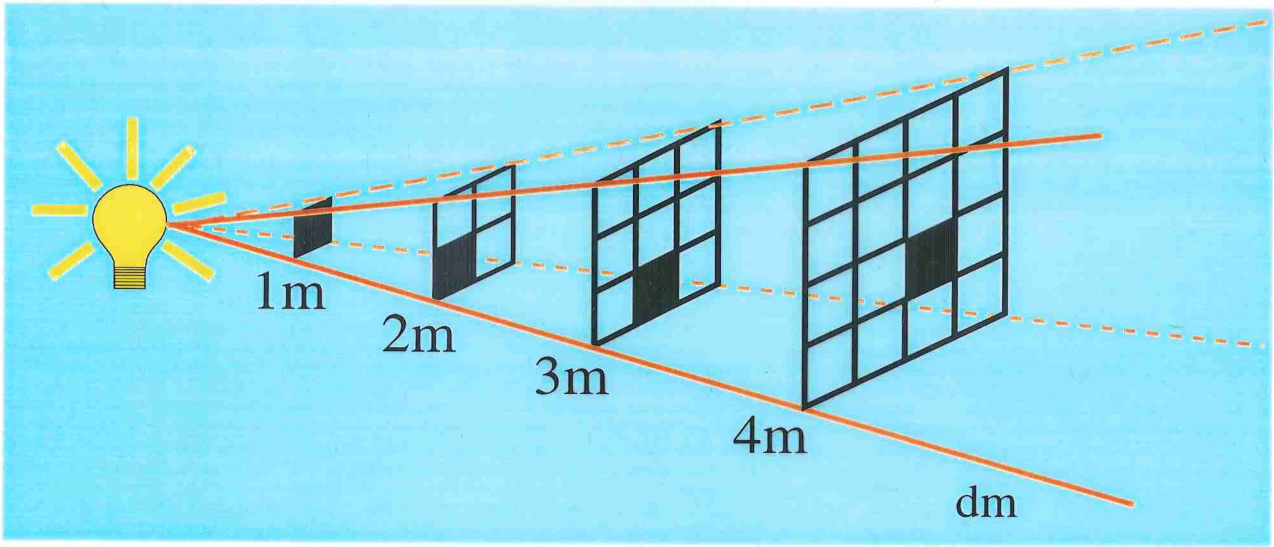
Stars

Brightness, Luminosity, Distance

- **Luminosity,**
  L ≡ Energy emitted by an object
- **Brightness,**
  B ≡ Energy received from an object
- **Relation of B to L:**

$$B \propto \frac{L}{D^2}$$

Where D is distance to object and assume space is totally transparent.



Distance	1m	2m	3m	4m	dm
#Squares	1	4	9	16	$\propto$Dist^2

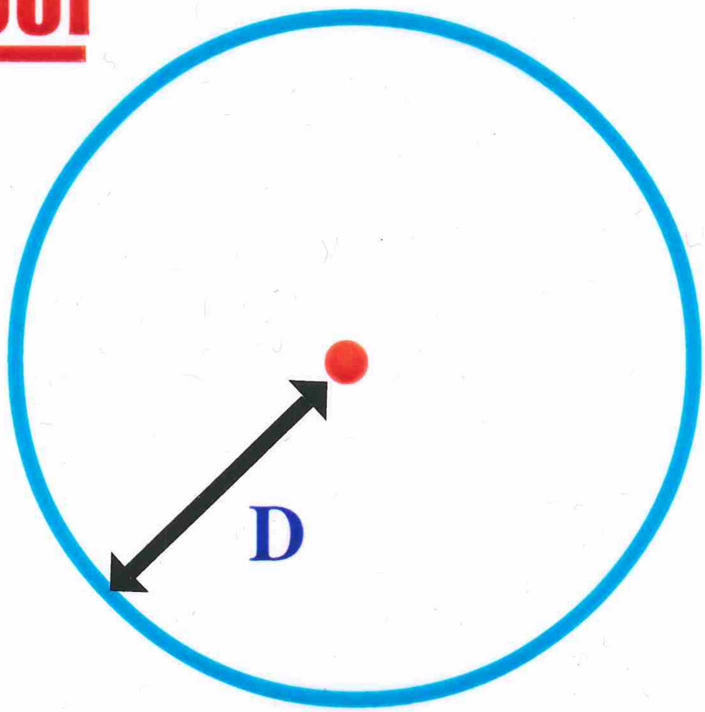
$$\text{Brightness} \propto \frac{1}{\#\text{Squares}}$$

$$\propto \frac{1}{\text{Distance}^2}$$

An example of an Inverse Square Law

$$\textbf{Brightness} \propto \frac{\textbf{Luminosity}}{\textbf{Distance}^2}$$

Another Proof



- Energy crossing surface of sphere is L (= Luminosity of star)
- Brightness (B) at Distance D is energy crossing unit area
  = L ÷ total area of sphere's surface

