DEVIL PHYSICS
THE BADDEST CLASS ON CAMPUS
IB PHYSICS

TSOKOS LESSON 7-1A
DISCRETE ENERGY

Essential Idea:

- In the microscopic world energy is discrete.

Theory Of Knowledge:

- The role of luck/serendipity in successful scientific discovery is almost inevitably accompanied by a scientifically curious mind that will pursue the outcome of the "lucky" event.
- To what extent might scientific discoveries that have been described as being the result of luck actually be better described as being the result of reason or intuition?

Understandings:

- Discrete energy and discrete energy levels
- Transitions between energy levels
- Fundamental forces and their properties
- Isotopes

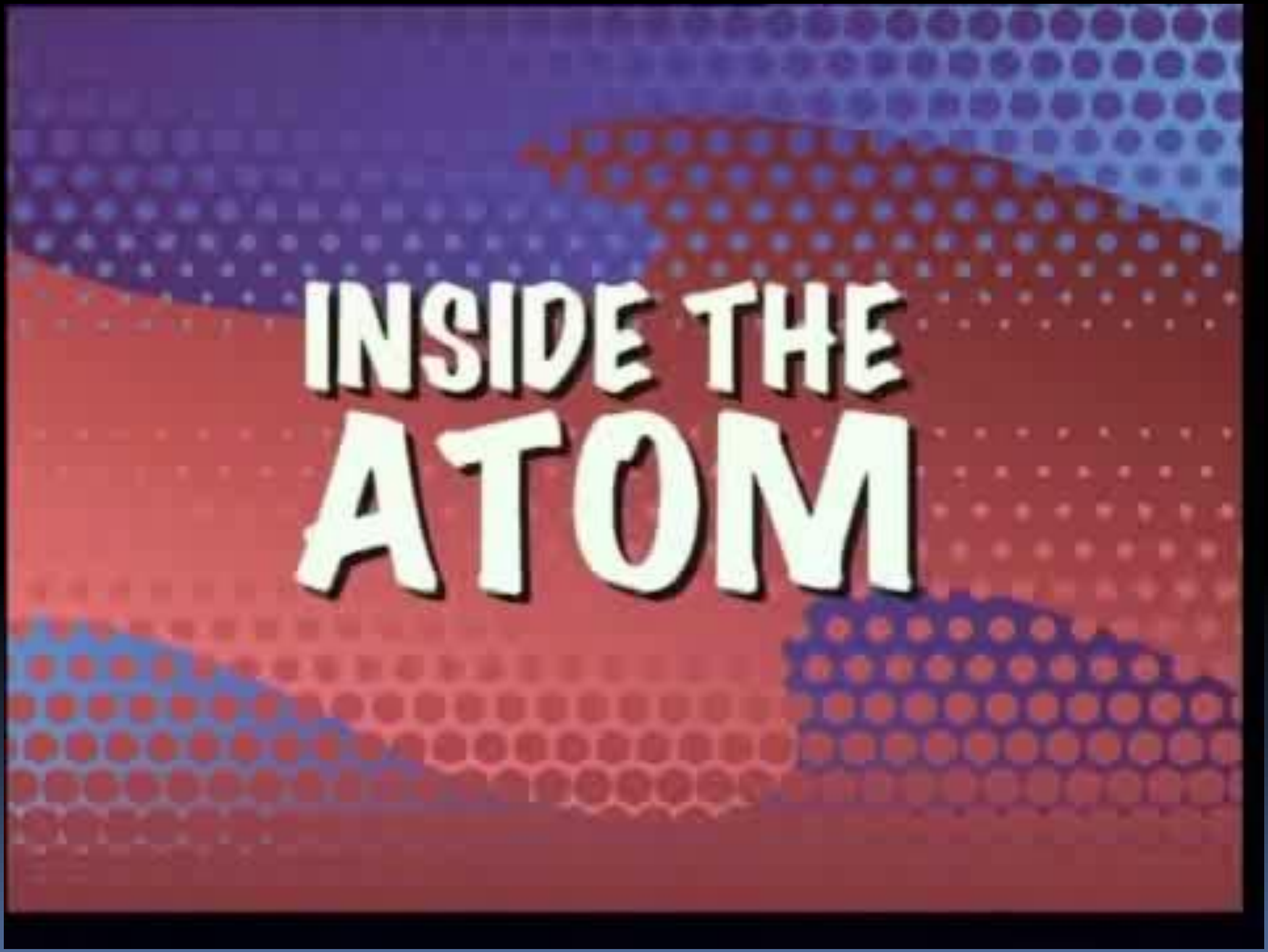
Applications And Skills:

- Describing the emission and absorption spectrum of common gases
- Solving problems involving atomic spectra, including calculating the wavelength of photons emitted during atomic transitions

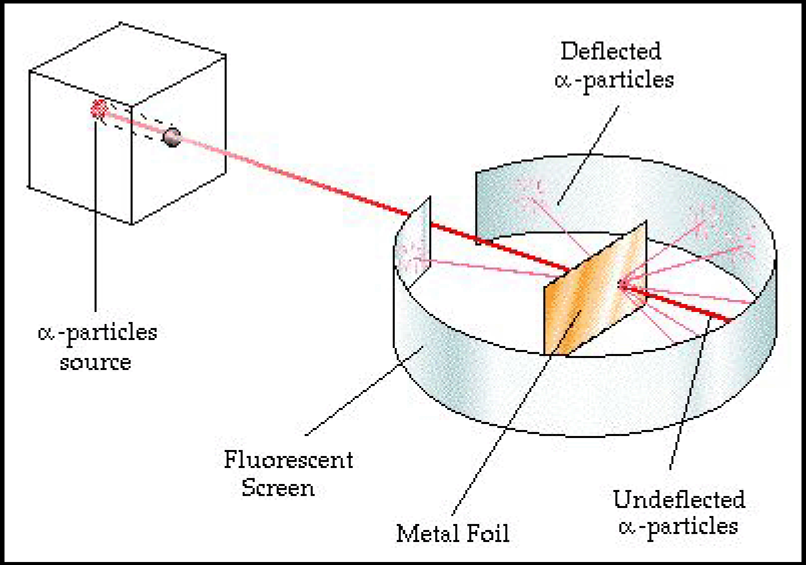
Data Booklet Reference:

