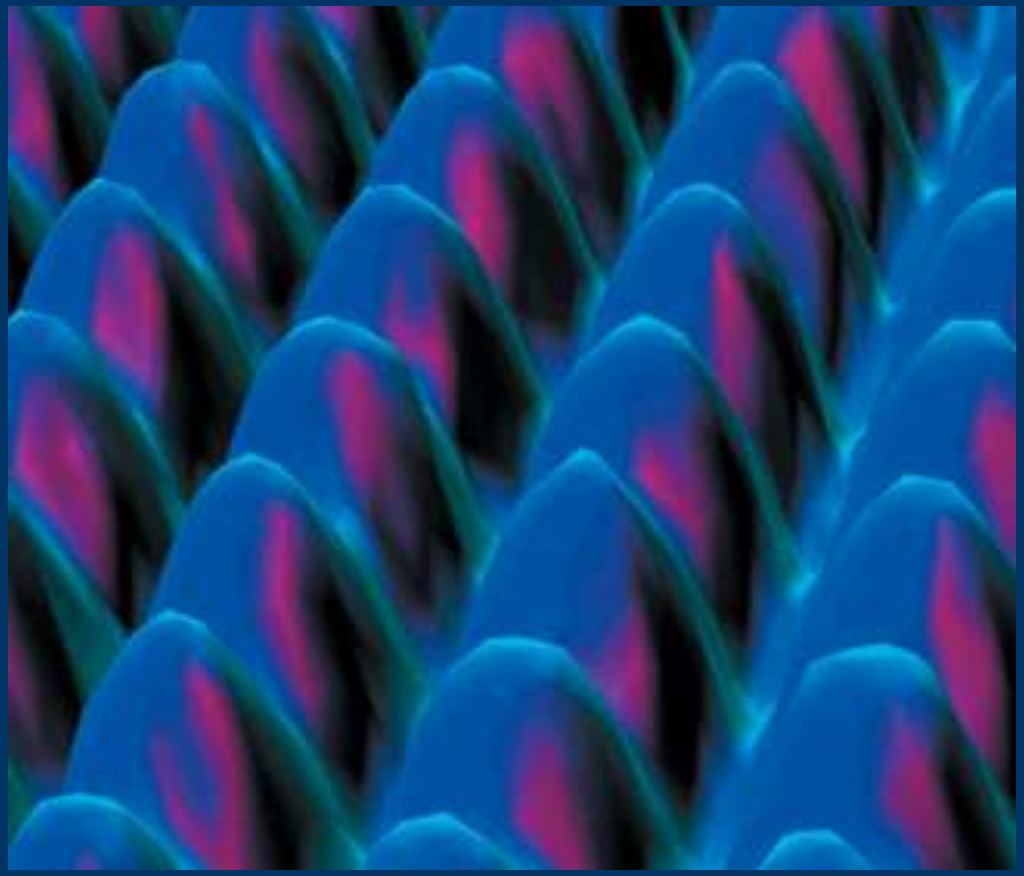
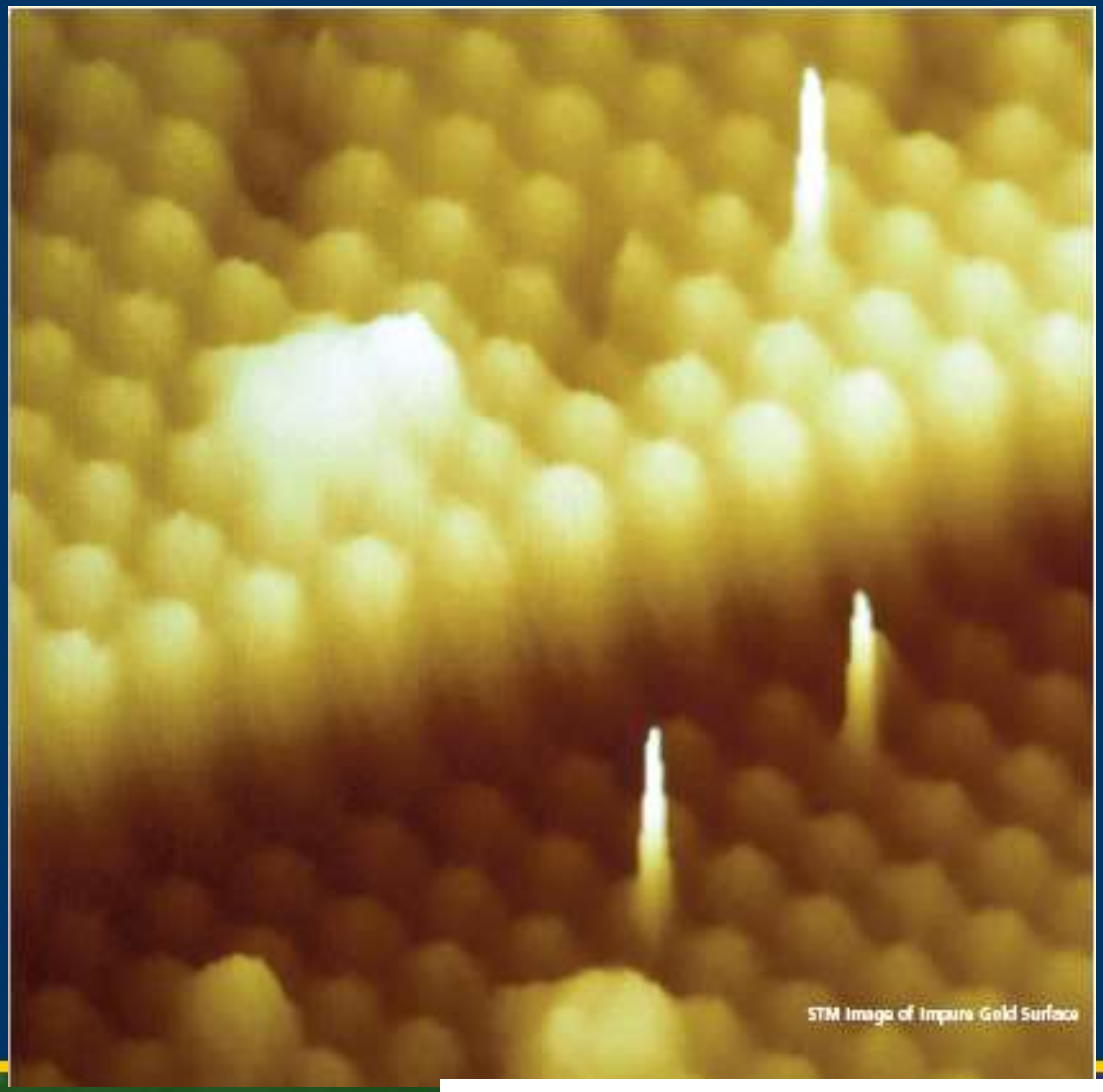
# Atomic Structure Notes

