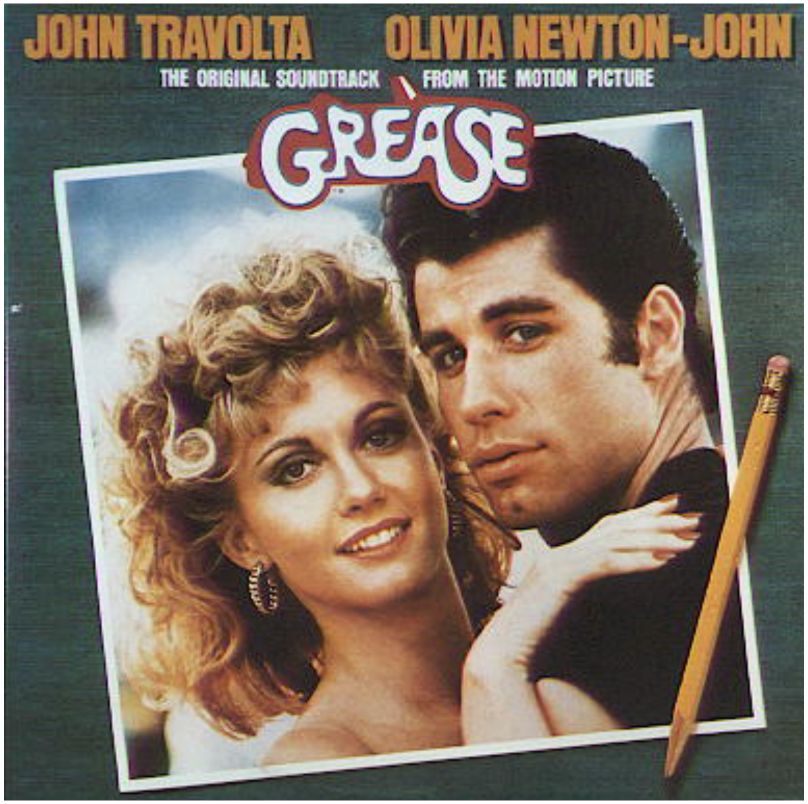
Max Born

- There were still some “details” to work out but many felt like Max Born, who said, "Physics as we know it will be over in six months."
- One of those “details” was the behavior of Beta Particle Decay.
- Now a question: Max Born has a famous granddaughter. Who is she?

