PHYS 3446 – Lecture #2

Wednesday, Aug. 31, 2016

Dr. Jae Yu

1. Introduction
2. History on Atomic Models
3. Rutherford Scattering
4. Rutherford Scattering with Coulomb force
5. Scattering Cross Section
6. Measurement of Cross Sections

Extra Credit Project #1

- Extra credit opportunities
  - Obtain a particle data booklet and a pocket diary
    - http://pdg.lbl.gov/pdgmail/
    - Both 2016 booklets and review as well as 2014 versions
  - Subscribe to the email version of Symmetry Magazine & Fermilab Frontiers
    - http://www.symmetrymagazine.org
    - http://news.fnal.gov/newsroom/subscribe-to-fermilab-frontiers/
  - Subscribe to the printed copy of CERN Courier Magazine
    - http://www.cerncourier.com/
    - Send e-mail to the US distribution center
  - 3 points each if done by Wednesday, Sept. 7.
  - Please print out the confirmation e-mails of these requests, staple them, put your name on a cover sheet with the title "Extra Credit Project #1" and date of submission, and submit

Homework Assignment #1

1. Compute the masses of electron, proton and alpha particles in MeV/c^2, using $E=mc^2$. (9 points)
   - Need to look up and specify the masses of electrons, protons and alpha particles in kg on your paper.
2. Compute the gravitational and the Coulomb forces between two protons separated by 10^{-10}m and compare their strengths (15)
3. Derive the following equations in your book:
   - Eq. # 1.3 (5 pts) , 1.17 (8 pts), 1.32 (12 pts)
   - Must show detailed work and accompany explanations
   - Copying the book or your friend will result in no credit for both of you!

- These assignments are due next Monday, Sept. 12.

Information & Communication Source

- Course web page: http://www-hep.uta.edu/~yu/teaching/fall16-3446-001/fall16-3446-001.html
  - Contact information & Class Schedule
  - Syllabus
  - Homework
  - Holidays and Exam days
  - Evaluation Policy
  - Class Style & Communication
  - Other information
- Primary communication tool is e-mail: Make sure that your e-mail at the time of course registration is the one you most often read!!
- Office Hours for Dr. Yu: 4:00 – 5:00pm, M-Th or by appointments

Class Specification

- Text Books
  - Das and Ferbel, “Introduction to Nuclear and Particle Physics”
  - D. Perkins, “Introduction to High Energy Physics”
  - R. Fernow, “Introduction to Experimental Particle Physics”
- Reading Assignments and Special Projects
  - Not just based on the books
  - We will use published papers as well
  - Extra credit on class participations and attendances up to 10%
- Homework Assignments:
  - There will be homework problems randomly assigned throughout the semester
- Two Written Term Exams (15% each)
  - Term #1: Mon. Oct. 10
  - Term #2: Mon. Dec. 5 (this date could change)
- Research Projects and Presentations (20%+10%)

Syllabus

- Nuclear Physics (~1/3 of the semester)
  - Nuclear Phenomenology
  - Nuclear Models
  - Nuclear Radiation
- High Energy Experimental Techniques
  - Particle energy deposit in matter
  - Particle detector techniques and detectors
  - Accelerators
- HEP Phenomenology
  - Elementary particle interactions
  - Symmetries
  - Discrete Transformations
  - CP violations
  - The Standard Model

Syllabus

- Neutrinos
  - Neutrinos and proton structure functions
  - $\sin^2\theta_W$ measurements and its impact to Higgs
  - Neutrino Oscillation
- Electroweak Symmetry Breaking
  - Standard Model EWSB formalism & Higgs
  - Minimal Super-symmetric Extension of Standard Model
  - Other EWSB Theories (SUSY) & Other Types of Higgs
  - Strategy for Higgs search
- New Phenomena
- Will be mixed with appropriate experimental techniques

Attendances and Class Style

- Attendances:
  - Will be taken randomly
  - Will be used for extra credit
- Class style:
  - Lectures will be on electronic media
    - The lecture notes will be posted on the web **AFTER** each class
  - Will be mixed with traditional methods
  - Active participation through questions and discussions are **STRONGLY** encouraged ➔ Extra credit….