2014, Semester 2

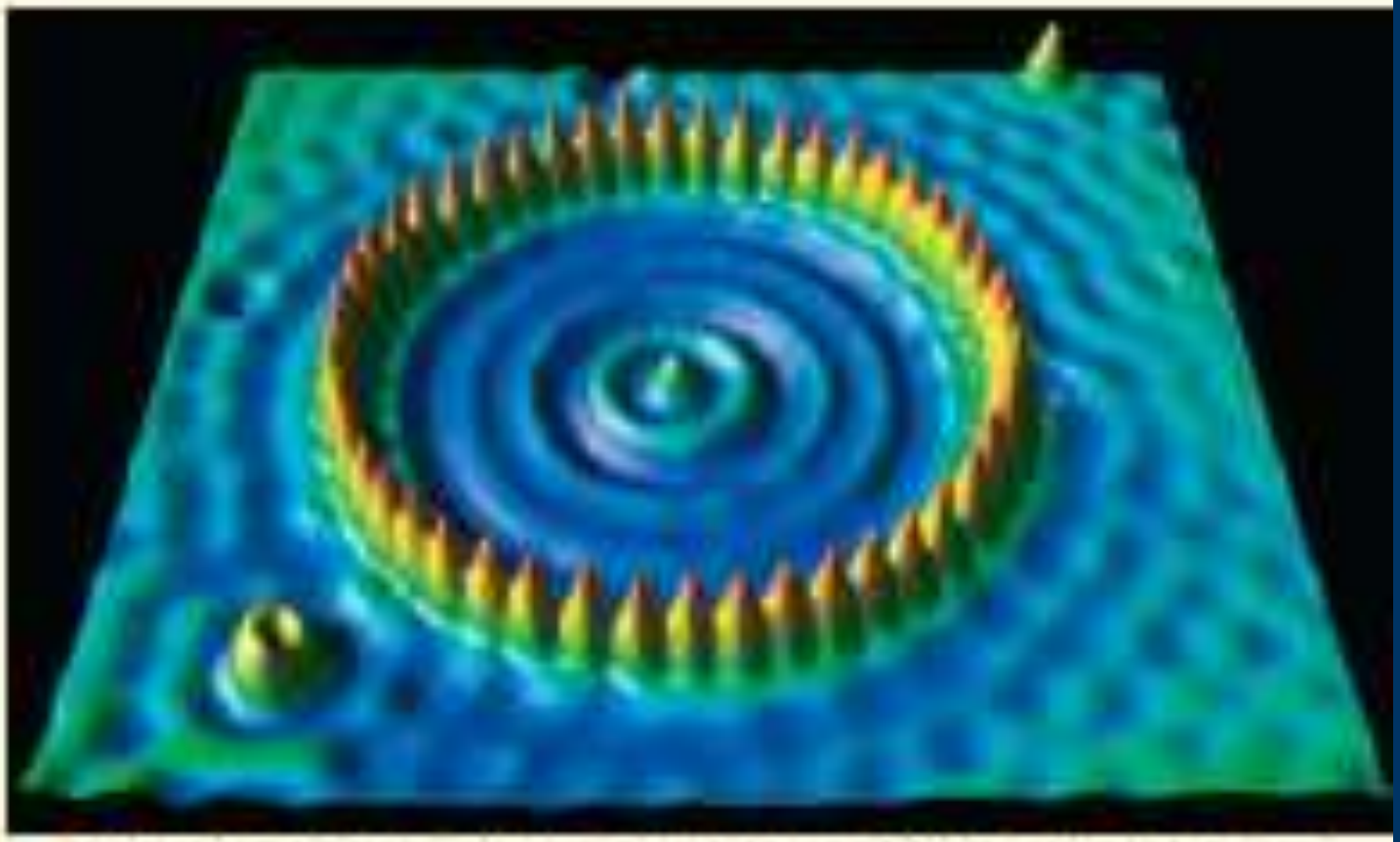
# Can atoms be seen?



# Do atoms really exist?



# • Can we see atoms?



▲ This STM image shows a "corral" of iron atoms on a copper surface.