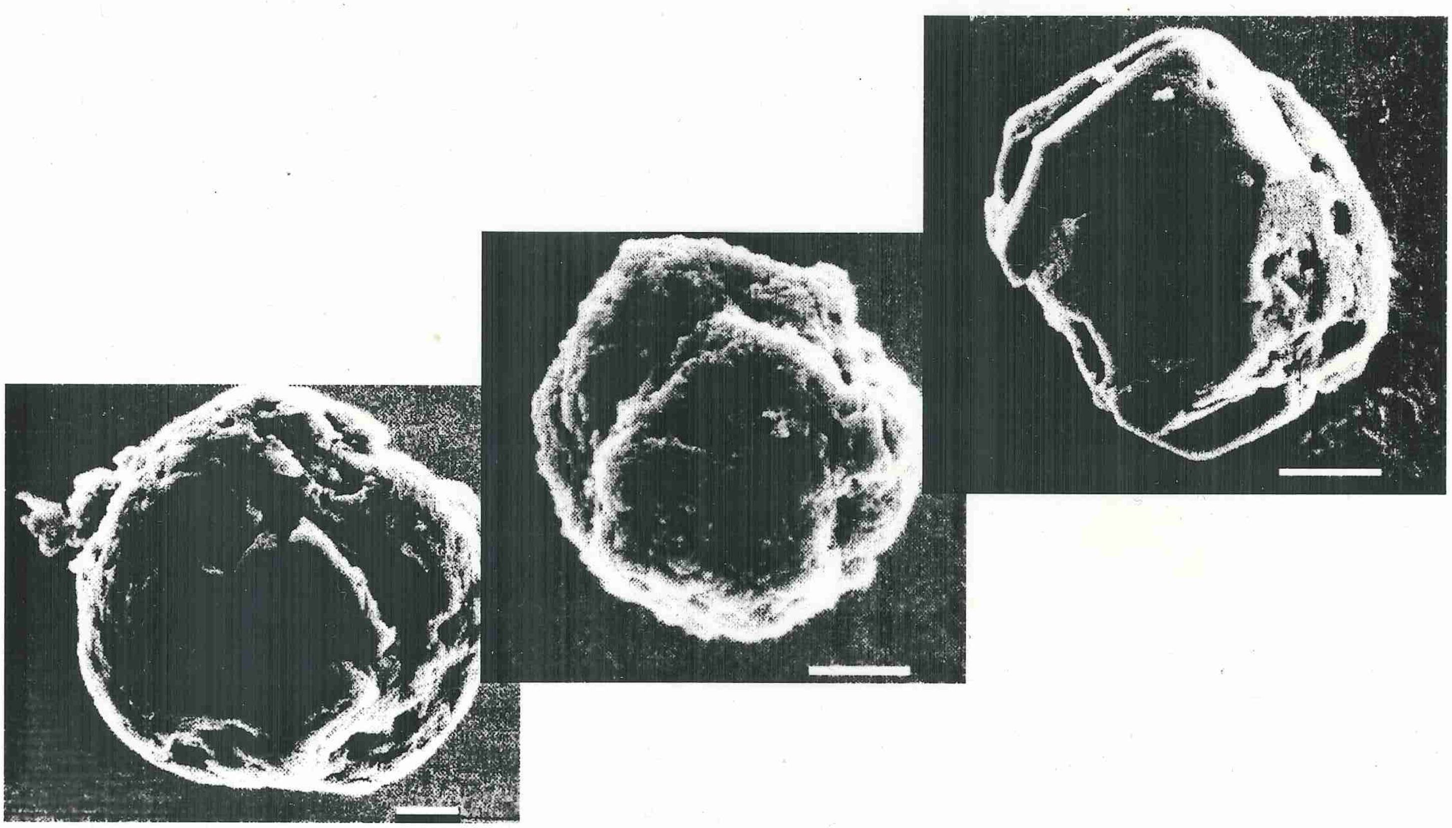
$$\propto \frac{L}{D^2}$$

$$\boxed{B \propto \frac{L}{D^2}}$$

CAVEAT!

- **Space between stars is not fully transparent**

- **Minute dust grains scatter / absorb light → Dim and Redden light**



STAR OF LUMINOSITY L

$B \propto \frac{L}{D^2}$

d (ly)	B
10	1
100	?
5	?
1	?
?	25
?	$\frac{1}{16}$
?	10^{-4}

- STAR A
  - LUMINOSITY L
  - DISTANCE 10 parsecs
- STAR B
  - LUMINOSITY 10L
  - DISTANCE 100 parsecs

WHICH IS BRIGHTER?

- STAR A

BRIGHTNESS	B
LUMINOSITY	L

- STAR B

	(i)	(ii)	(iii)
BRIGHTNESS	100B	B	100B
LUMINOSITY	L	100L	100L

WHICH IS MORE DISTANT?

$$B \propto \frac{L}{d^2}$$

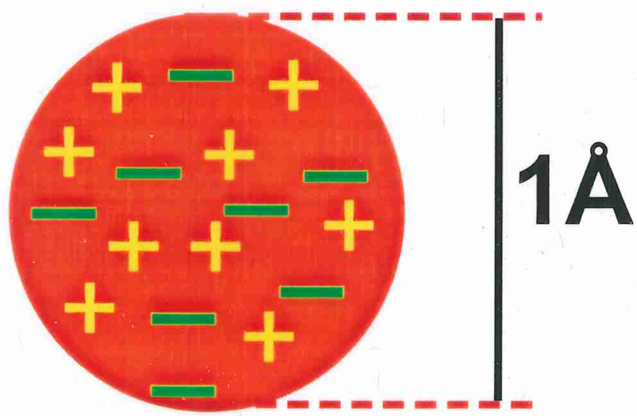
$$d^2 \propto \frac{L}{B}$$

$$d \propto \sqrt{\frac{L}{B}}$$

Model Atom

Before 1900:
J. J. Thomson's 'Plum pudding' model

Size/positive and negative charges (electrons)



Lord Rutherford:

"I was brought up to look at the atom as a nice hard fellow, red or grey in colour, according to taste."