Semester Projects

- Detailed studies on the impact of NP and HEP to everyday lives
- Final project consists of
  - A > 7 page paper each (must become a UTA-HEP note): 20% of the total
    - References must be papers and printed materials NOT web sites!!
  - A 12+5 minute power point presentation for each group: 10% of total
- Report Due and Presentation Dates
  - Presentation: Wed. Dec. 7, if needed Mon. Dec. 12
  - Report Due: At the beginning of the class on Wed. Dec. 7

Semester Projects

1. Medical Use of Nuclear Physics
2. Use of Particle Accelerator Technologies in everyday lives
3. Use of Nuclear Fission in Power Generations and the Future with Nuclear Fusion
4. Study of Fundamental Physics of Nucleus and The Formation of Stars using Rare Isotope Accelerators
5. Use of Particle Detection Technologies in Everyday Lives

Laboratory

- Location: SH Room 018 in basement
- Lab to begin in the week of Sept. 12
- Requirements: **Must be trained for radiation safety**
- A few measurements throughout the semester
  - Lab can be accessed in times other than regular lab
- Lab reports are due one week after each measurement
  - The report will be peer reviewed by someone out of your team
  - Review comments are due the week after ➔ Will be reflected into the lab grade
- Lab score will be 15% of the total

Evaluation Policy

- Two Term Exams: 15 % each ➔ 30%
- Lab Score: 15%
- Final semester project paper (individual): 20%
- 5+2 minute project oral presentation (group): 10%
- Homework: 15%
- Quizzes: 10%
- Extra Credit: 10%
  - Consists of random attendances, colloquium (4pm Wednesdays – starts week of Sept. 12) attendances, special projects and other opportunities

In This Class

- You will learn
  - Frontier physics and its history
  - Building blocks of matters are
  - How matters interact
  - The current theories that predict the nature
  - The experimental techniques to verify and test these theories
  - How we can make our lives better by establishing good theories
- You are strongly encouraged to work together
  - One learns enormously describing one's thoughts to others
- This is not going to be a stroll in the park….
- You will earn your grade and feel a total fulfillment!!
- But most importantly…

We will have a lot of FUN!!!!

Why do Physics?

Exp.
- To understand nature through experimental observations and measurements (**Research**)

Theory
- Establish limited number of fundamental laws, usually with mathematical expressions
- Predict nature's courses

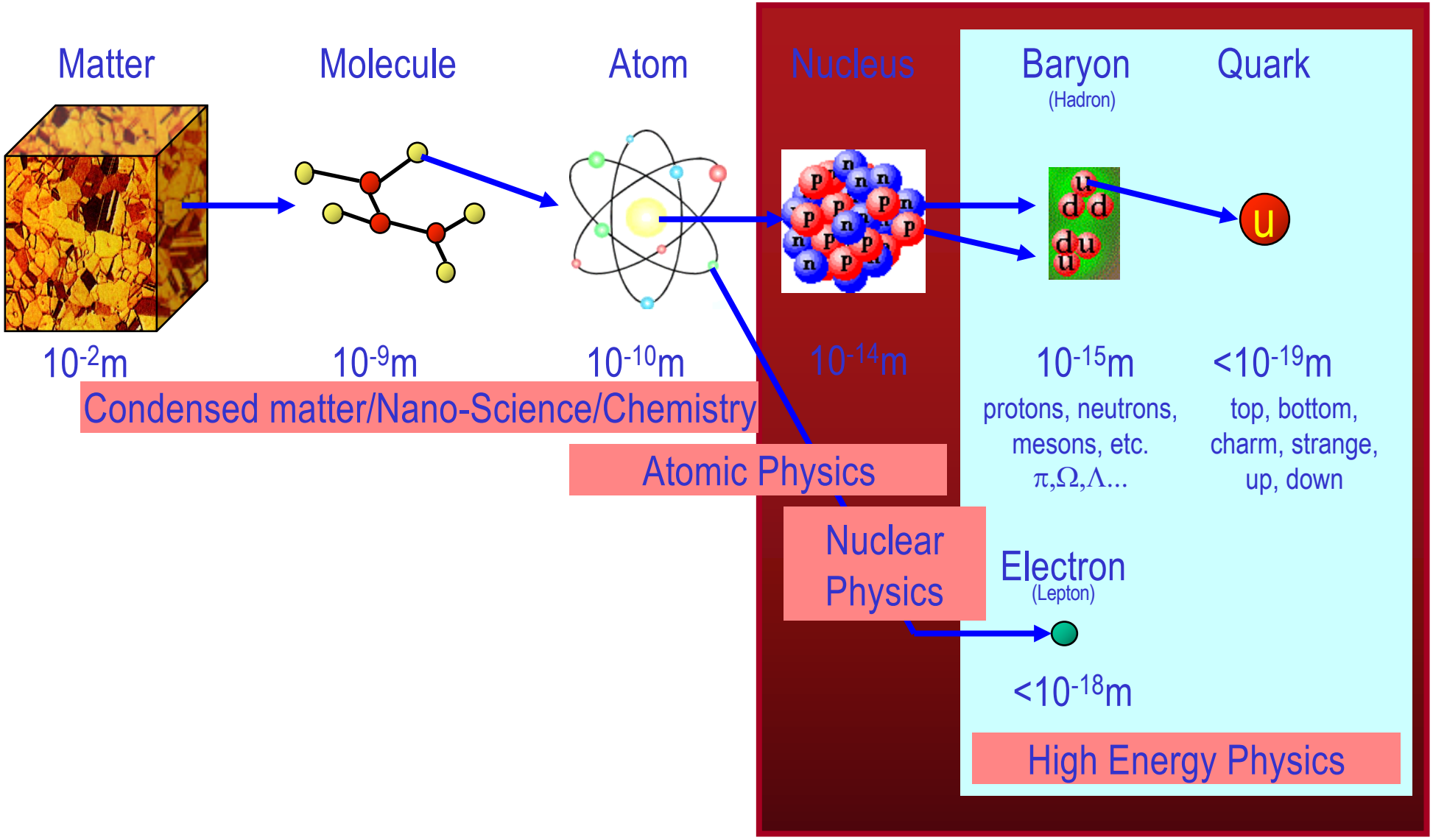
⇒Theory and Experiment work hand-in-hand