## Dalton's model of an atom:

**One of his conclusions led to the hypothesis the atom is the smallest unit of matter. It is indivisible.**

**His atomic model looked like a marble:**

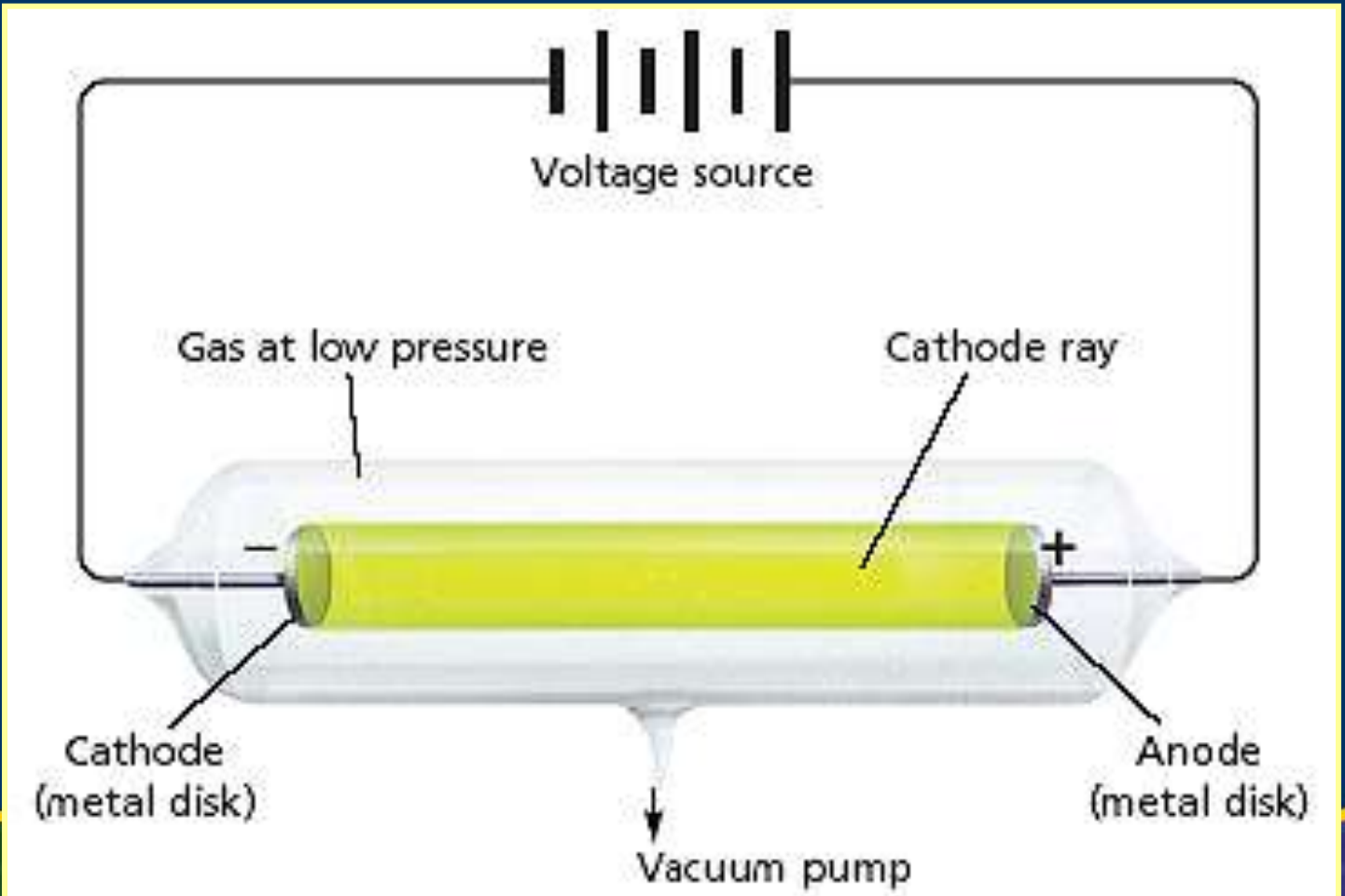
## Electrons

In 1897, the English physicist **J. J. Thomson** (1856–1940) **discovered the electron.**

- **Electrons are negatively charged subatomic particles.**

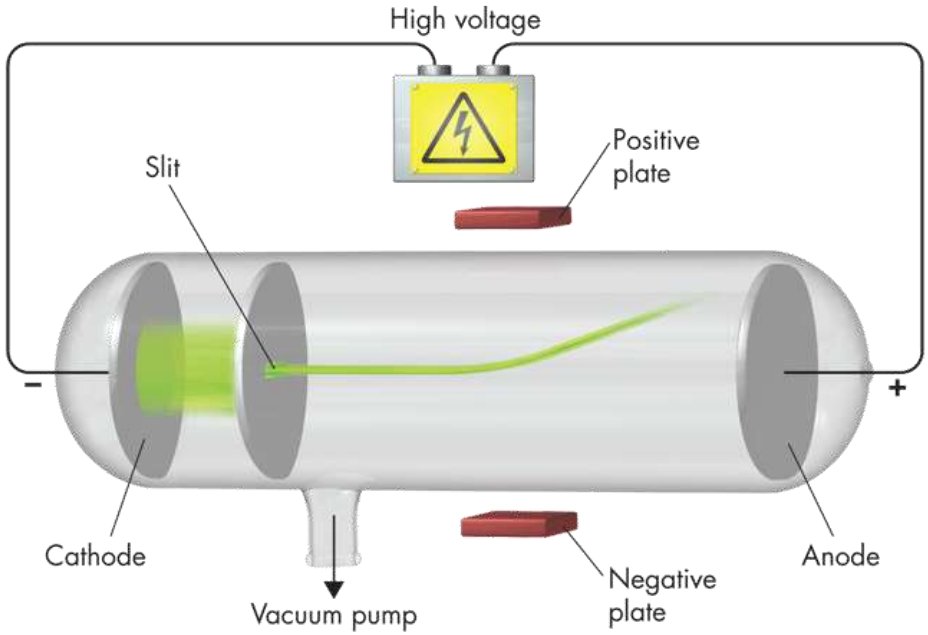
# Thomson's Cathode-Ray Tube Experiment

## Using a CATHODE RAY TUBE



## Electrons

Thomson found that a cathode ray is deflected by electrically charged metal plates.




- A positively charged plate attracts the cathode ray, while a negatively charged plate repels it.

# Thomson's Cathode-Ray Tube Experiment

Click below to watch the Visual Concept.

Visual Concept

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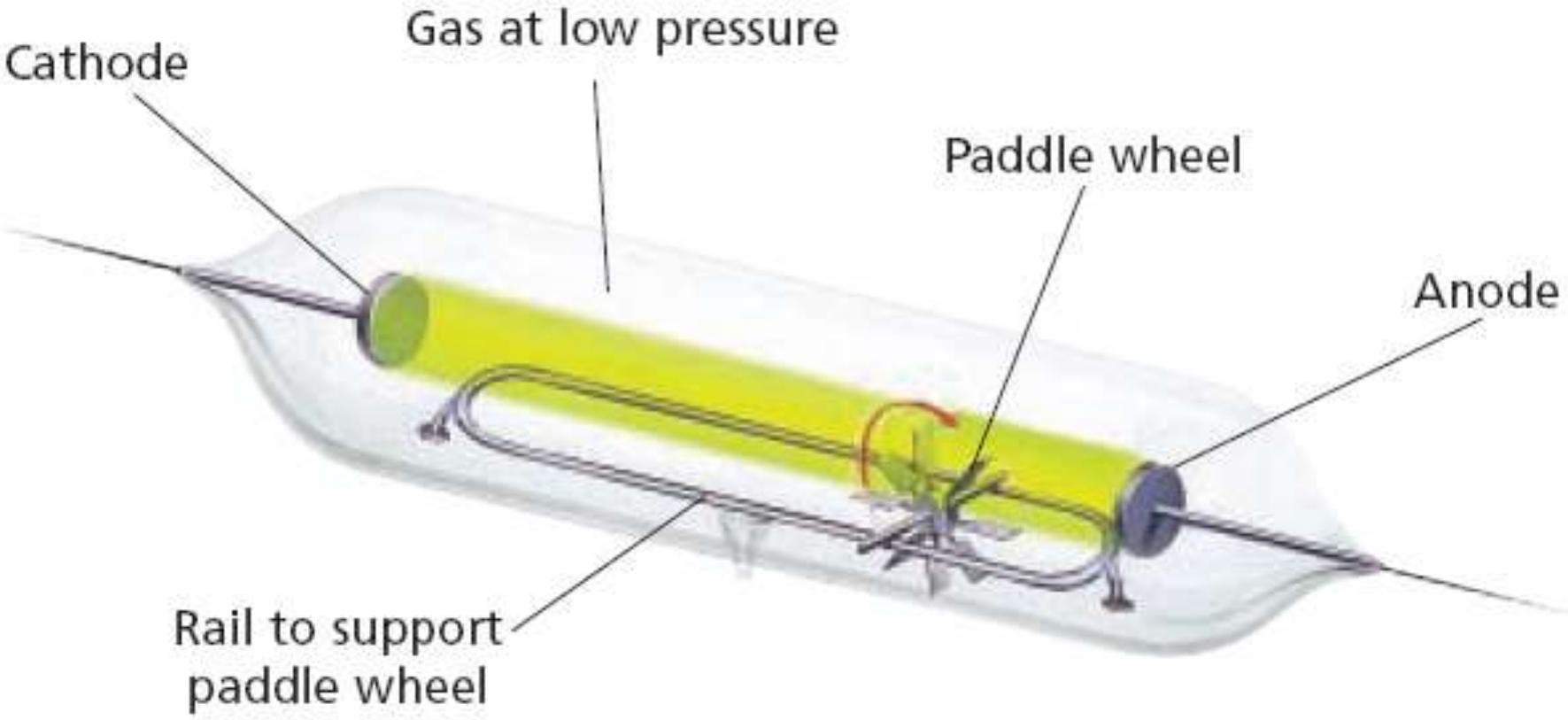
A paddle wheel placed in the path of the cathode ray moves away from the negatively charged cathode and toward the positively charged anode