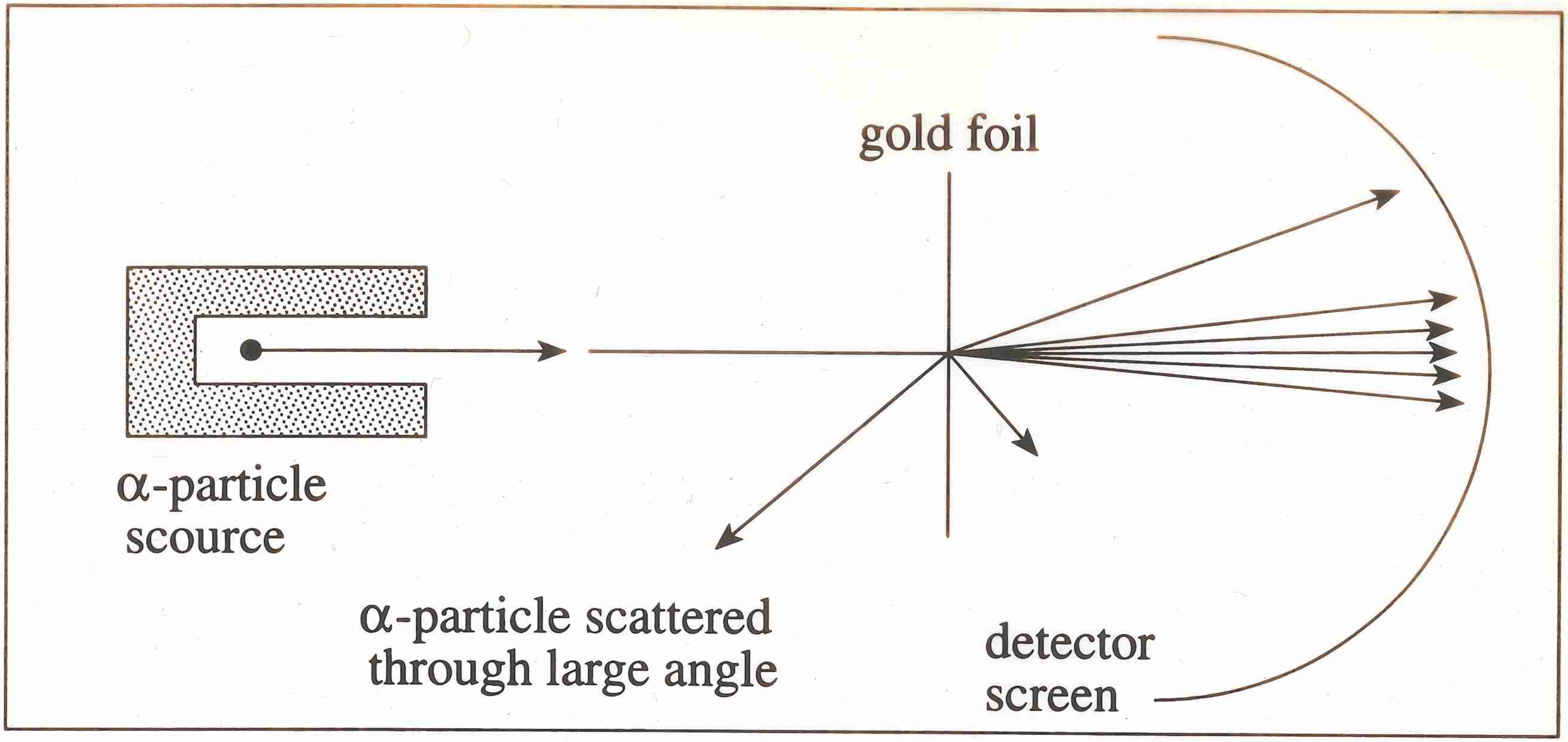
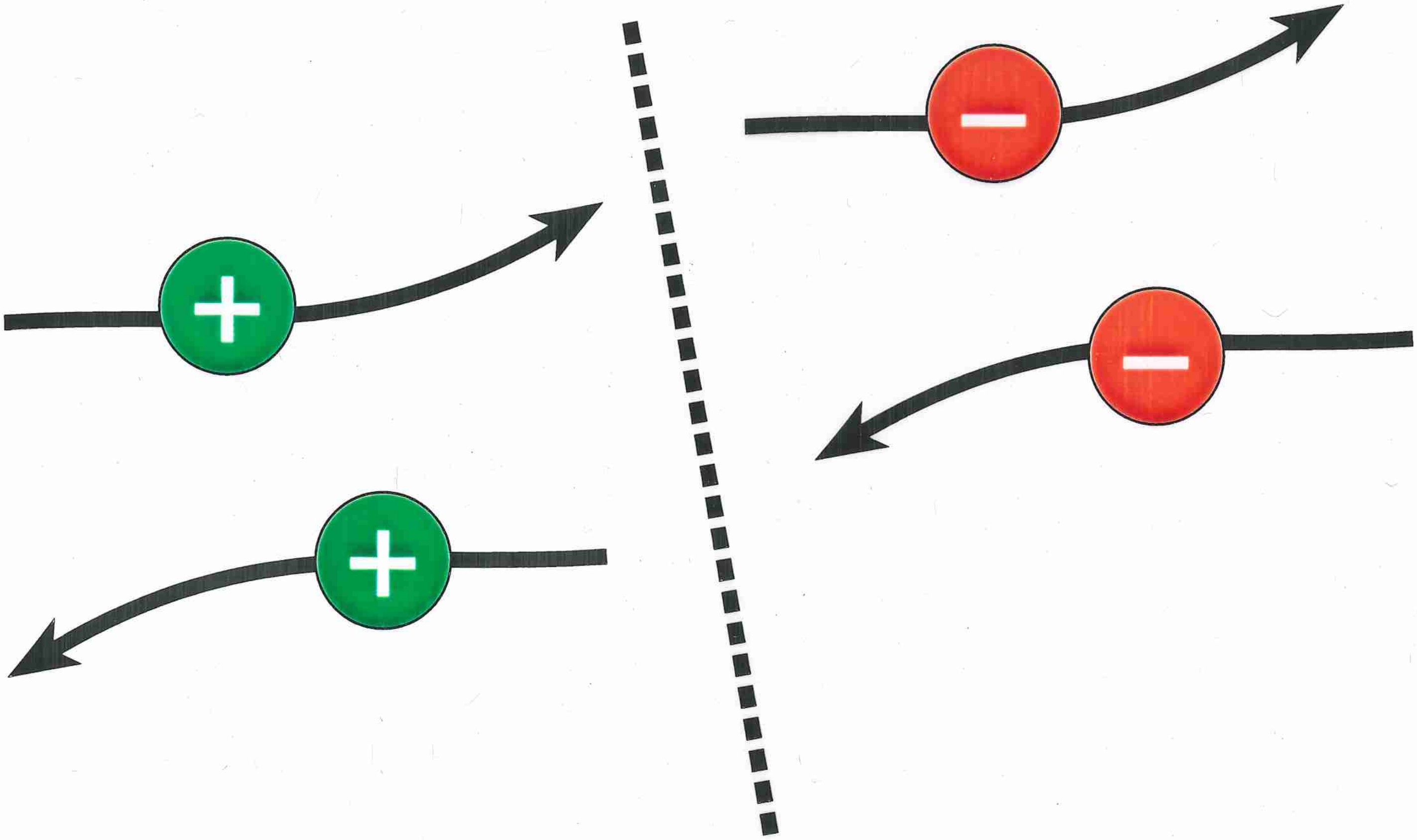


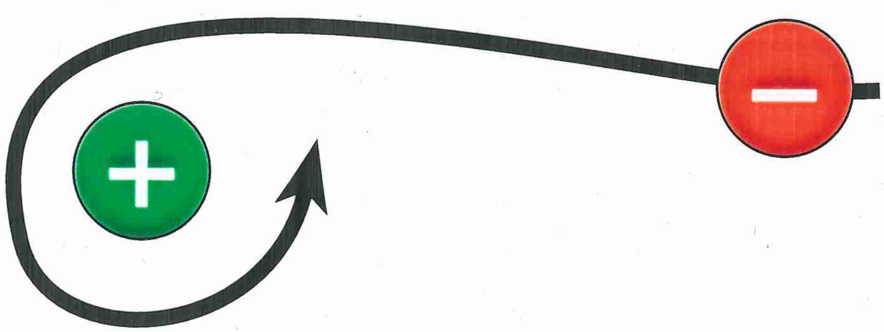
Figure 1 Rutherford's apparatus for an analysis of α-particle scattering by gold foil.

