

# Science

**Creating models of the universe so we can...**  
**understand the universe**  
**make predictions**  
**build better stuff better**

**All models are false...**  
**but some are useful anyway...**  
**because they simplify things**

# Early Greek Philosophers

**Xenophanes – religious nutcase**

**“The one is all.”**

**“The universe is singular, eternal, and unchanging.”**

**The “Eleatic” school**

# Early Greek Philosophers

## Parmenides - logical thinker

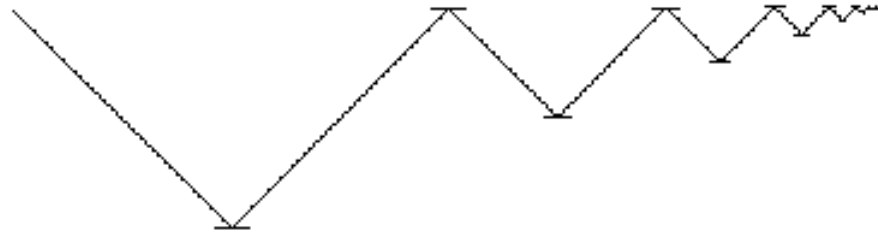
**“The universe is the One, an infinite all-encompassing motionless mass with no empty space (void).”**

**“If you keep dividing it up into pieces, eventually you won’t have anything, and clearly, there is something.”**

# Early Greek Philosophers

**Zeno – Added logical examples  
(paradoxes)**

**Achilles & the Tortoise**



# Leucippus

and his pupil, Democritus

who was a much better and more prolific writer!

**“You’re idiots! There is motion! And Achilles would certainly catch the tortoise!”**

**“Motion requires a void through which things move”**

**“You can break things down into ‘atoms’ but no further.”**

# Atoms according to Democritus

- An infinite number of them
- Are indivisible
- Don't contain any "void"
- Weigh a lot for their size
- The more dense a material, the less void it contains

# Fire

## Eleatics

An element or  
state of matter

Others are  
water, earth, air

## Atomists

Contains more  
void than solid  
matter, so it rises  
out of the  
material that  
produces it

# Dark Ages – The Alchemists



**Discovered:**

**Arsenic**

**Zinc**

**Phosphorus**

**Platinum**

**Nickel**

**Oxygen**

**Chlorine**

**Aluminum**

...