***The movement of the wheel led scientists to conclude that cathode rays have mass and a negative charge.***



**In 1897, English physicist Joseph John Thompson came to the following *conclusions*:**

**The ray must have a negative charge because**

**The ray was attracted to positive charge and deflected by negative charge.**

**The ray must have mass and therefore be made out of particles because**

**The ray caused the paddle wheel to spin.**

**All matter must contain these negatively charged particles because**

**Every material placed in the cathode ray tube behaved exactly the same way: spun the paddle wheel towards positive, ray deflected by negative.**

## Electrons

The U.S. physicist Robert A. Millikan (1868–1953) carried out experiments to find the exact quantity of an electron's charge.

**An electron has one unit of negative charge, and its mass is 1/1840 (2000 times smaller than) the mass of a hydrogen atom.**

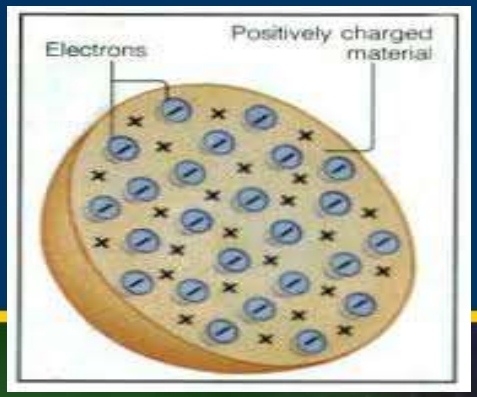
## Thomson's Model of the Atom, *continued*

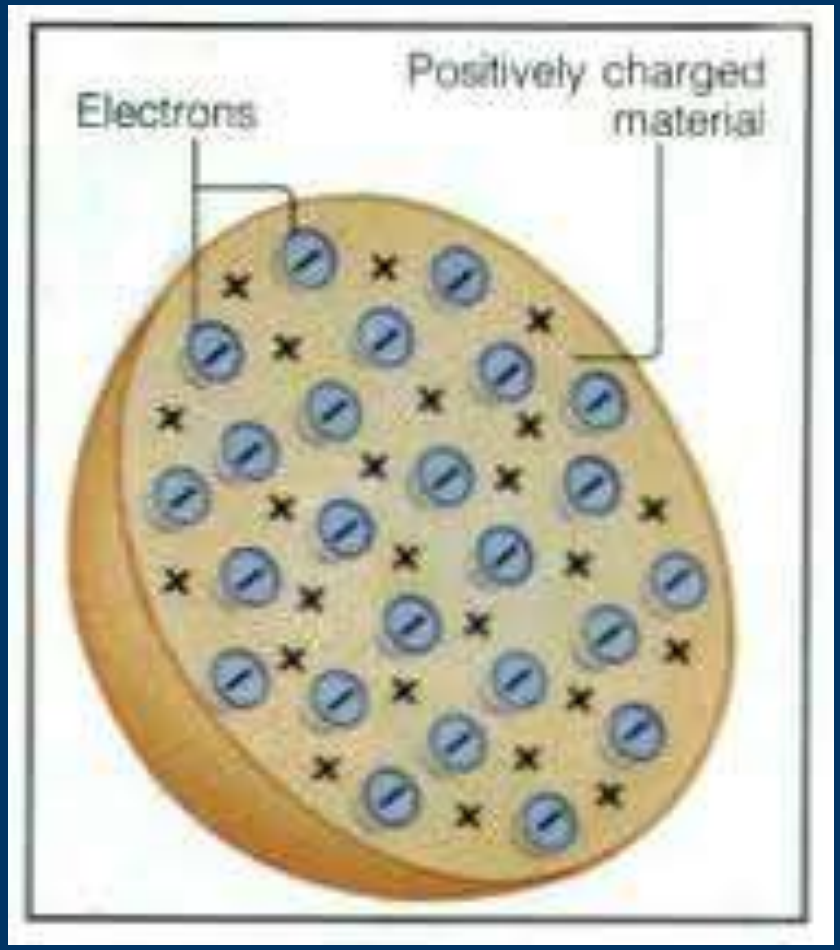
# Thomson developed the plum-pudding model.

In his cathode-ray tube experiment, Thomson had discovered electrons.