- $E = hf$
- $\lambda = \frac{hc}{E}$

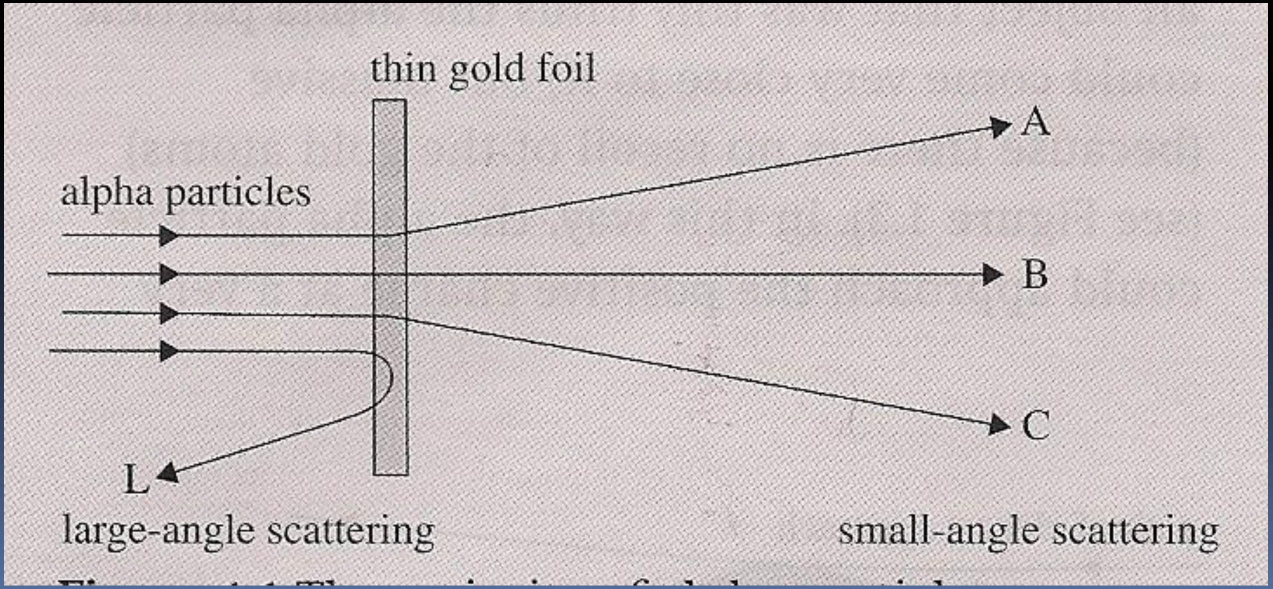
Theories of Atomic Structure



The Nuclear Atom



- Geiger and Marsden
  - Working for Rutherford
  - Directed alpha particles from radon gas in a narrow beam toward a thin gold foil



The Nuclear Atom

- Rutherford/Geiger/Marsden Experiment
  - Proved Thompson's plum pudding model wrong

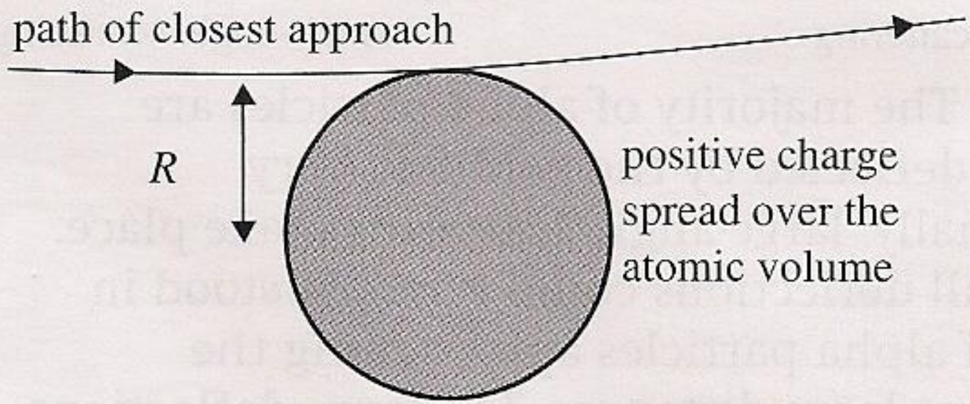
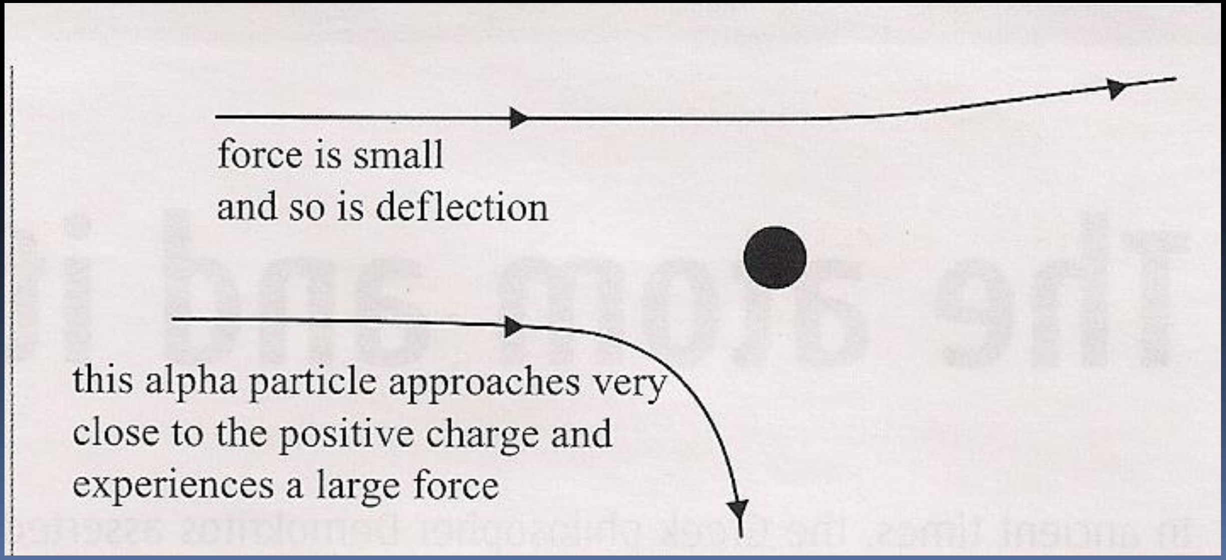