α-particles are helium nuclei (+ve charges)

Rutherford's Scattering Experiment



But



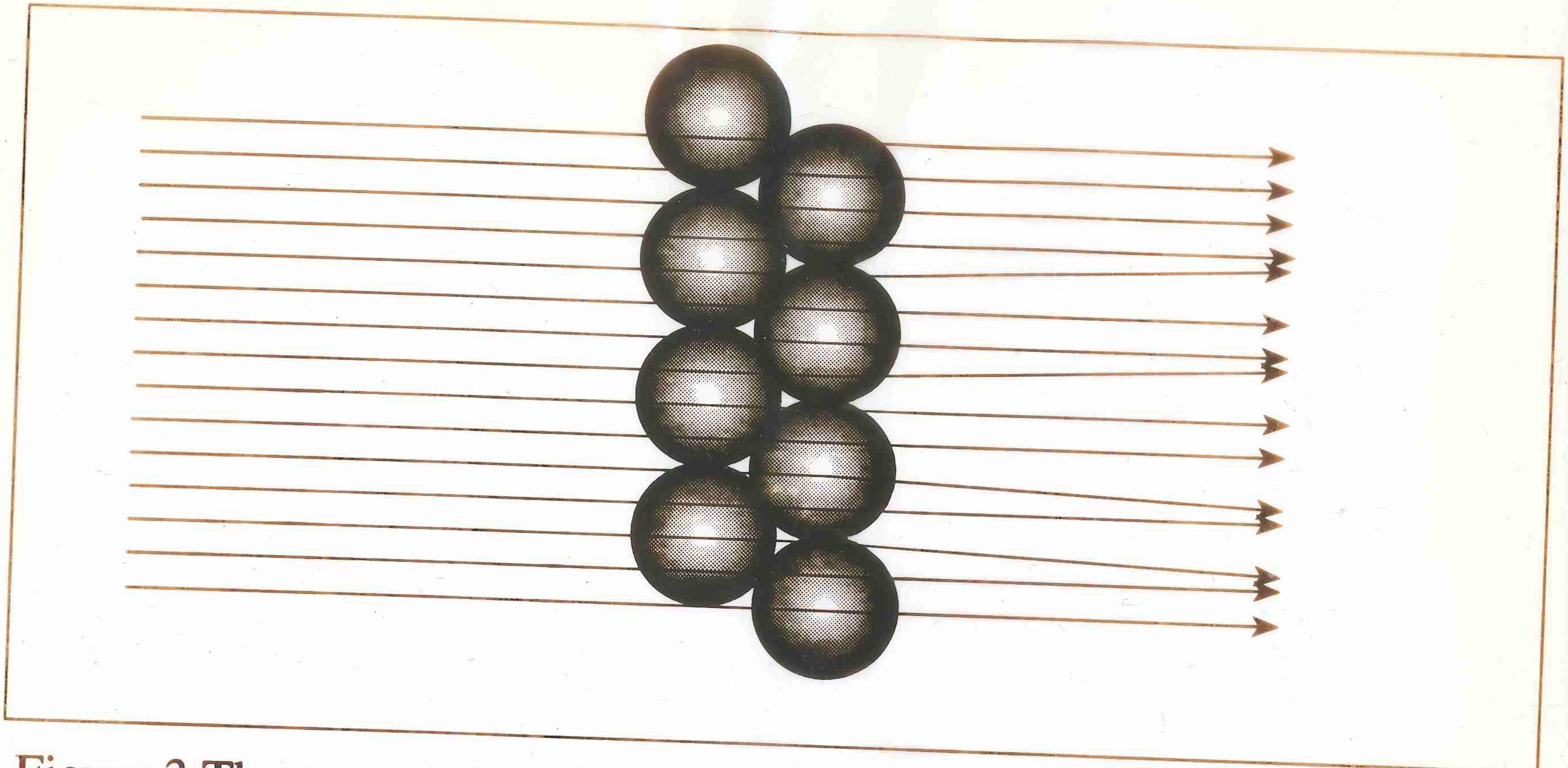


Figure 3 The expected result of the Rutherford α-particle scattering experiment, assuming the Thomson model.