# “Scientific” Chemistry

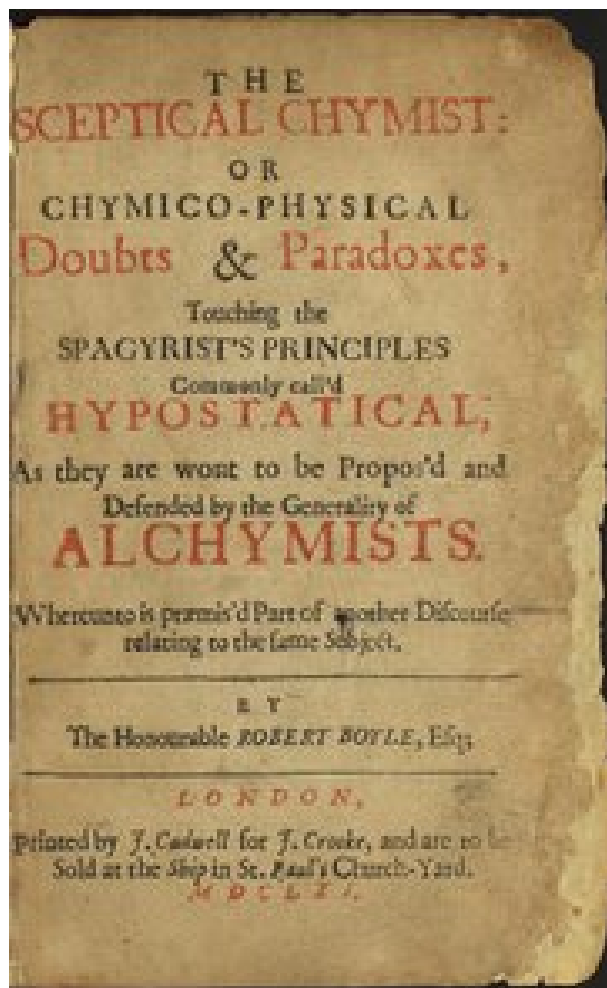


**Robert Boyle**  
**1627 – 1692**

**Still believed in  
transmutation of metals**

**Experiments led to  
Boyle’s Law**

# “Scientific” Chemistry



Chemistry (the composition of substances) should be pursued scientifically

Compounds and mixtures are made of elements

Matter consists of atoms and clusters of atoms in motion

# Daniel Rutherford - 1777

- When something burns, it gives off “phlogiston” and the air becomes phlogisticated
- If the air is fully phlogisticated, you can't burn anything (or breathe) in it
- If the air is “dephlogisticated”, it can support burning longer than normal air

# Antoine Lavoisier



**First Chemistry Textbook in  
1789**

**Fire (combustion) combines  
a substance with oxygen.  
*Take that, you phlogisticators!***

**Quantitative experiments  
showed that the same  
amount of matter is present  
at the beginning and end of  
a reaction**

# Joseph Proust

## The Law of Definite Proportions

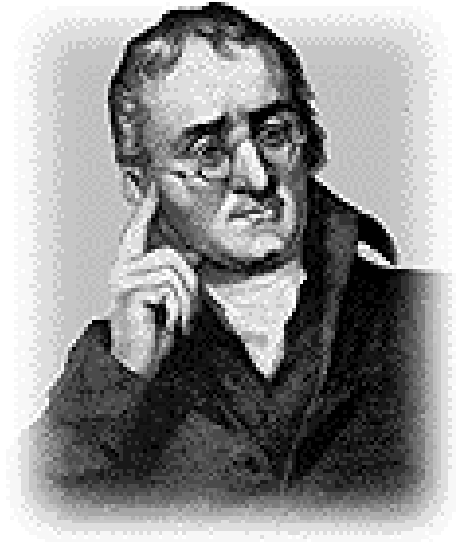
1794



Water is always 11% hydrogen  
and 89% oxygen by weight

*In a pure compound, elements  
combine in definite  
proportions to each other*

# John Dalton's Atomic Theory



1766 - 1844

- All matter is made up of atoms
- Atoms cannot be created, destroyed, or divided into smaller parts
- All atoms of one element are exactly alike, and different from all other elements
- A chemical reaction is a rearrangement of atoms

# So far, so good...

- When elements react, their atoms combine in simple, whole number ratios
  - ...sometimes more than one, but they're in turn very simple whole number ratios!
    - Dalton's Law
    - Law of Multiple Proportions
- Ex. Carbon and Oxygen:
- 100:133 or 100:266, and 266:133 = 2:1 !

## A conclusion too far...

- Oh, and when they combine in only one ratio (like H and O in 1:8), there's usually only one atom of each
  - So water is HO

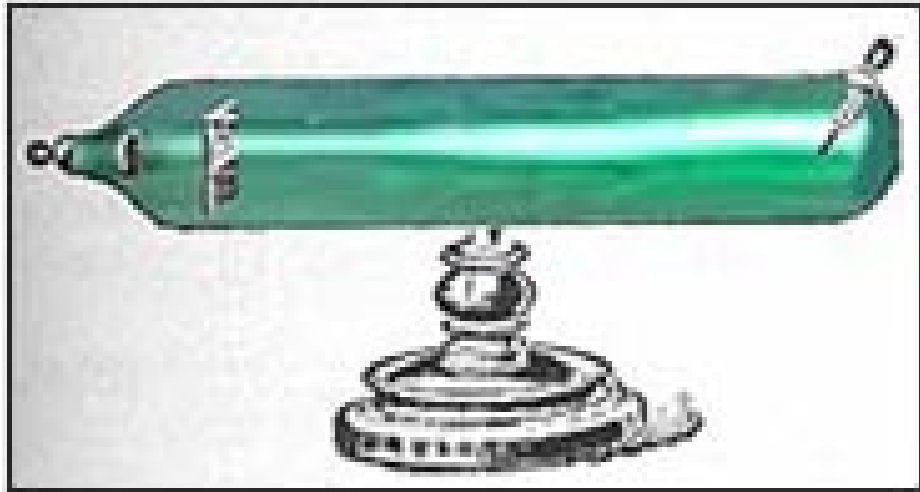
*Oops! This led to incorrect atomic weights, and other problems that gave his critics 100 years of ammunition*