⇒Theory works generally under restricted conditions

⇒Discrepancies between experimental measurements and theory presents opportunities to quantum leap

⇒Improves our everyday lives, though some laws can take a while till we see amongst us

Structure of Matter

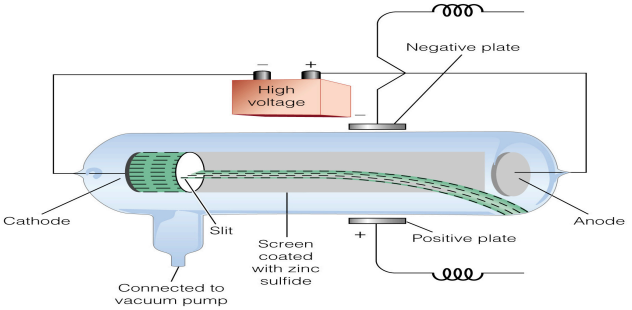


Theory for Microscopic Scale, QM

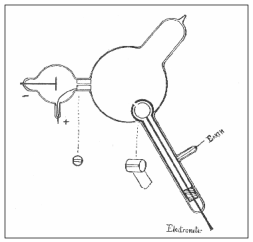
- Difficult to describe small scale phenomena w/ just CM and EM
- The study of atomic structure led to quantum mechanics
  - Long range EM force is responsible for holding atoms together (why?)
  - Yet sufficiently weak for QM to estimate properties of atoms reliably
- In Nucleus regime, the simple Coulomb force does not work. Why?
  - The force in nucleus holds positively charged particles together
- The known forces in nature
  - Strong ~ 1
  - Electro-magnetic ~ 10^{-2}
  - Weak ~ 10^{-5}
  - Gravitational ~ 10^{-38}

Evolution of Atomic Models

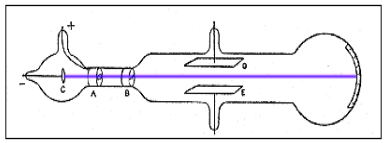
- 1803: Dalton's billiard ball model
- 1897: J.J. Thompson Discovered electrons
  - Built on all the work w/ cathode-ray tubes
  - Called corpuscles
  - Made a bold claim that these make up atoms
  - Measured m/e ratio
- 1904: J.J. Thompson Proposed a "plum pudding" model of atoms
  - Negatively charged electrons embedded in a uniformly distributed positive charge