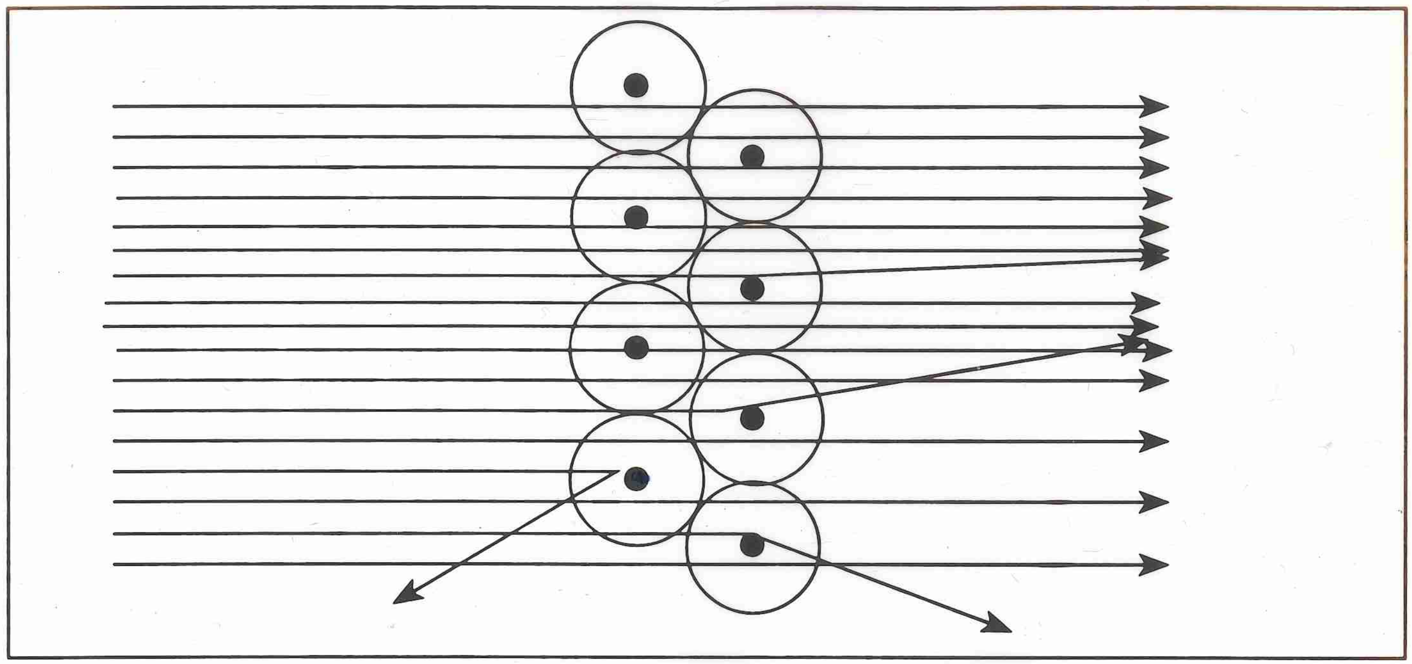
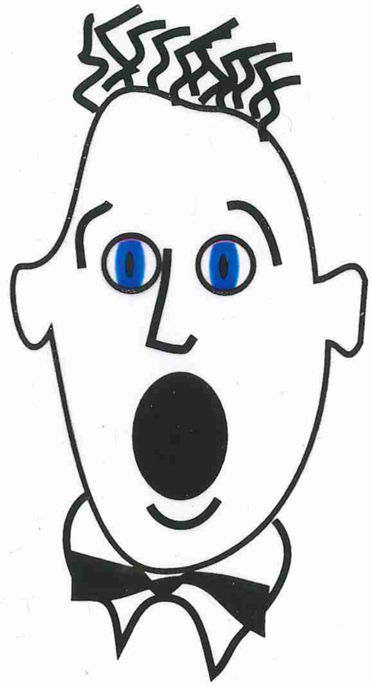


Figure 4 The results of the Rutherford α-particle scattering experiment.

Surprise!

A few α-particles were "**bounced back**"

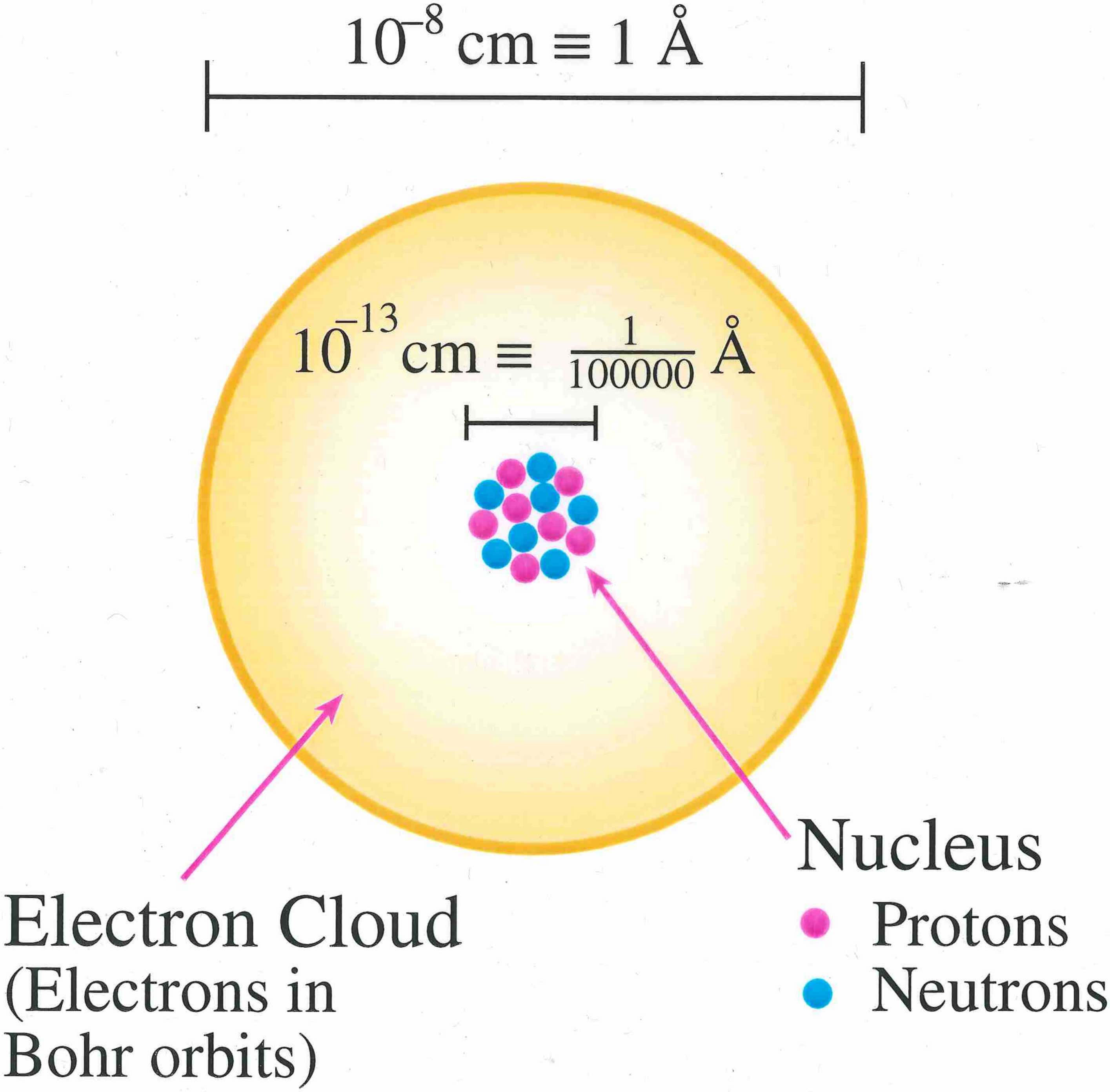


Why?

Lord Rutherford:

"It was quite the most incredible event that has ever happened in my life. It was almost as incredible is you fired a 15-inch shell at a piece of tissue paper and it came back and hit you."