# J J Thomson

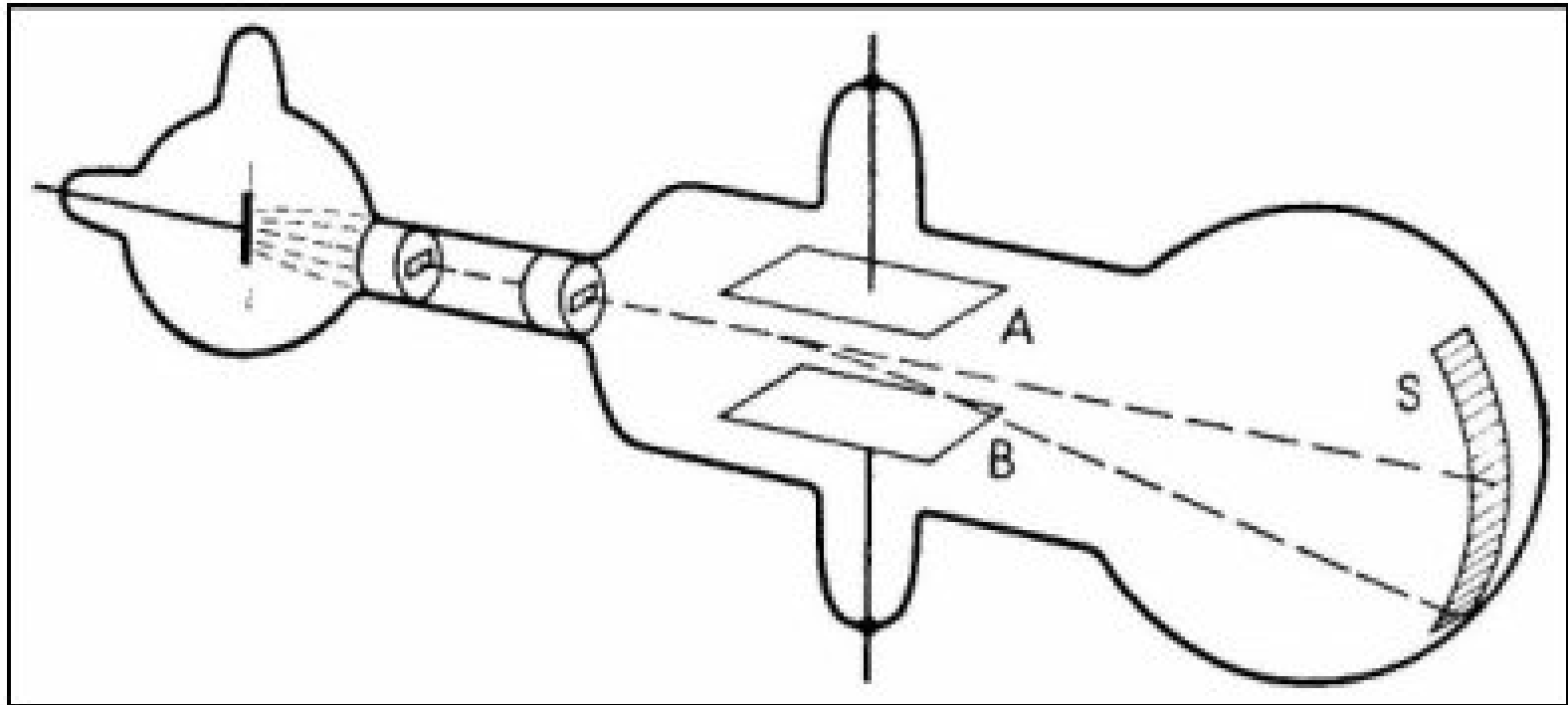


1856 - 1940



A "Cathode Ray" tube

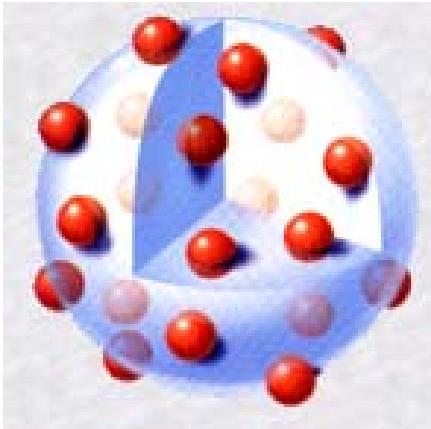
# Thomson's Experiment



# J J Thomson



- Uh, I can bust negatively charged doodads out of a supposedly indivisible atom
- I shall call them “corpuscles”
- I think they’re stuck in and on the atom like raisins in a plum pudding (how British!)