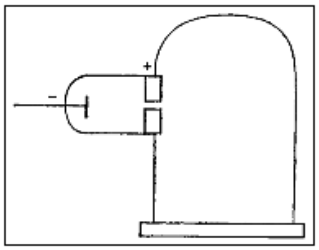


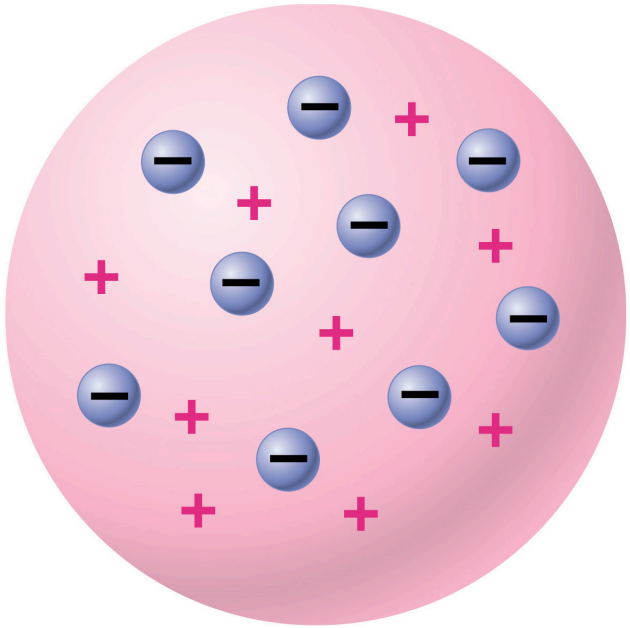
Cathode ray tube



Thompson's tubes

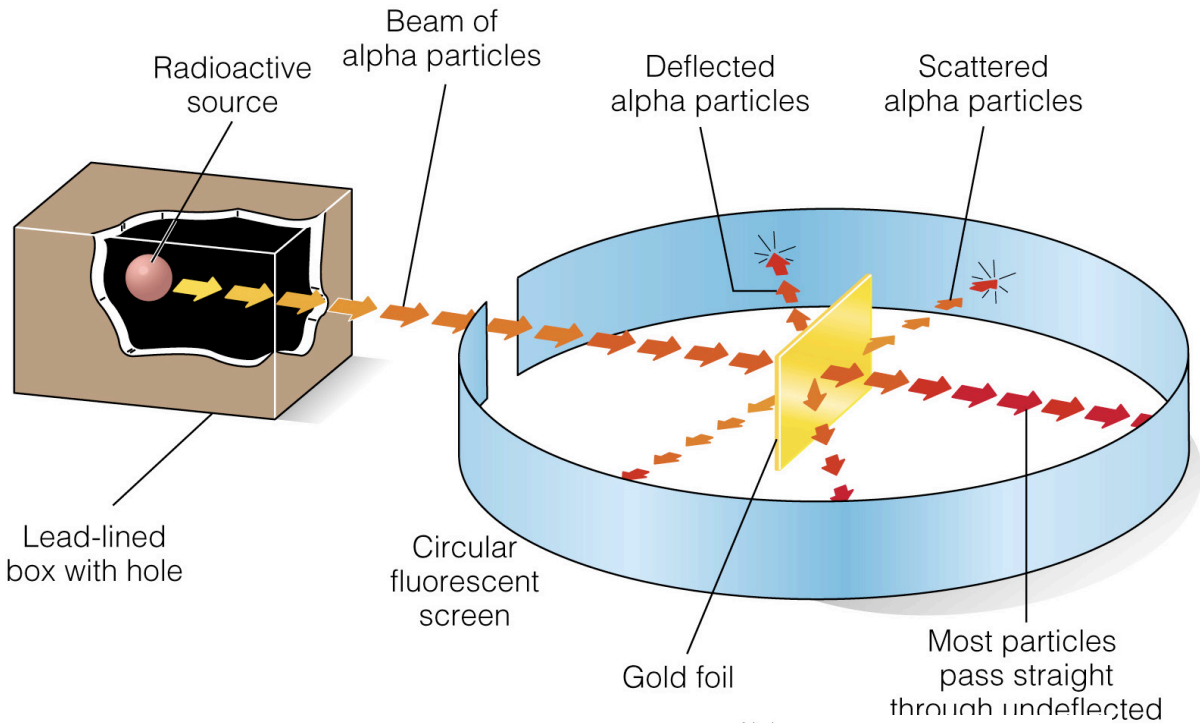


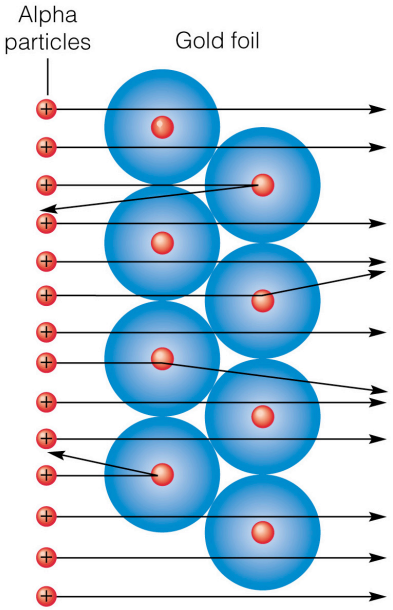