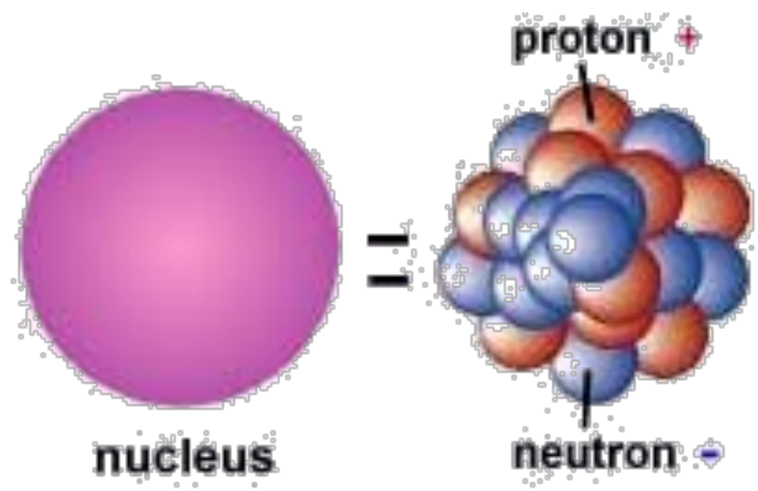
Nobel prize in 1954

Max Born's grand-daughter

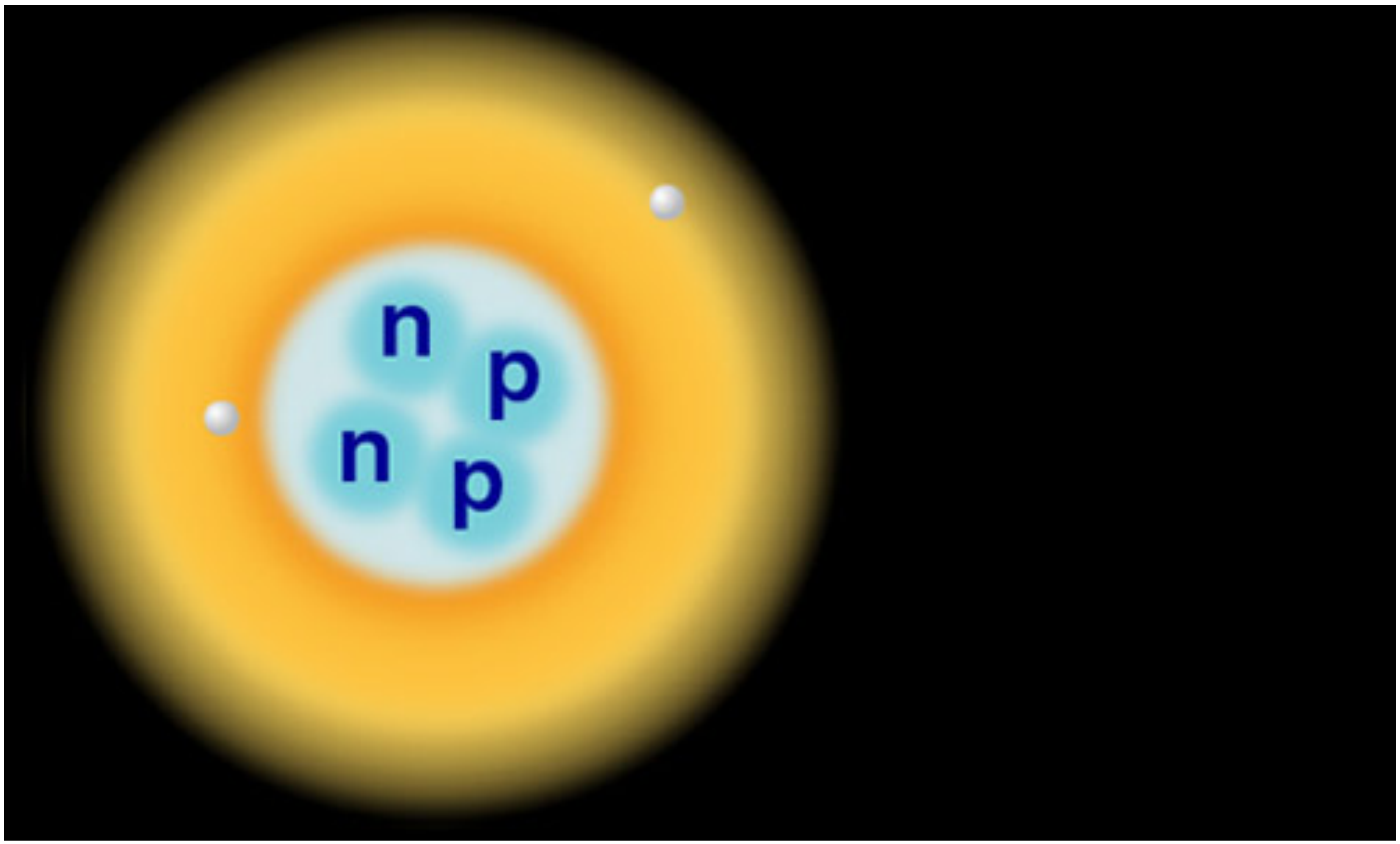
- Olivia Newton-John was born in Cambridge, England on September 26th 1948; her family moved to Australia when she was 5. Her mother was German, daughter of the physicist Max Born, her father was Welsh, a professor of German at Cambridge and Melbourne. Despite the academic background, early on Olivia showed an interest in singing, forming a band called the Sol Four with some schoolfriends, and later on singing at her brother in law's coffee bar in Australia.



- The nucleus had ceased to be fundamental. It was composed of positively charged protons and neutrally charged neutrons (not actually discovered until 1931 by Chadwick).