Figure 1.2 In Thomson's model, the closest an alpha particle can come to the atom's centre is a distance equal to the atomic radius.

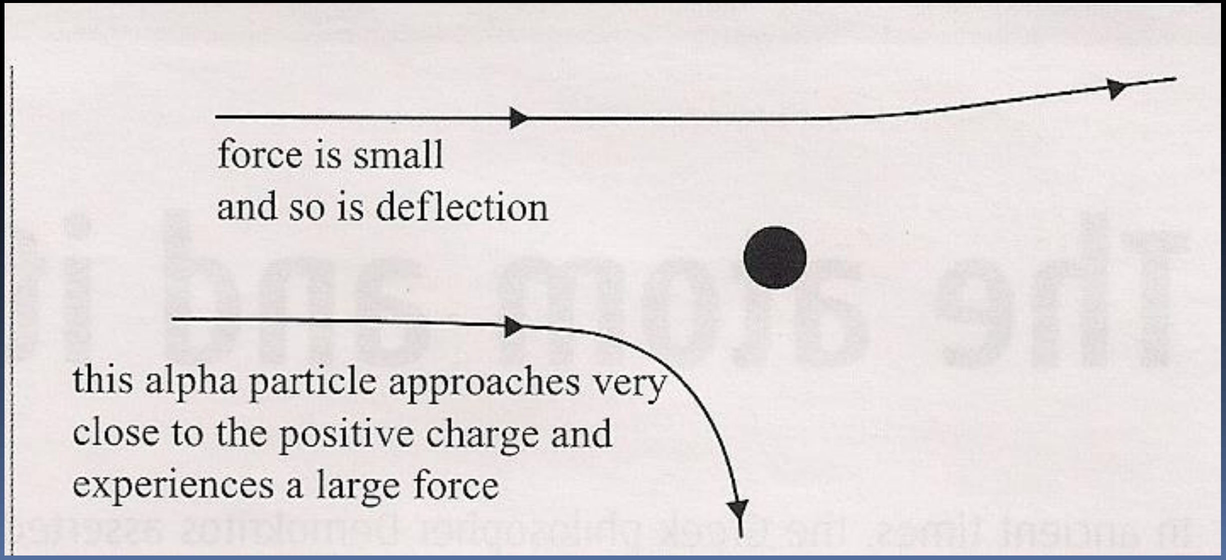
The Nuclear Atom

- Rutherford/Geiger/Marsden Experiment
  - Positive charge resides in a small, very dense center of the atom
  - The alpha particle could thus come very close to the center of charge before being repulsed by the concentrated charge – a nucleus



The Nuclear Atom

- Rutherford/Geiger/Marsden Experiment
  - Rutherford used Coulomb's force law and Newton's laws of motion to calculate the number of particles expected at different deflection angles
  - This led to determination of a nuclear sphere with radius 10^{-15}m



The Nuclear Atom

- Compare the electric field due to one unit of positive charge at the surface of the nucleus (radius 10^{-15} m) to that at the surface of the atom (radius 10^{-10} m)
  - Nucleus surface
  - Atom surface
  - 10^{10} times larger

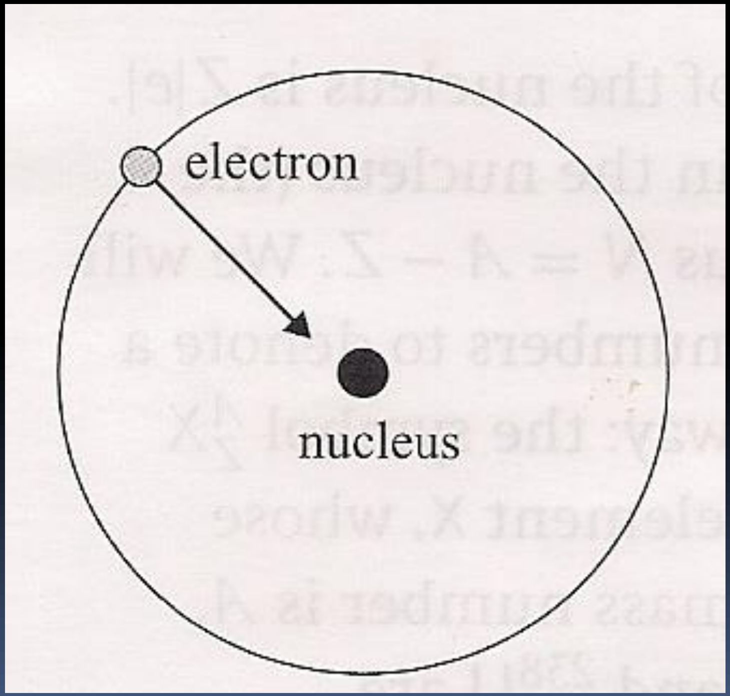
$$E = k\frac{Q}{r^2}$$

$$E = \left(9x10^9\right)\frac{1.6x10^{-19}}{\left(10^{-15}\right)^2} = 1.4x10^{21} N/C$$

$$E = \left(9x10^9\right)\frac{1.6x10^{-19}}{\left(10^{-10}\right)^2} = 1.4x10^{11} N/C$$