**electron:** a subatomic particle that has a negative charge

Thomson's *plum-pudding model:* electrons are spread throughout the atom, like blueberries in a muffin




Electrons
Positively charged material

## Protons and Neutrons

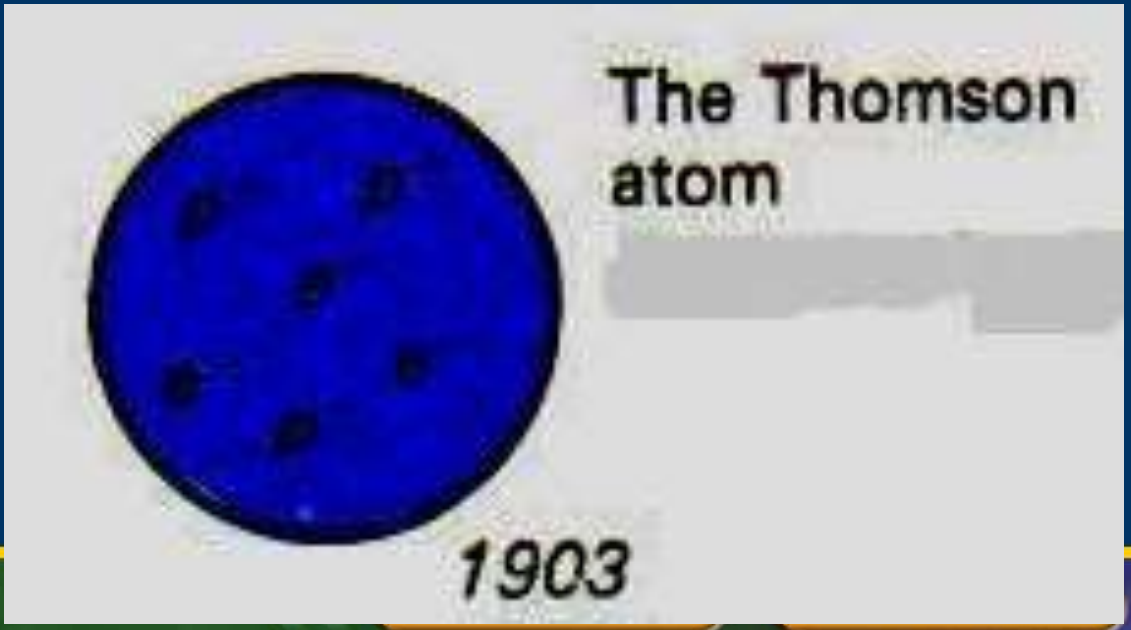
If cathode rays are electrons given off by atoms, what remains of the atoms that have lost the electrons?

- For example, after a hydrogen atom (the lightest kind of atom) loses an electron, what is left?

Thompson purposed the following model of an atom

The atom is made up of negative particles embedded in an equal amount of positive charged cloud like material, thus

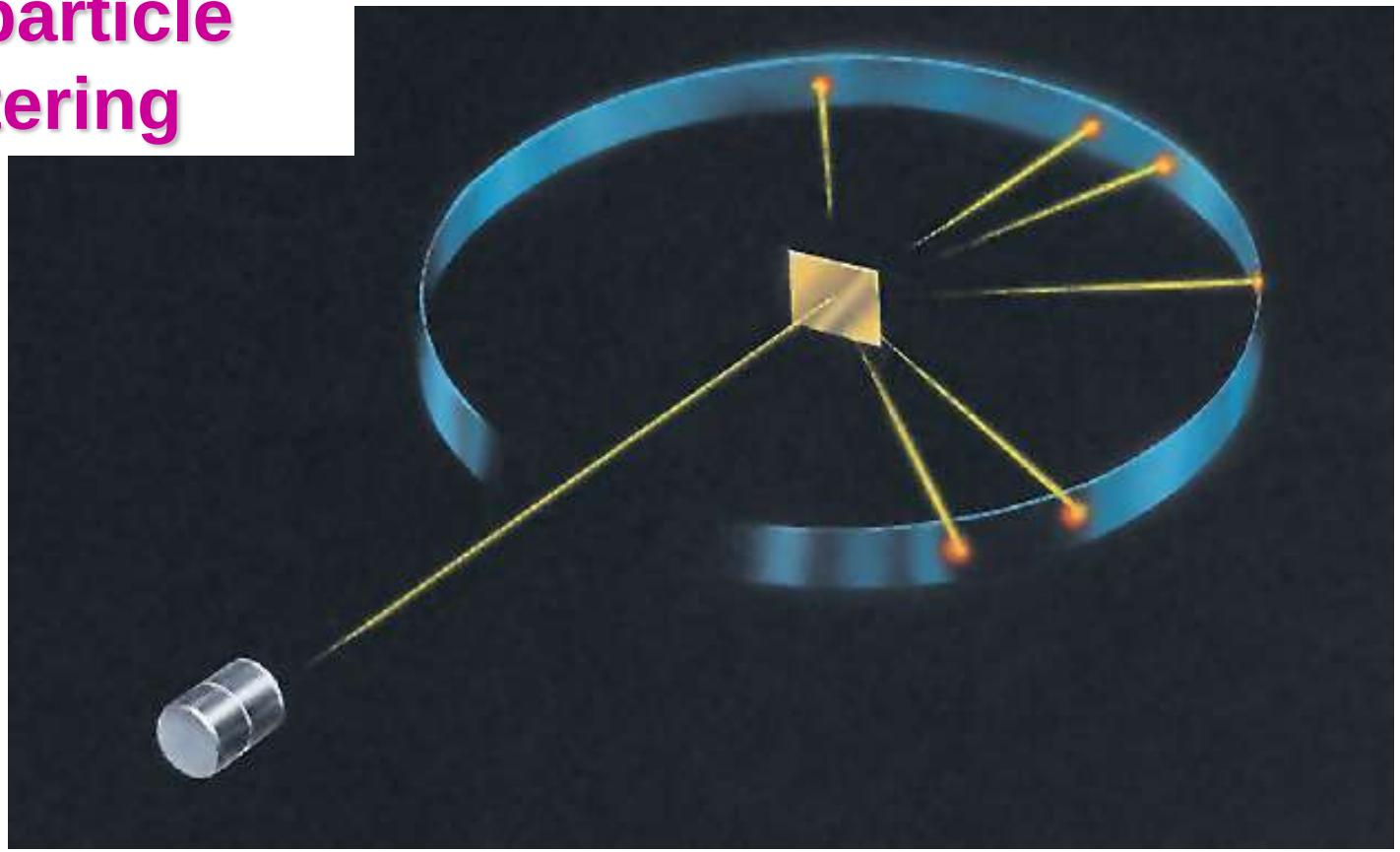
The atom is net neutral at any given point



## Rutherford's Experiment

**Shooting the nucleus of a helium atom (alpha particle) at gold foil.**

**alpha particle scattering**



This model of the atom turned out to be short-lived, however, due to the work of a former student of Thomson, Ernest Rutherford (1871–1937).

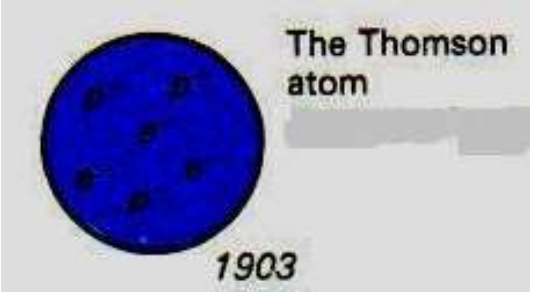
- Born in New Zealand, Rutherford was awarded the Nobel Prize for Chemistry in 1908. His portrait appears on the New Zealand $100 bill.