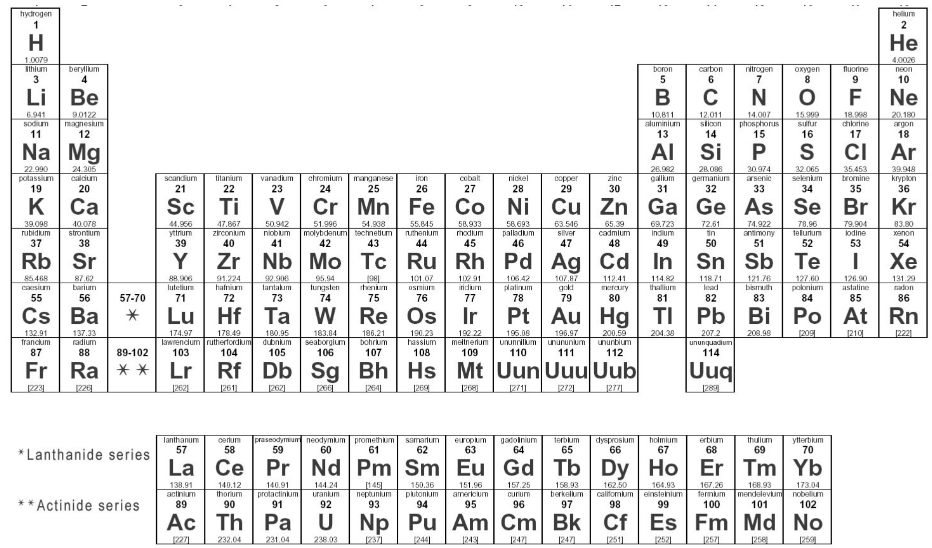
Simple Atom 1930s



Nuclear interlude

Isotopes

- The number of protons in a nucleus determines which element it is
  - which equals the number of electrons in a normal atom
- But there can be different isotopes of a particular element
  - same number of protons, but different number of neutrons

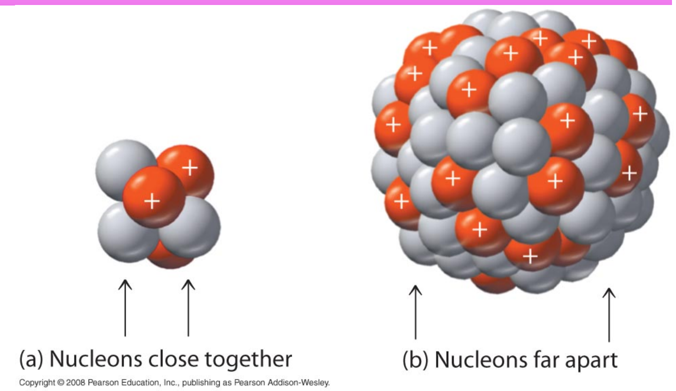


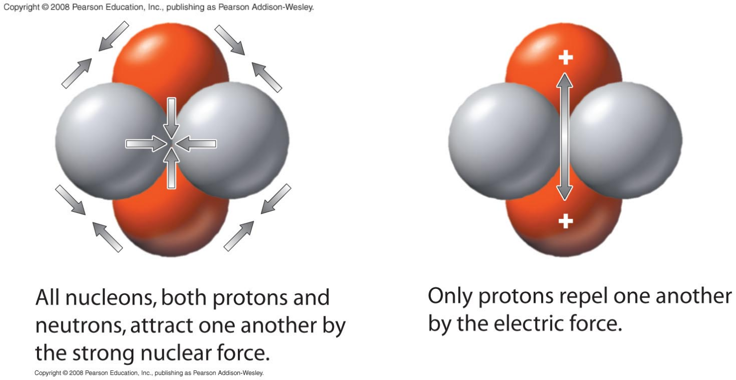
The most common isotope Of uranium is 238, with 238-92=146 neutrons $^{238}_{92}U$

About 0.7% of uranium is the isotope 235, which has the same number of protons (otherwise it wouldn't be uranium), but 3 less neutrons $^{235}_{92}U$

Nuclei

- The atomic nucleus only occupies a few quadrillionths of the total volume of the atom
  - most of the atom is empty space
- The nucleus consists of protons and neutrons packed closely together
- Since the protons are positively charged and they all repel each other, there must be another still stronger force that keeps the nucleus together
  - the strong force
- The strong force is short range, acting over ~10^{-15} m, or about the size of a proton or neutron
  - the electromagnetic force has an infinite range