Rutherford Model

- Positive charge concentrated in nucleus, electrons held in orbits like planets by electrical forces



Rutherford Model

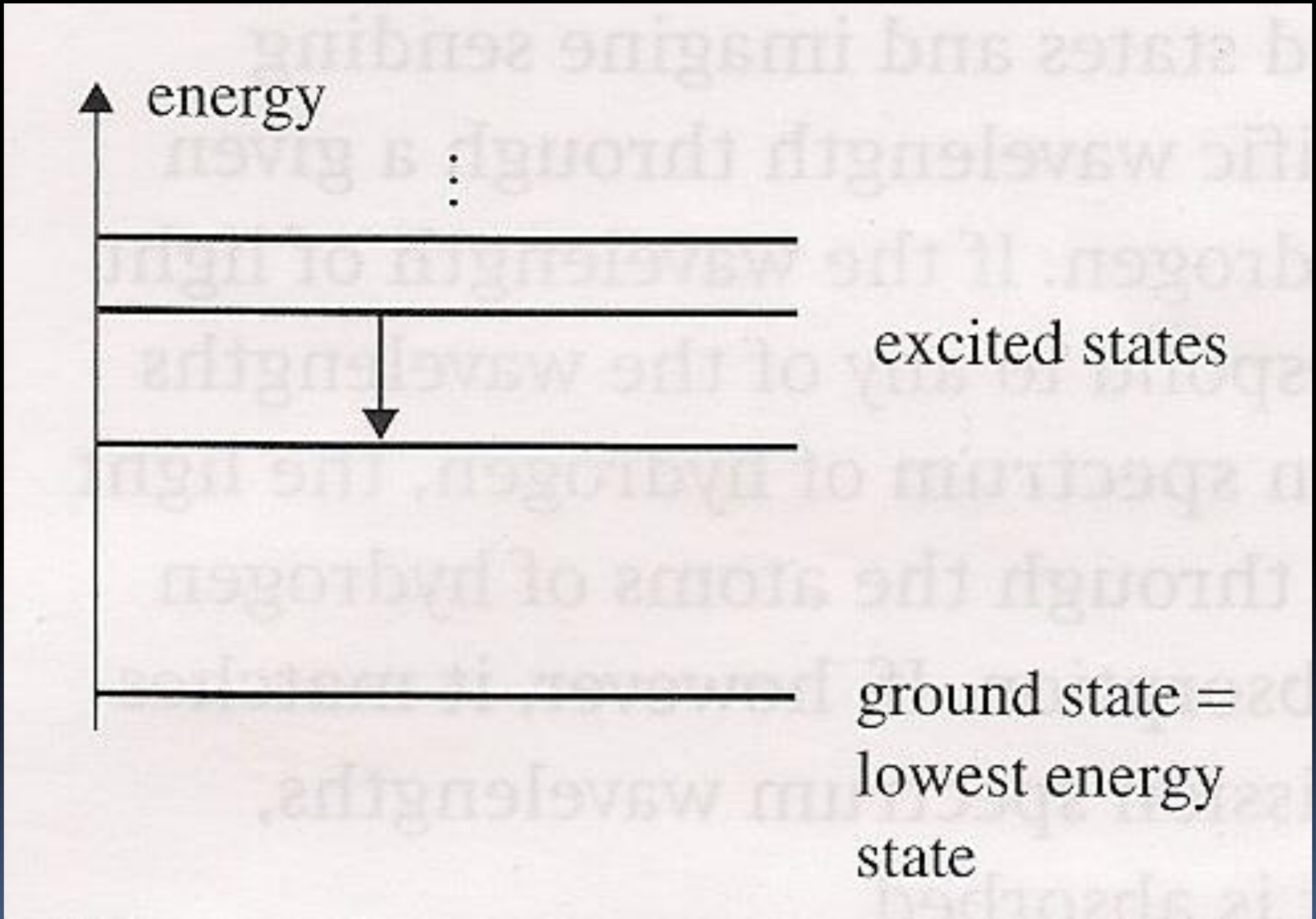
- Houston, we have a problem
  - If electrons orbit, they have centripetal acceleration
  - According to electromagnetism, an accelerated charge will radiate electromagnetic waves
  - If they radiate, they lose energy
  - If they lose energy, they will spiral into the nucleus, crash and burn
  - This would happen within nanoseconds
  - Without stable atoms, matter cannot be maintained and the universe ceases to exist as we know it and Homecoming would be cancelled

Bohr Model
(Not Boar or Bore)

- (Niels) Bohr Postulates (1911)
  - Electrons can exist in certain specific states of definite energy without radiating energy, provided a certain condition was met by the radius
  - Electron energy is discrete as opposed to continuous
  - Electrons can only lose energy when they transition from one state to a lower energy state
  - Emitted energy is equal to the difference in energy between the two states (NJ not included)

Bohr Model

(Not Boar or Bore)