History of Atomic Models cnt'd

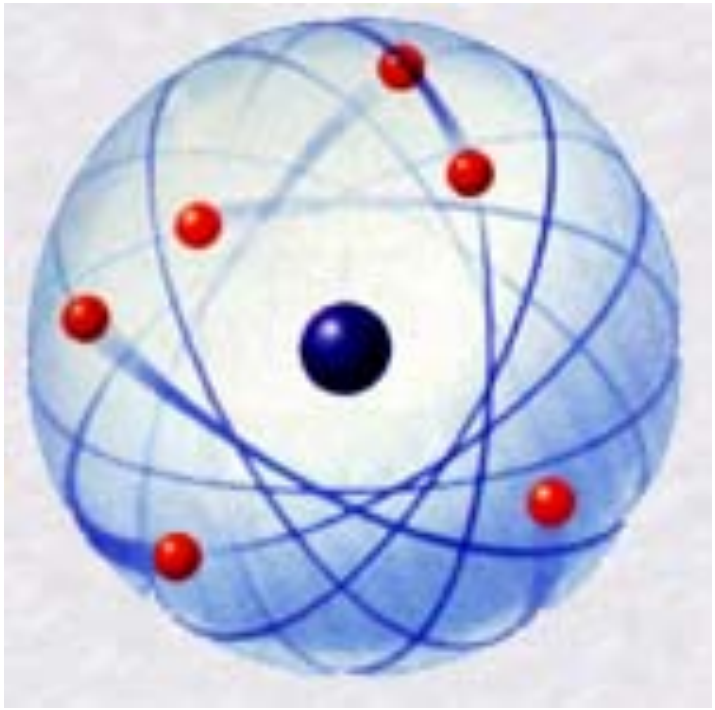
- 1910: Geiger and Marsden with Rutherford performed a scattering experiment with alpha particles shot on a thin gold foil