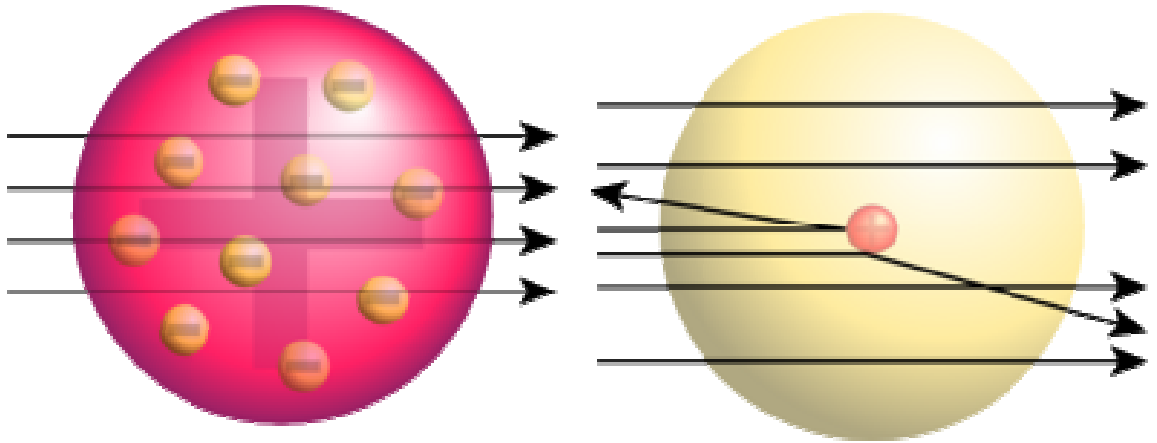


# Ernest Rutherford

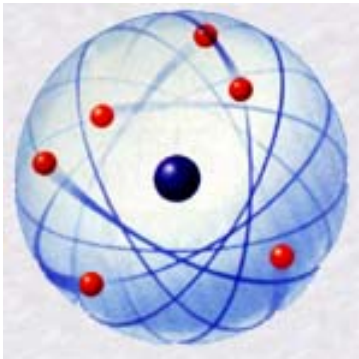


1871 - 1937

<http://micro.magnet.fsu.edu/electromag/java/rutherford/>



# Ernest Rutherford



- If I throw stuff into an atom, most of it passes right through, but some of it bounces off at weird angles
- It must be hitting something heavy and small
- I shall call it a “charge concentration”
- The electrons must be very small and light by comparison, scattered around it randomly

# Relative Sizes



**Nucleus**

**Nearest electron is  
probably about 1 mile  
away**

**If the electrons are negative and the nucleus is positive, what's keeping them apart?**

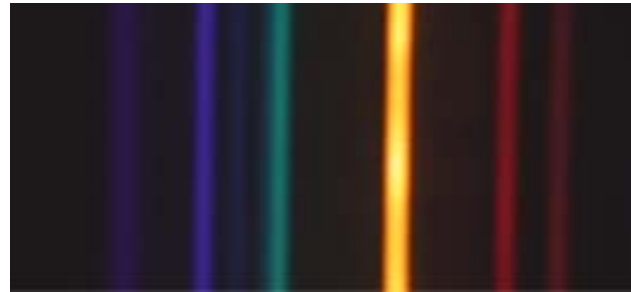
**Aha! They must be “orbiting”!**

**But...**

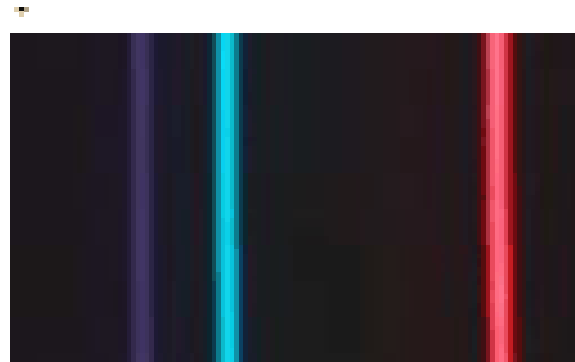
- 1. The orbits would decay**
- 2. What about ....**