Review
Atomic Structure



Rutherford's (and Our) Model Atom:

Electron Cloud around compact nucleus

Where is the positive charge?
Where is the negative charge?
Where is the bulk of the mass?
What is the Atom's size?
What is the Nucleus' size?

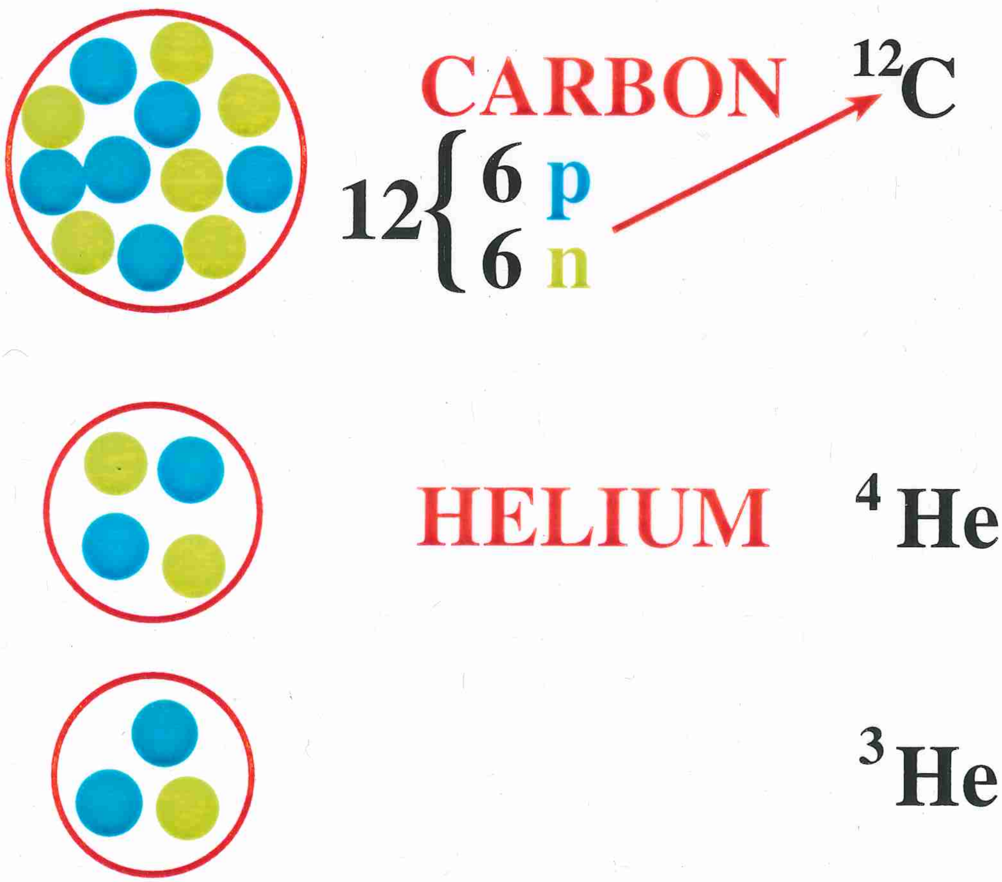
Hydrogen	Oxygen
1e + 1p	8e + (8p + 8n)

mass =
1.7×10^{-24} gm

* chemical elements distinguished by number of protons in nucleus

- **Chemical elements distinguished by number of protons in nucleus (≡ # of electrons in neutral atom)**

- **Protons + Neutrons retain identity in a Nucleus**



The Family of Atoms

Neutral atoms

  No. of e's = no. of p's

Positive ions

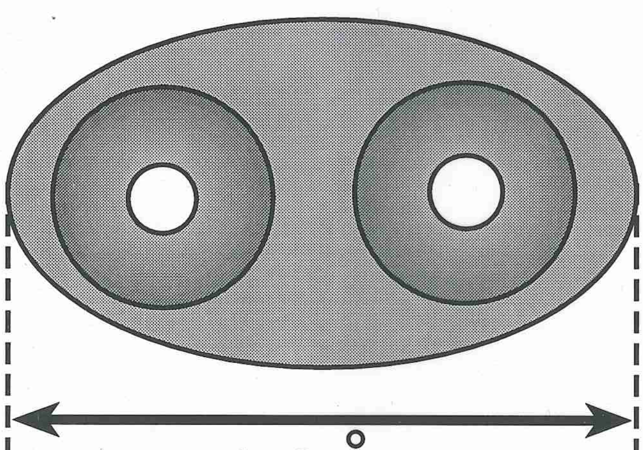
  No. of e's < no. of p's

Negative ions

  No. of e's > No. of p's

Molecules

  Contain 2 or more atoms of same or different elements



O_2

1.2Å

Some Fundamental Particles

	Charge	Mass
Proton	+	1
Neutron	0	1
Electron	–	$\frac{1}{1836}$
Neutrino	0	0

Proton, Neutron composed of Quarks

Neutron decays in ~11 minutes to Proton + Electron + Neutrino

Bohr's Model of Atomic Electron Cloud

- Problem: Orbiting - accelerating - electrons expected to radiate energy away and very quickly spiral into nucleus
- Solution: New rules apply to the atomic world: quantum mechanics