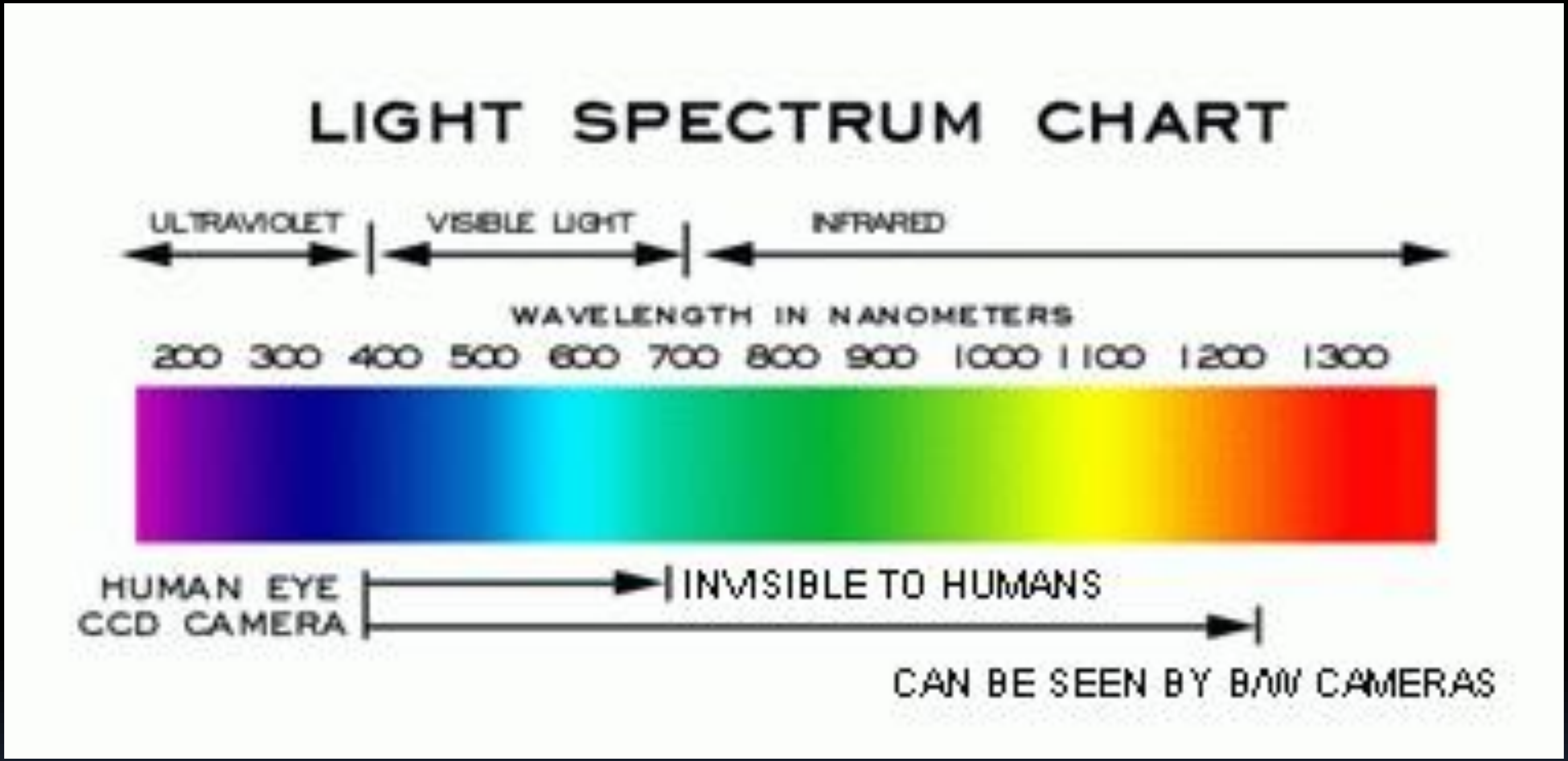


Spectra

- Electrons normally exist in the lowest state / level called the ground state
- If the electrons become excited (due to temperature rise or IA/EE/English journal/CAS reflection due date), they leave the ground state for a higher energy level
- As soon as it reaches the higher state, it transitions back down to the ground state, sometimes in steps

Emmision Spectra

- When it transitions down to a lower state, it emits energy in the form of light equal to the difference in energy between the two states
- Energy released in the form of a photon
- The distinct energy creates light of a distinct wavelength
- Depending on the energy level obtained, hydrogen emits light with wavelengths of 656 nm, 486 nm, or 410 nm


LIGHT SPECTRUM CHART
ULTRAVIOLET
VISIBLE LIGHT
INFRARED
WAVELENGTH IN NANOMETERS
200 300 400 500 600 700 800 900 1000 1100 1200 1300
HUMAN EYE
CCD CAMERA
INVISIBLE TO HUMANS
CAN BE SEEN BY B/W CAMERAS

Emmision Spectra

- Only hydrogen emits light corresponding to those wavelengths because only hydrogen has the energy states corresponding to those wavelengths
- Each element has distinctive energy levels and thus distinct emitted wavelengths
- ***The set of wavelengths of light emitted by the atoms of an element is called the emission spectrum of the element.***
- Thus, an element can be identified through spectrophotometry

Absorption Spectra

- When light is directed toward an element, wavelengths that do not correspond to the element's distinct energy levels pass right through
- Those that do correspond are absorbed by the element and the energy is used to raise the electrons to the higher energy levels
- ***The wavelengths that are absorbed make up the absorption spectrum of the element and are the same wavelengths as the emission spectrum.***

Nuclear Structure

- Nuclei are made up of protons and neutrons
- The word ***nucleon*** is used to denote either a proton or neutron
- Elements are distinguished by the number of protons they have, the ***atomic number***
- Elements and ***isotopes*** are distinguished by the number of nucleons, the ***atomic mass number***

Atomic Number and Atomic Mass Number

How many protons and neutrons?

$${}^{1}_{1}H$$

$${}^{4}_{2}He$$

$${}^{40}_{20}Ca$$

$${}^{210}_{82}Pb$$

$${}^{232}_{92}U$$

How many protons and neutrons?

$^{1}_{1}H$

$^{4}_{2}He$

$^{40}_{20}Ca$

$^{210}_{82}Pb$

$^{232}_{92}U$

1 Proton, 0 Neutrons

How many protons and neutrons?

$^{1}_{1}H$

$^{4}_{2}He$

$^{40}_{20}Ca$

$^{210}_{82}Pb$

$^{232}_{92}U$

1 Proton, 0 Neutrons

2 Protons, 2 Neutrons

How many protons and neutrons?