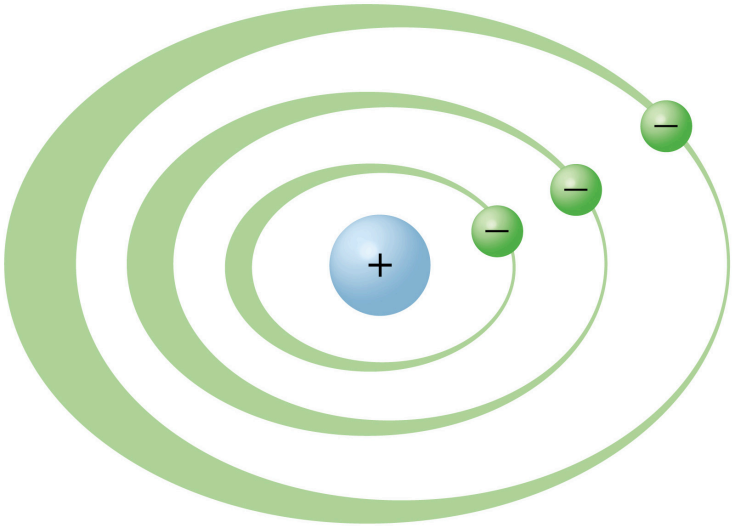




History of Atomic Models cnt'd

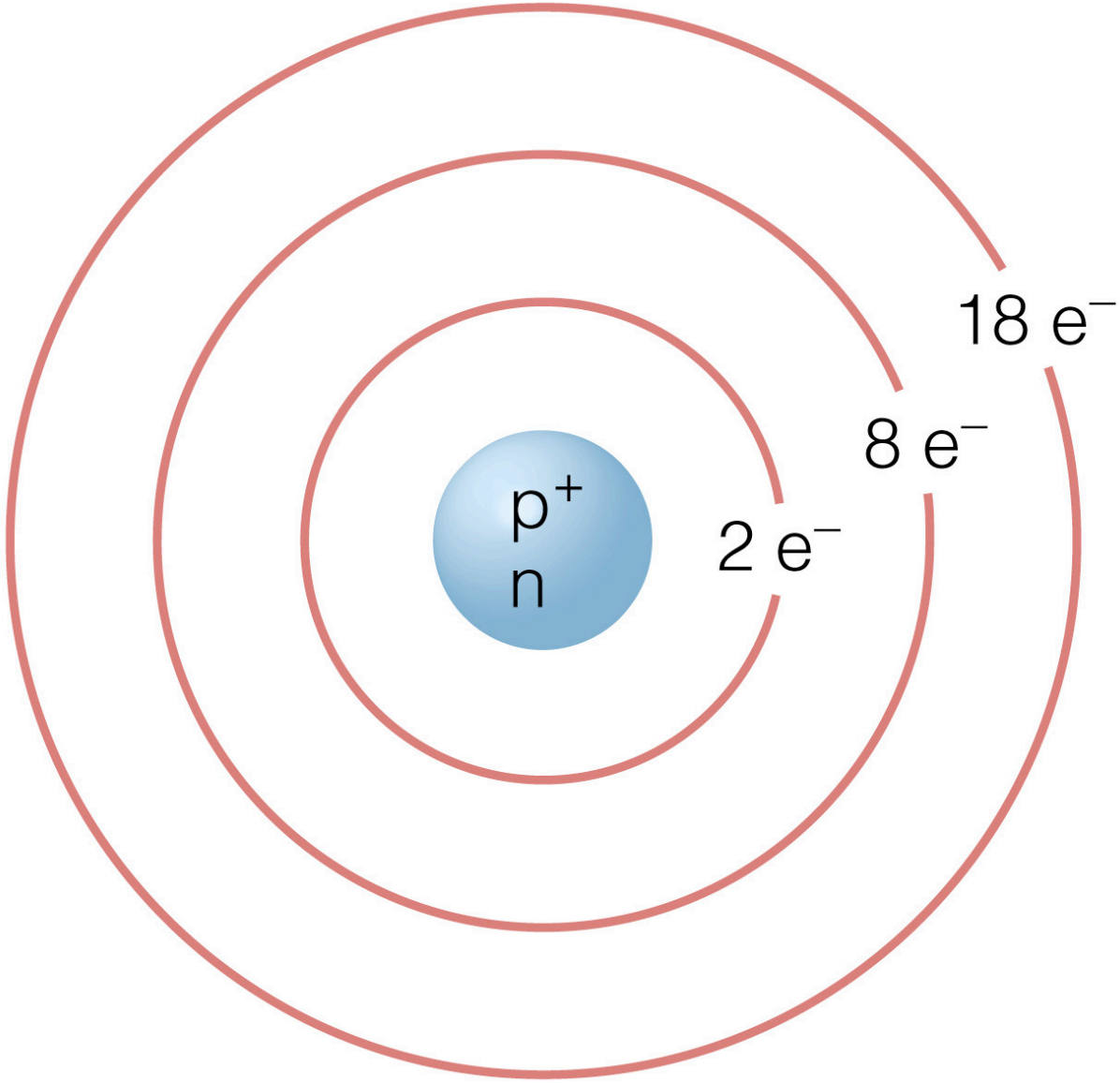
- 1912: Rutherford's planetary model, an atomic model with a positively charged heavy core surrounded by circling electrons
  - Deficiency of instability. Why?
    - The electrons will eventually get pulled onto the nucleus, destroying the atom





History of Atomic Models cnt'd

- 1913: Neils Bohr proposed the Orbit Model, where electrons occupy well quantified orbits
  - Electrons can only transition to pre-defined orbits



History of Atomic Models cnt'd

- 1926: Schrödinger and de Broglie proposed the Electron Cloud Model based on quantum mechanics