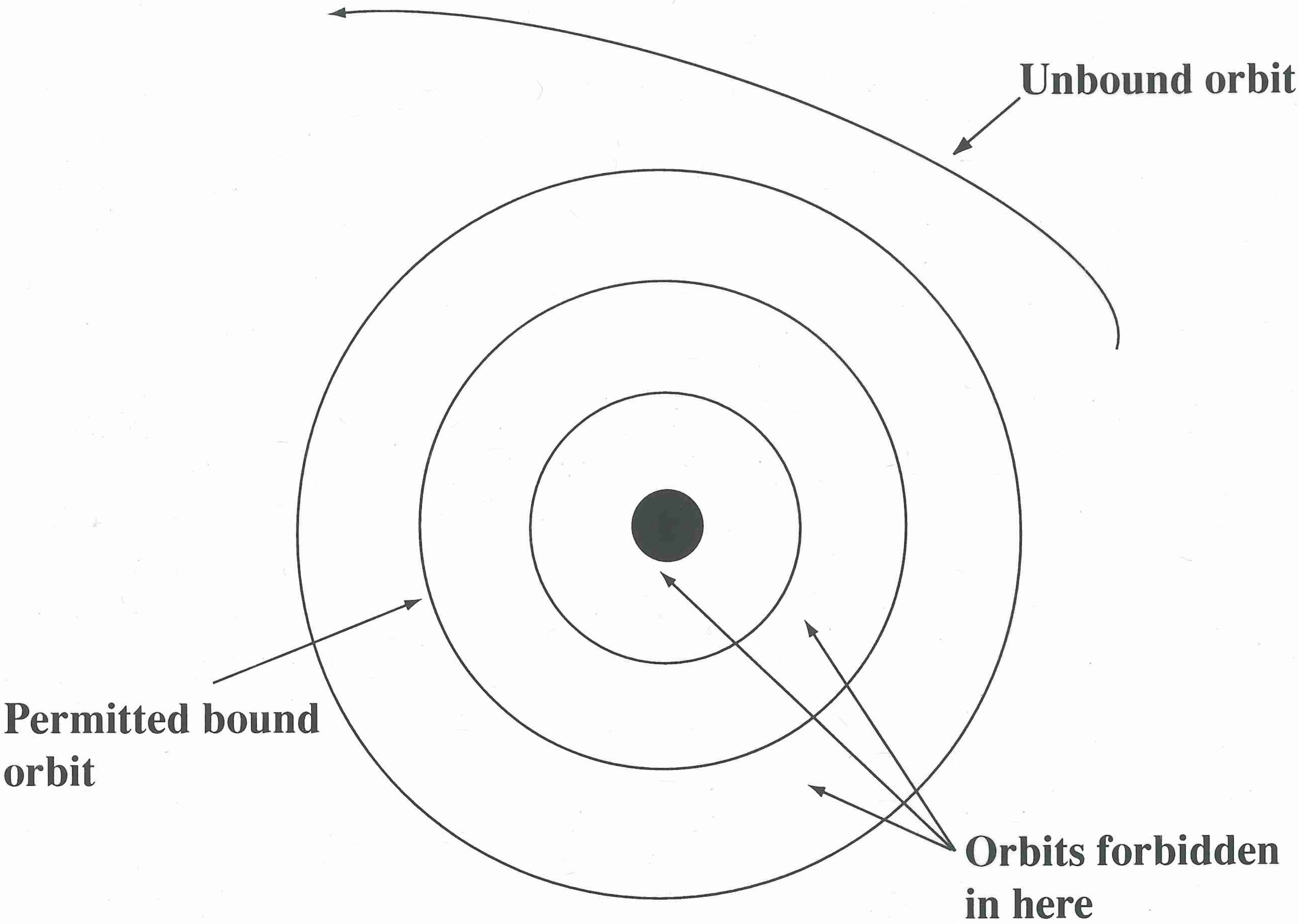
THE BOHR ATOM: **Some rules for a 1-electron atom**

- Only Bohr orbits allowed. Each orbit corresponds to a well-defined energy.
- Energy corresponding to orbit increases with orbit's distance from the nucleus.
- If undisturbed electron descends to innermost orbit and remains there.
- Electron may jump from an orbit to an outer orbit if it is supplied with energy.
- Electron may jump to an inner orbit and release energy. The jump may be stimulated or spontaneous.

- If a photon is involved in an orbit jump - absorption or emission - this relation applies

$$E_{photon} = hf = \frac{hc}{\lambda}$$

- Beyond outermost orbits, electron is in an unbound (free) orbit

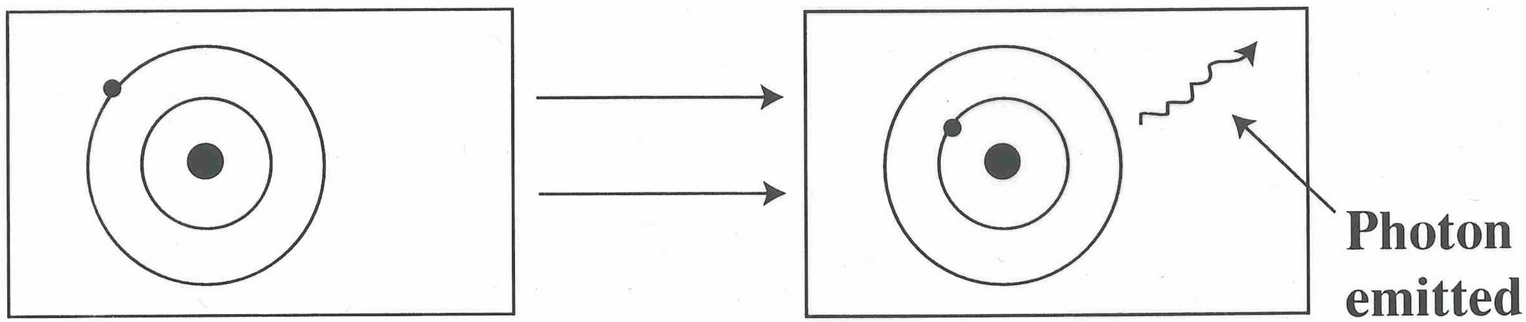

Unbound orbit
Permitted bound orbit
Orbits forbidden in here

- Atom with nucleus and electron orbit is <u>not</u> a mini-solar system

- Electron orbits limited to specific energies
- Spontaneous changes of orbits allowed (outer to inner orbit)
- Orbits not all in one plane
- Electron is a "fuzzy cloud" not a well-defined point