## Rutherford's Gold-Foil Experiment

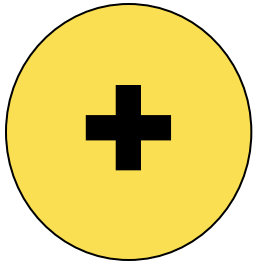
In 1911, Rutherford and his co-workers wanted to test the existing plum-pudding model of atomic structure.

- They devised the gold-foil experiment.
- Their test used alpha particles, which are helium atoms that have lost their two electrons and have a double positive charge because of the two remaining protons.

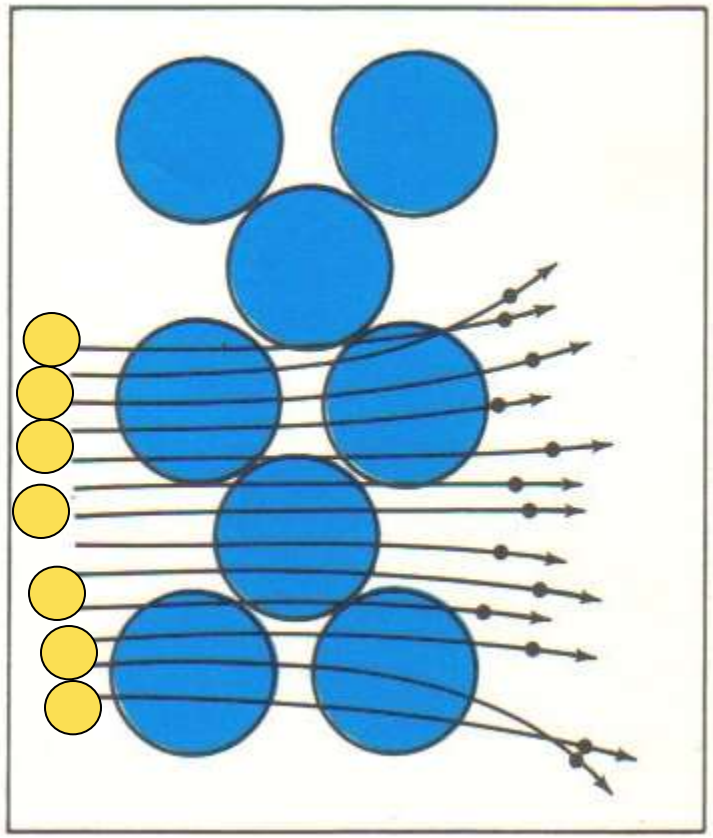
# Rutherford tests Thompsons hypothesis




**The Figure below shows how the alpha particle scattering would look like if the Thompson's theory correct.**



Alpha Particle



# Rutherford's Gold Foil Experiment

Click below to watch the Visual Concept.

Visual Concept

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Rutherford tests Thompsons hypothesis

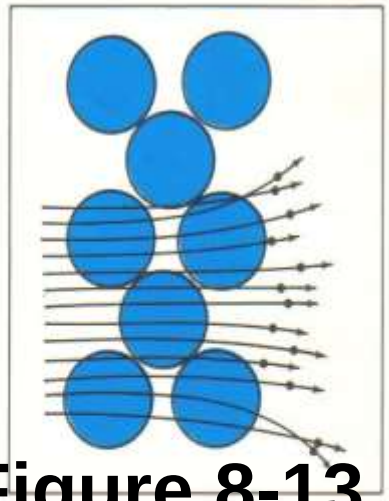


Figure 8-13

FIGURE 8-13

The scattering of alpha particles by a metallic crystal made up of Thomson atoms. Rutherford's results are *not* explained.

Figure 8-13 show how the alpha particle scattering would look like if the Thompson theory was correct.

Figure 8-14 show the actual results of the alpha particle scattering experiment.

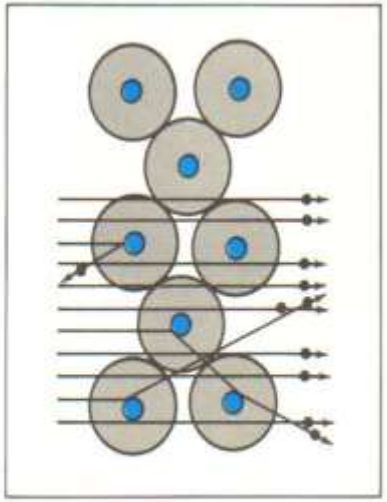
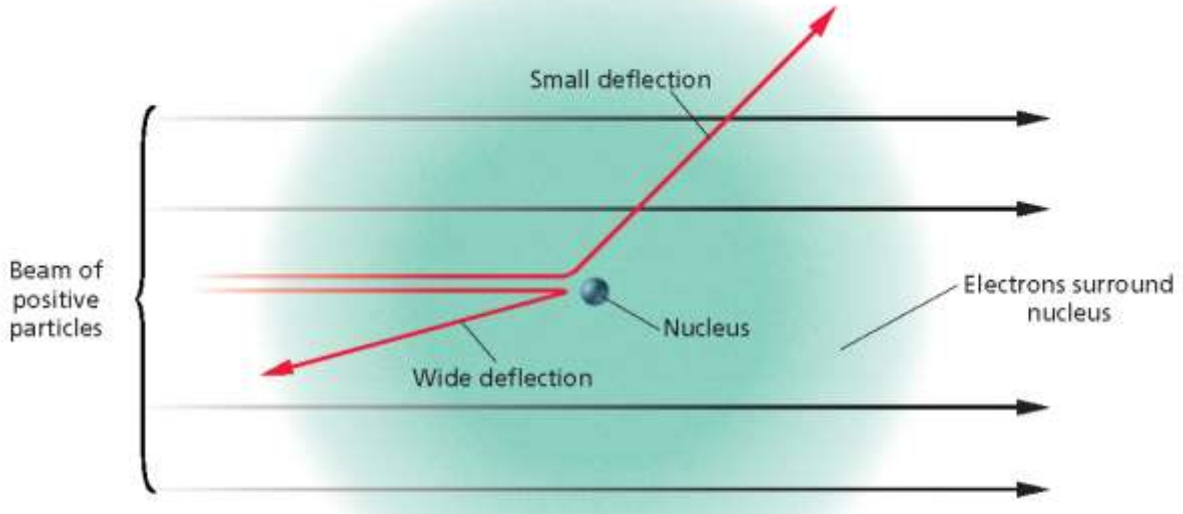


Figure 8-14

The scattering of alpha particles by a metallic crystal made up of Rutherford atoms. Rutherford's results *are* explained.