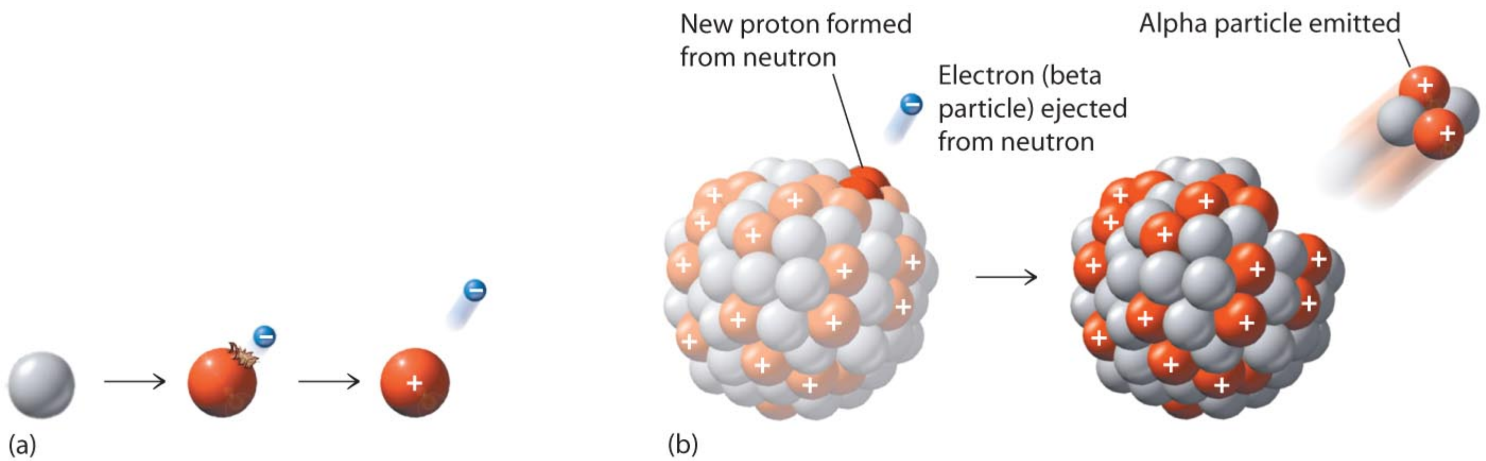




The more protons in a nucleus, the more neutrons are needed to keep the nucleus bound. Smaller nuclei are more stable than larger nuclei, because of the short range of the strong nuclear force.

All nuclei having more than 83 protons are very unstable, i.e. are radioactive.