# Atomic Spectra (spectrums)

**Helium**



**Hydrogen**





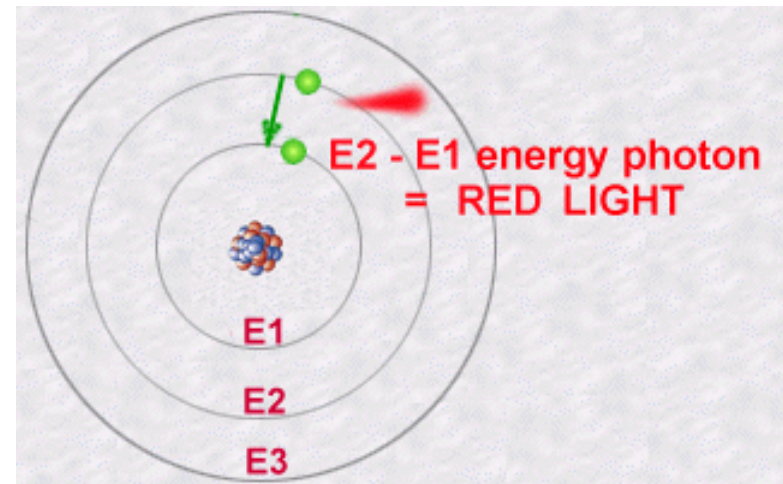
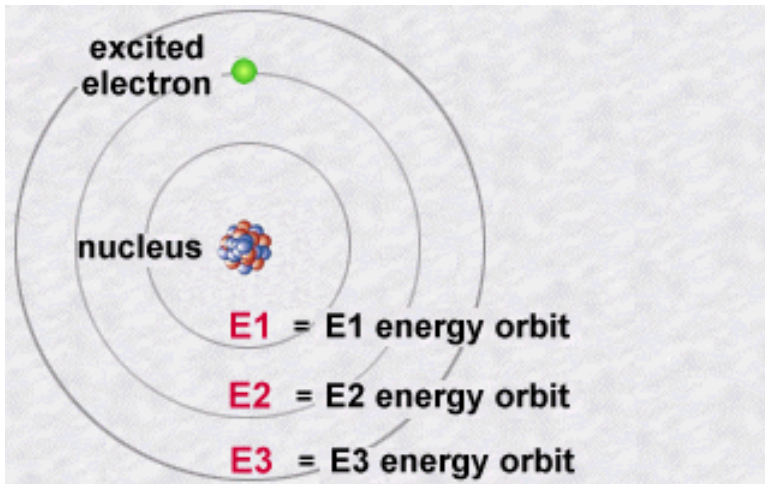
# Niels Bohr



- The electrons orbit in specific “quantized” energy levels
- When an electron drops from a higher energy level to a lower one, it emits a photon (light)

1885 - 1962

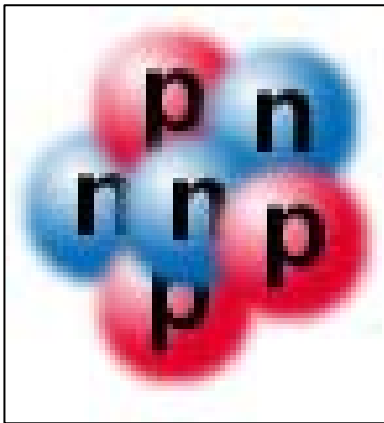
# Neils Bohr



# James Chadwick



- Atomic weights and charges show there must be something else in the nucleus than just a positive charged thing
- Rutherford calls it a “neutral doublet”
- Eureka! I found it!



[http://www-outreach.phy.cam.ac.uk/camp/hy/neutron/neutron2\\_1.htm](http://www-outreach.phy.cam.ac.uk/camp/hy/neutron/neutron2_1.htm)