$^{1}_{1}H$

$^{4}_{2}He$

$^{40}_{20}Ca$

$^{210}_{82}Pb$

$^{232}_{92}U$

1 Proton, 0 Neutrons

2 Protons, 2 Neutrons

20 Protons, 20 Neutrons

How many protons and neutrons?

$^{1}_{1}H$ — 1 Proton, 0 Neutrons

$^{4}_{2}He$ — 2 Protons, 2 Neutrons

$^{40}_{20}Ca$ — 20 Protons, 20 Neutrons

$^{210}_{82}Pb$ — 82 Protons, 128 Neutrons

$^{232}_{92}U$

How many protons and neutrons?

$^{1}_{1}H$	1 Proton, 0 Neutrons
$^{4}_{2}He$	2 Protons, 2 Neutrons
$^{40}_{20}Ca$	20 Protons, 20 Neutrons
$^{210}_{82}Pb$	82 Protons, 128 Neutrons
$^{232}_{92}U$	92 Protons, 140 Neutrons

Atomic Structure

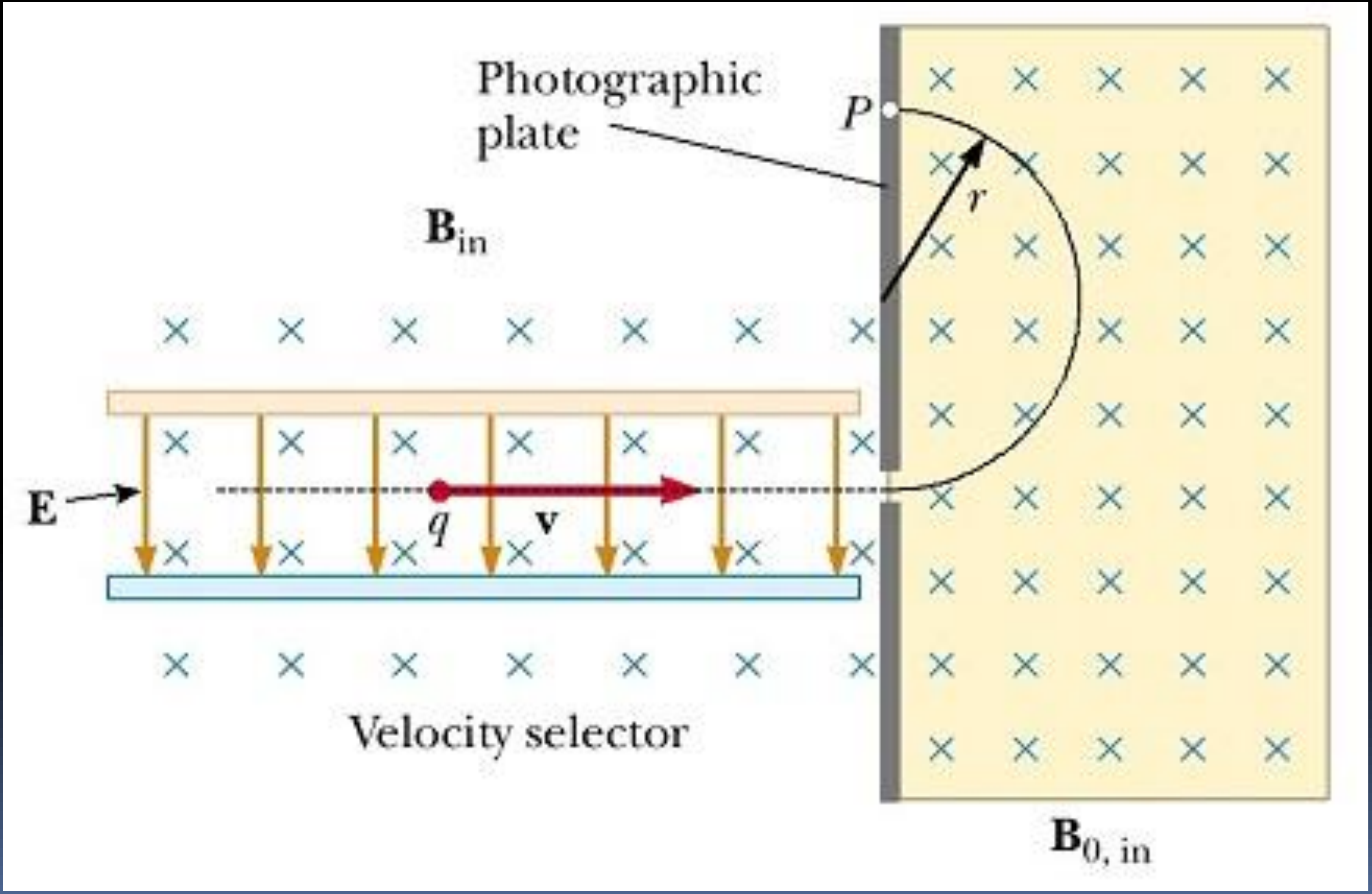
- A nucleus with a specific number of protons and neutrons is called a ***nuclide***
- To maintain electromagnetic balance, the number of electrons equals the number of protons
- The A-Z notation can be used for the parts of an atom as well as for the element as a whole

Atomic Structure

Particle	Symbol
Proton	${}^{1}_{1}p$
Neutron	${}^{1}_{0}n$
Electron	${}^{0}_{-1}e$
Photon	${}^{0}_{0}\gamma$
Alpha particle	${}^{4}_{2}He$ or ${}^{4}_{2}\alpha$