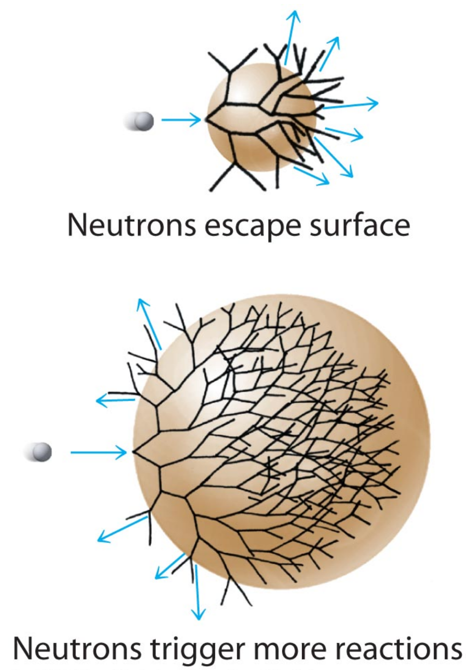
Neutrons

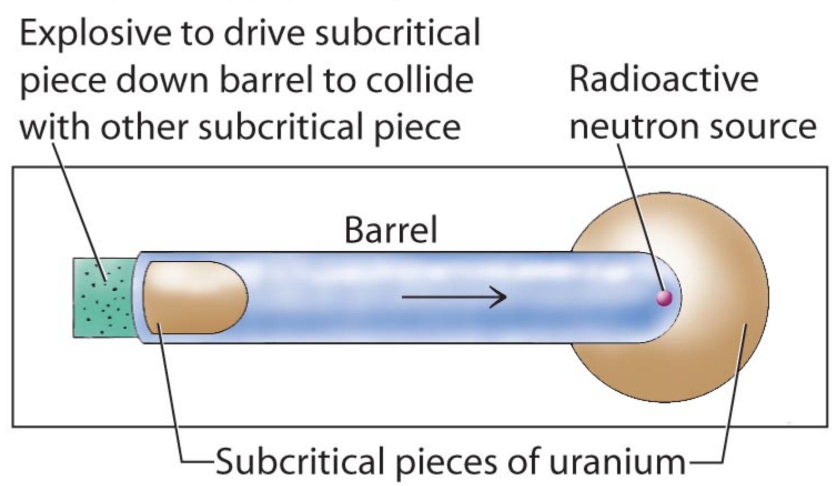


- Neutrons outside of a nucleus are not stable and decay into a proton, electron (and neutrino) with a half-life of about 10 minutes
- This can happen inside of a nucleus as well, with the beta (electron) being emitted
- A nucleus can also emit an alpha particle (2 protons and 2 neutrons)

Fission bomb

- Most of the naturally occurring uranium is the ^{238}U isotope
- Only the ^{235}U isotope can be used for fuel/bomb, so the two have to be separated
  - it took more than 2 years during WWII to make enough for 1 bomb
- There will be no explosion unless a critical mass of ^{235}U is present
  - otherwise the neutrons escape from the bomb before triggering more reactions
  - about 1 kg
- In one bomb design, a piece of uranium is fired towards a hollow sphere of uranium
  - each is sub-critical, but together they make a critical mass





Lise Meitner

- "Mother of the atomic bomb"
- …and last chaper in 'Einstein's Big Idea"

Conservation of Energy

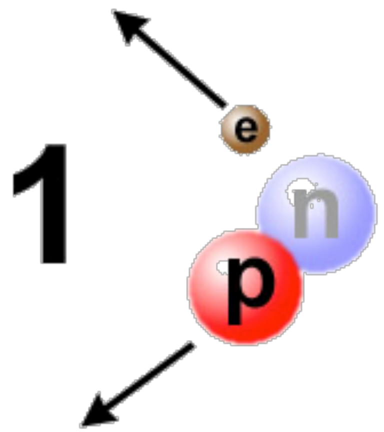
- The Law of the Conservation of Energy had been found to work in combination with Einstein's Theory of Relativity (i.e. $E=mc^2$) at the atomic level.
- For example, when a radioactive thorium-232 decays into a new element radium-228 and an alpha particle, it turns out that the mass of the new radium and the alpha particle <u>does not</u> equal the original mass of the thorium.
- But the missing mass is changed into the kinetic energy of the alpha particle.

But Beta Decay…

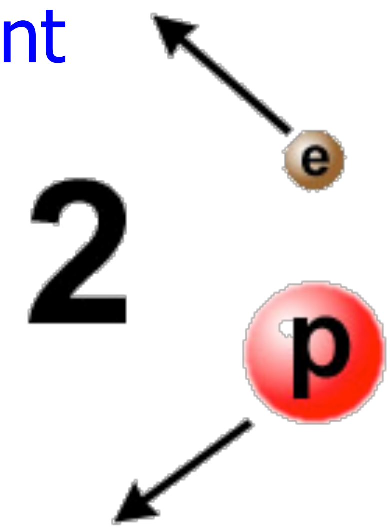
- The Conservation of Energy did not work for beta particle decay (the emission of an electron). The emitted electron's Kinetic Energy was too low.
- What was happening to the missing energy?

& Conservation of Momentum?