Examples of Electron Jumps

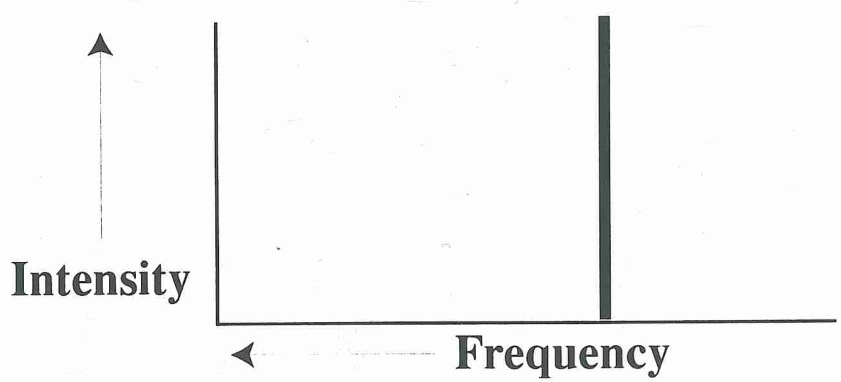
Spontaneous Emission of Photon



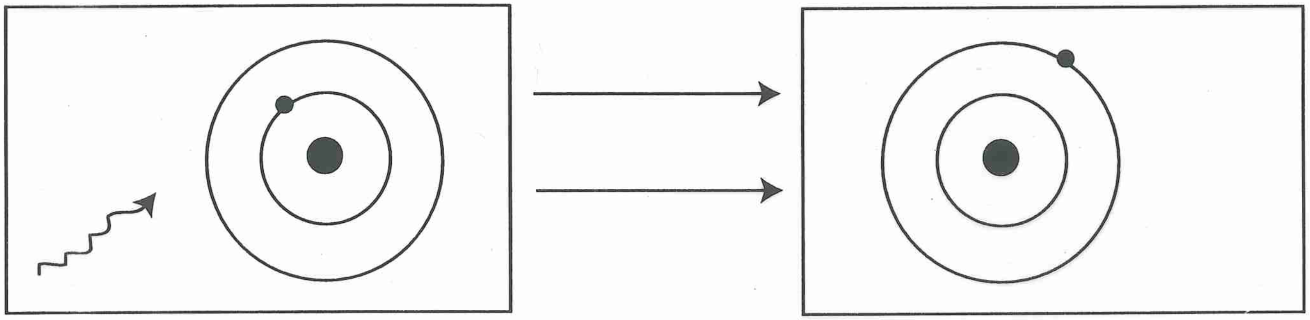
Energy of Photon = Energy of initial orbit — Energy of final orbit

$$\text{Frequency of photon} = \frac{E(\text{initial}) - E(\text{final})}{h}$$

Frequency is well defined and a signature of the particular atom

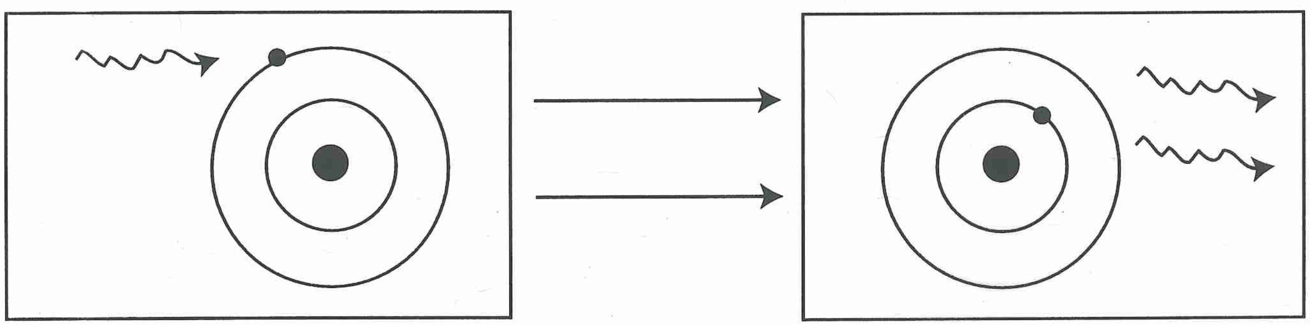


Induced absorption of photon is the reverse of spontaneous emission



Photon must have correct frequency

Stimulated emission of photon

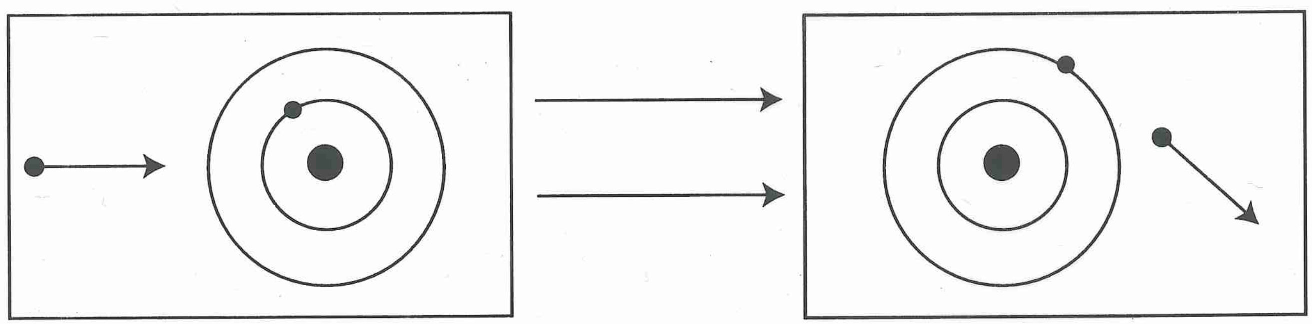


Stimulating photon must be of correct frequency

(Principle of the Laser)

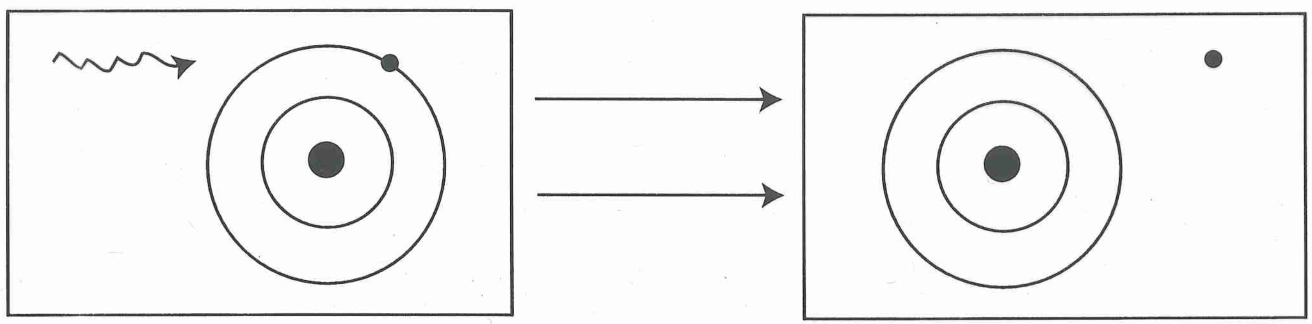
Jumps up (down also) by collisions with particles (electrons,...)

Excitation by a free electron



Incoming particles must have energy equal to or greater than the energy difference between the orbits.

Ionization: Loss of a Bound Electron



Free electron released ≡ Atom is ionized

- **Photon energy must exceed a minimum value.**
- **Ionization also by collisions with particles, as long as energy exceeds the minimum value.**