Table 1.1

Isotopes



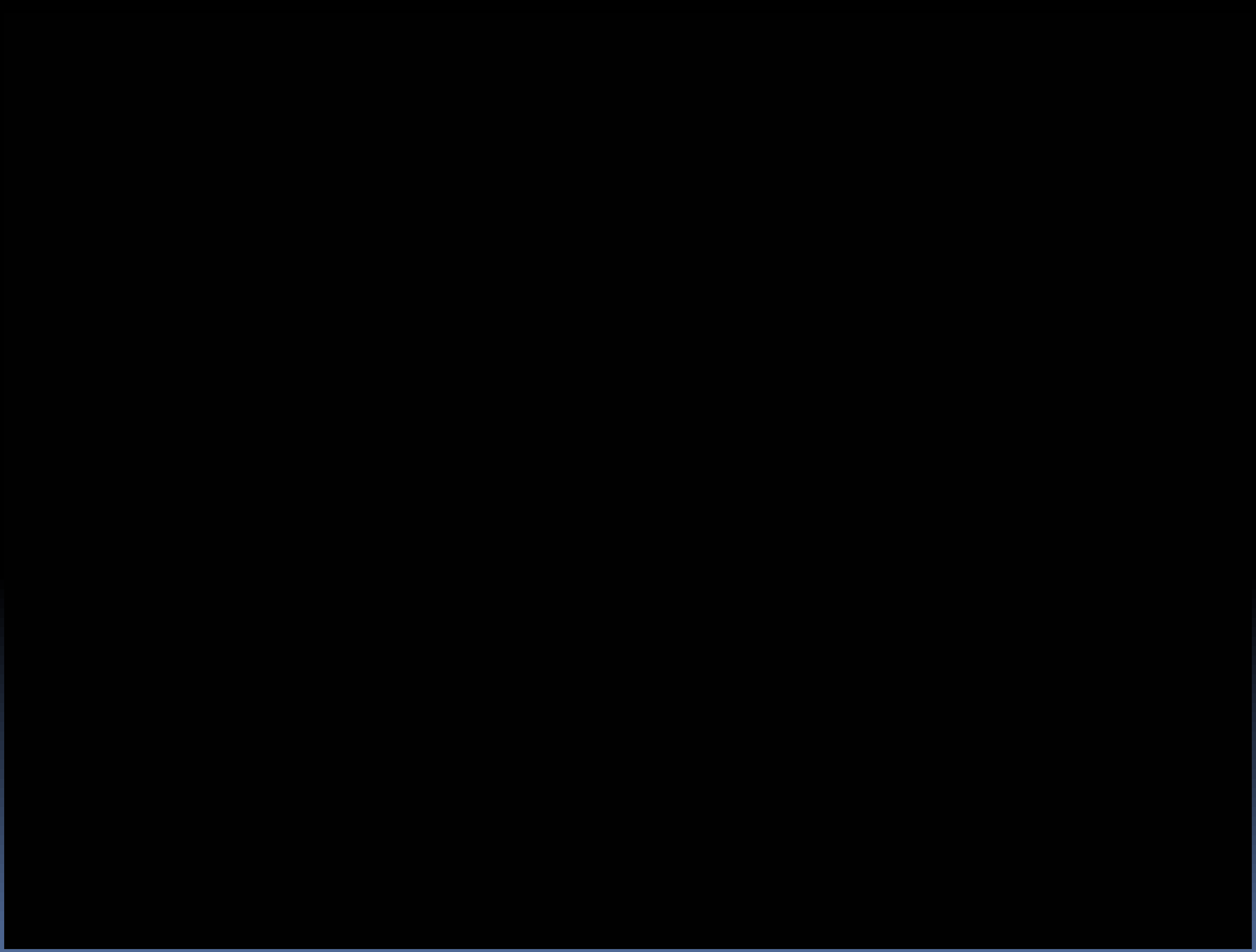
Photographic plate
P
r
$\mathbf{B}_{in}$
E
q
v
Velocity selector
$\mathbf{B}_{0,\,in}$

Isotopes

- Nuclei that have the same number of protons but different number of neutrons are called ***isotopes***
- Isotopes have the same number of protons and electrons, so chemically they are identical, but different physical properties
- ***If an element can have different isotopes, how do you determine the mass number?***

Average Atomic Mass

(A video made from dark matter and dark energy)