An atom has a very small positively charged nucleus which is surrounded by electrons.

# Gold Foil Experiment on the Atomic Level




Rutherford reasoned that each atom in the gold foil contained a small, dense, positively charged nucleus surrounded by electrons. A small number of the alpha particles directed toward the foil were deflected by the tiny nucleus (red arrows). Most of the particles passed through undisturbed (black arrows).

# The Rutherford new Atomic Model

- He proposed that the atom is mostly empty space.
  - Thus explaining the lack of deflection of most of the alpha particles.
- He concluded that all the positive charge and almost all of the mass are concentrated in a small region that has enough positive charge to account for the great deflection of some of the alpha particles.

## The Rutherford Atomic Model

The Rutherford atomic model is known as the nuclear atom.

***In the nuclear atom, the protons and neutrons are located in the positively charged nucleus. The electrons are distributed around the nucleus and occupy almost all the volume of the atom.***

**proton: a positively charged subatomic particle found in the nucleus of an atom.**

## The Sizes of Atoms

According to this model, the nucleus is tiny and densely packed compared with the atom as a whole.

- If an atom was the size of the Superdome, the nucleus would be the size of a marble sitting at the 50 year line.

## The Rutherford Atomic Model

Rutherford's model turned out to be incomplete.

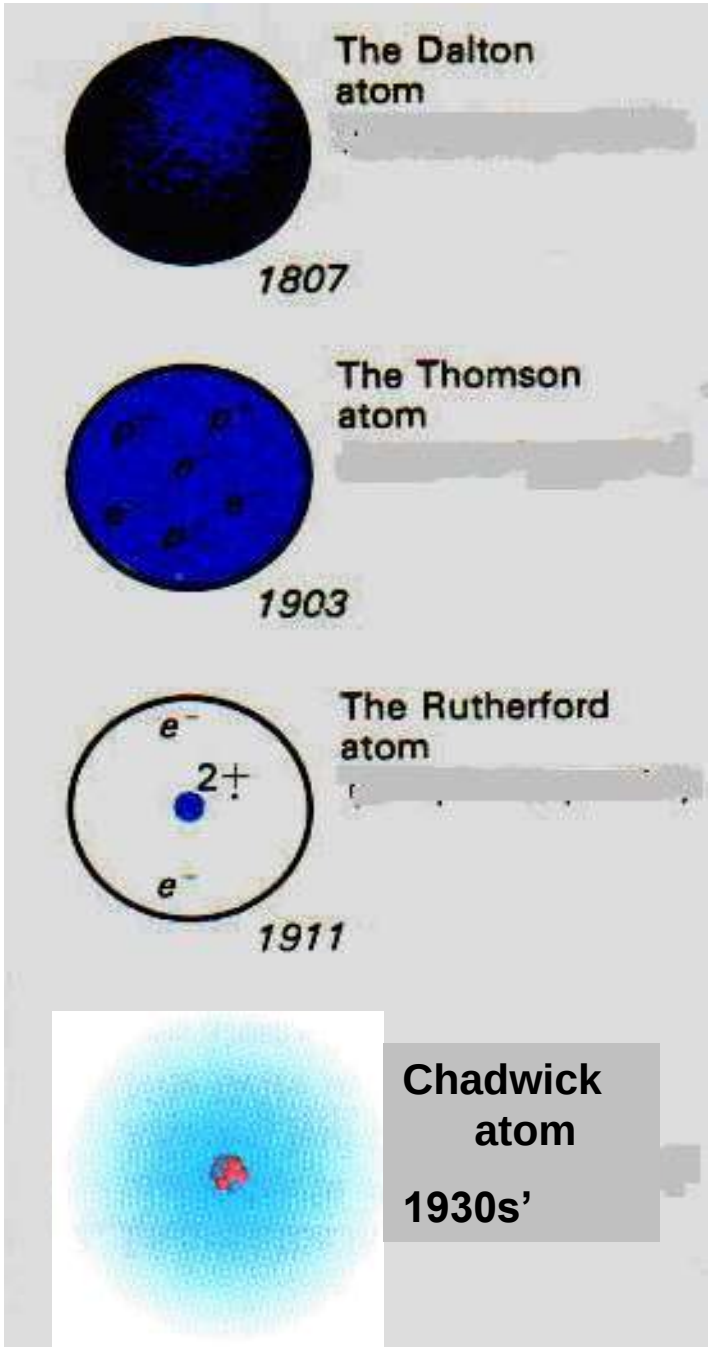
- The Rutherford atomic model had to be revised in order to explain the chemical properties of elements.

## Protons and Neutrons

In 1932, the English physicist **James Chadwick** (1891–1974) **discovered** the existence of yet another subatomic particle: **the neutron.**

- **Neutrons are subatomic particles with no charge but with a mass nearly equal to that of a proton.**