- Look at diagram to right, a neutron spontaneously decays into a proton and an electron (beta particle).
- Momenum seemingly is not conserved

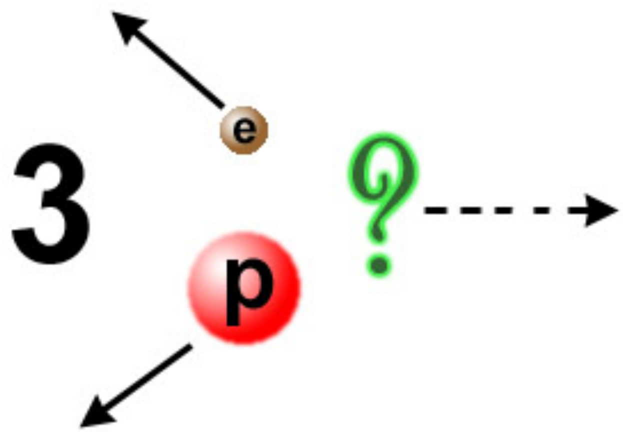


- Is Momentum Conserved?
- How can we account for the discrepancies?

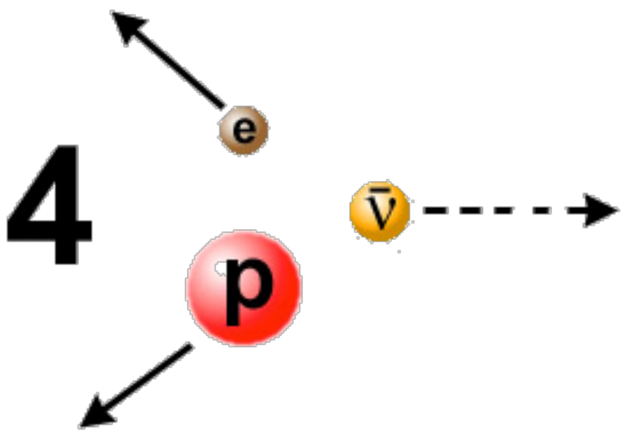


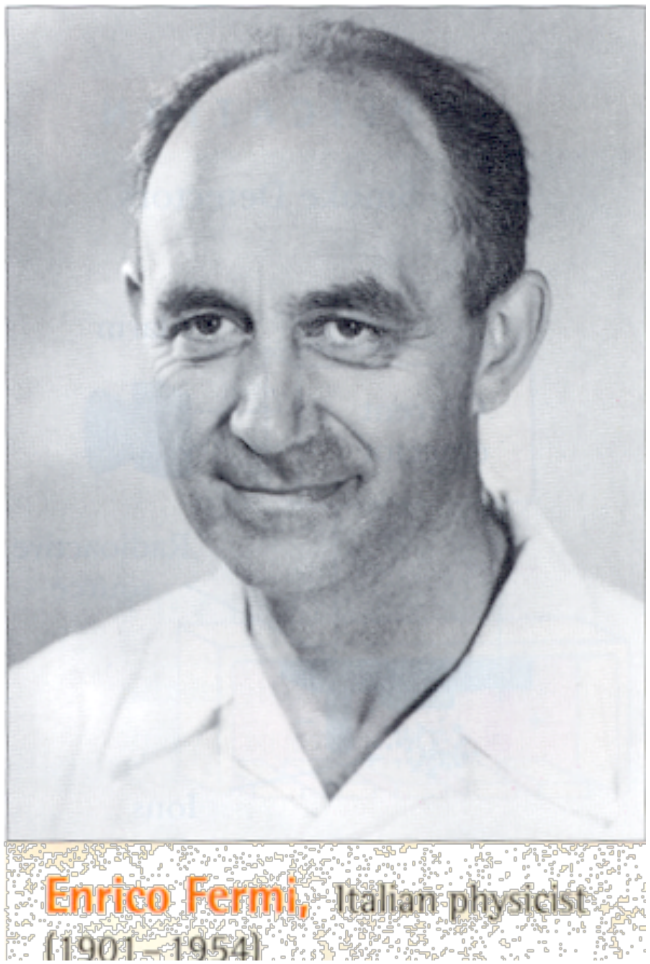
A Possible Answer

- Wolfgang Pauli suggested a bizarre idea, another particle, one not yet seen, was carrying the missing energy and could be used to solve the momentum issue.



- For Conservation of Charge, the new particle would have to be neutral.
- According to other experiments, the particle would have to be incredibly light, perhaps even be massless!





- Due to those characteristics, the Italian physicist Enrico Fermi suggested calling it

Neutrino

Italian for "little neutral one."