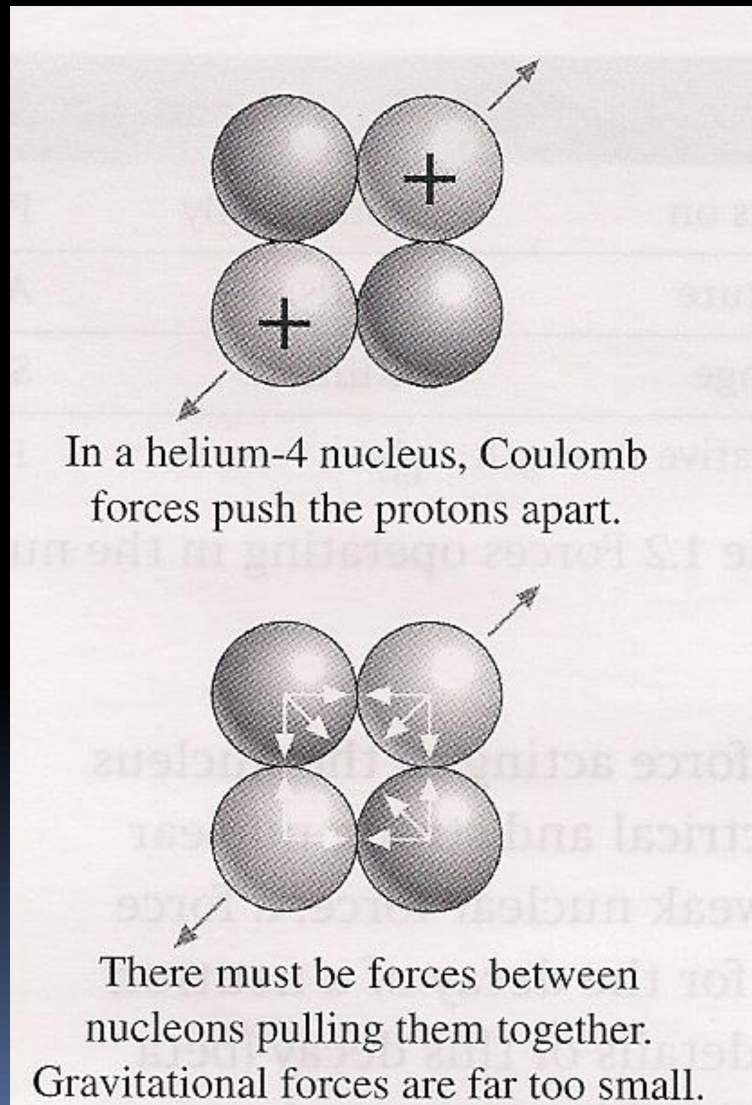
A New Force

- ***How do you keep a bunch of protons tightly packed together when there is such a strong repulsive force between them?***

A New Force

- The nucleons are bound together by a new force – the strong nuclear force
- ***The strong nuclear force is an attractive force and much stronger than the electrical force, <u>if the separation between nucleons is kept very small (on the order of 10^{-15} m or less)</u>***
- ***For larger separations, the strong nuclear force becomes so small as to be negligible***
- The nuclear force is thus a short-range force

Strong Nuclear Force



Nuclear Structure

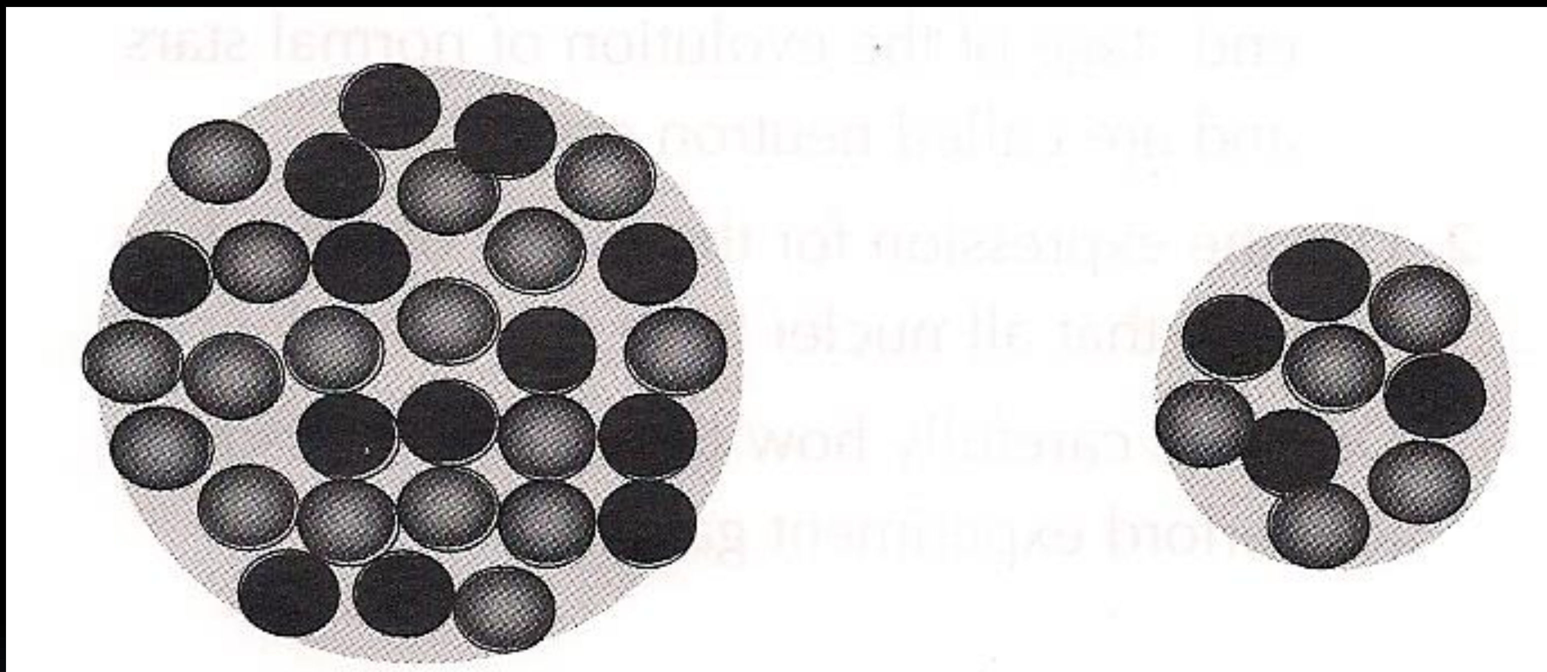
- Scattering experiments have shown that the radius R of a nucleus can be found by,

$$R = 1.2 x A^{1/3} x 10^{-15} m$$

where A is the number of nucleons (mass number)

- This implies that all nuclei have the same density regardless of their size
- This is because the strong nuclear force only acts between neighboring nucleons

Nuclear Structure



Another force?

- There is still another force called the ***weak nuclear force***
- The weak nuclear force is responsible for neutrons decaying into protons (beta decay – covered in next lesson – foreshadowing!!!)

∑mary of Forces

Force	Electromagnetic	Strong nuclear	Weak nuclear
Acts on	Protons only	Protons and neutrons	Protons and neutrons
Nature	Repulsive	Attractive (mainly)	Attractive/repulsive
Range	Infinite	Short (10^{-15} m)	Short (10^{-17} m)
Relative strength	$\frac{1}{137}$	1	10^{-6}

Table 1.2 Forces operating in the nucleus.

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Applications And Skills:

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Essential Idea:

- In the microscopic world energy is discrete.

QUESTIONS?

Homework Time!!!

 # 1-7