# Historic Atomic Models (Theories)



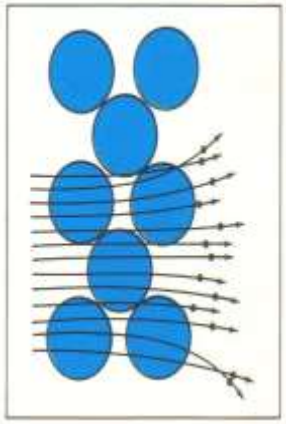

**These pictures are models.**

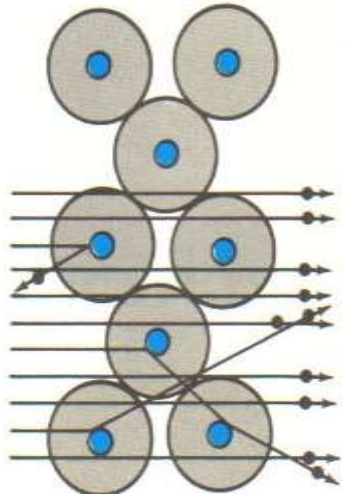
**They help us visualize a theory.**

**Theories change when the results of new experiments can not be explained by those theories.**

# Study Guide,Thursday, May 15, 2014

**Explain how Rutherford's experimental observations could not have been explained by Thomson's model of the atom.**

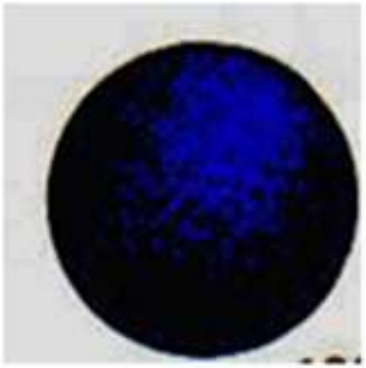




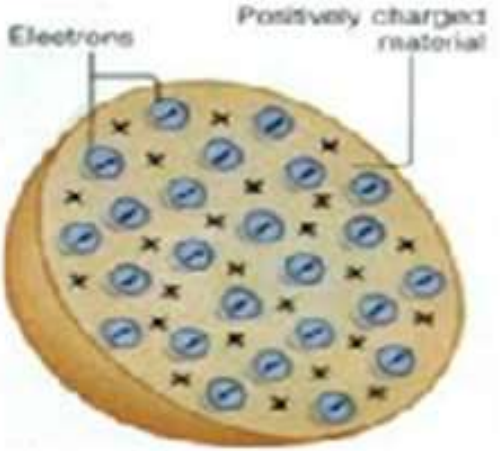
**Because most particles fired at metal foil passed straight through, Rutherford concluded that atoms were mostly empty space.**

**A very few positively charged particles were greatly deflected back from the metal.**

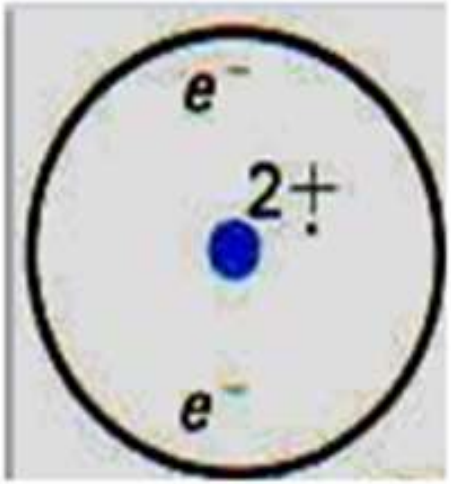
# Study Guide



A




B




C

- Which model of the atom did J.J. Thomson propose? **B**
- Which model of the atom did John Dalton propose? **A**
- Which model of the atom did Ernest Rutherford **C**

## Properties of Subatomic Particles

| Particle | Symbols | Relative electric charge | Relative Mass |
|---|---|---|---|
| Electron | $e^-$, ${}^{0}_{-1}e$ | –1 | 0 |
| Proton | $p^+$, ${}^{1}_{1}\mathrm{p}$ | +1 | 1 |
| Neutron | $n^\circ$, ${}^{1}_{0}n$ | 0 | 1 |

## Properties of Subatomic Particles

**Charge of a proton = +1.6 x $10^{-19}$ Coulombs**

**Charge of an electron = -1.6 x $10^{-19}$ Coulombs**

| Particle | Symbols | Relative electric charge | Mass number | Relative mass (amu*) | Actual mass (kg) |
|---|---|---|---|---|---|
| Electron | $e^-$, $_{-1}^{0}\beta$ | -1 | 0 | 0.000 5486 | $9.109 \times 10^{-31}$ |
| Proton | $p^+$, $_1^1H$ | +1 | 1 | 1.007 276 | $1.673 \times 10^{-27}$ |
| Neutron | $n^\circ$, $_0^1n$ | 0 | 1 | 1.008 665 | $1.675 \times 10^{-27}$ |

## Composition of the Atomic Nucleus, *continued*

- All atoms have protons, neutrons and electrons Yet each element has different properties
- The nuclei of atoms of different elements differ in their number of protons and therefore in the amount of positive charge they possess.

- **Thus, the number of protons determines that atom's identity.**

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## Atomic Number

- Atoms of different elements have different numbers of protons.
- Atoms of the same element all have the same number of protons.
- The atomic number of an element is the number of protons in the nucleus of that element.

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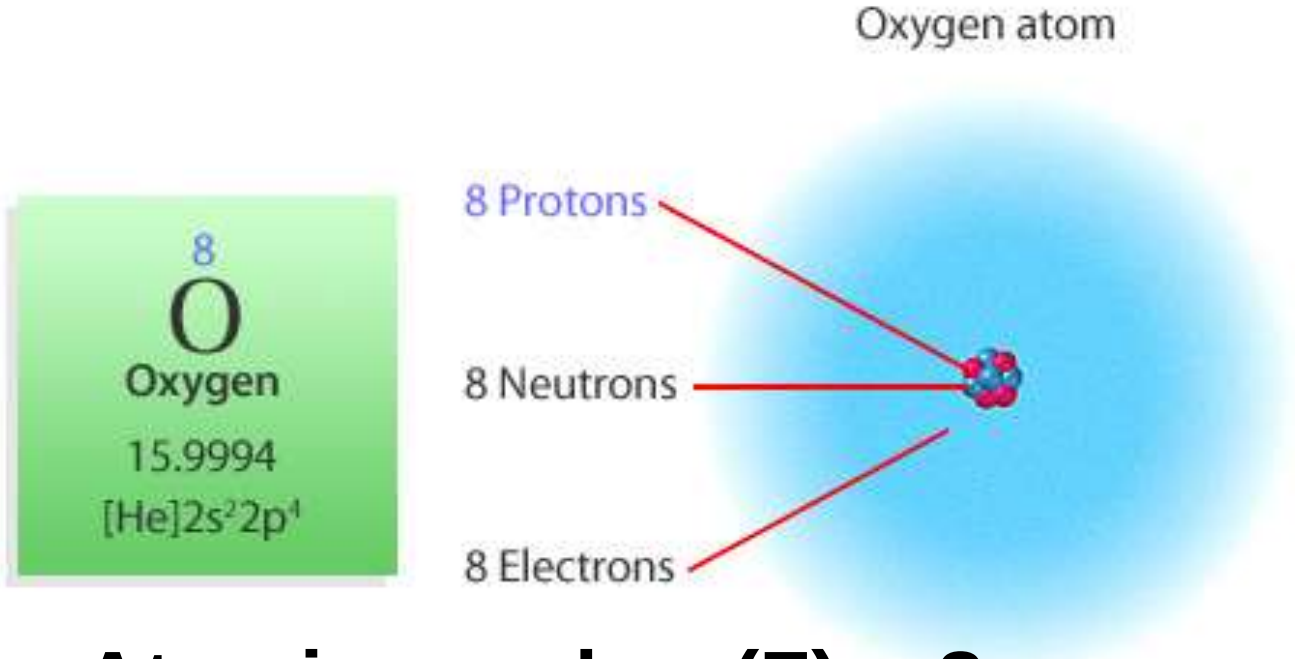


**Atomic number (Z) = 8**

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