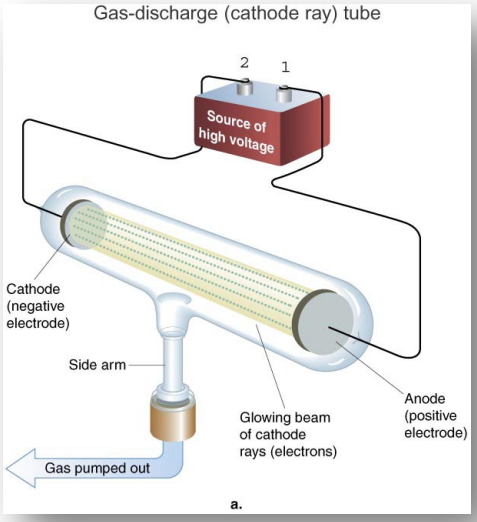
Module-5 Structure of the Atom

ATOMIC MODEL: A BRIEF HISTORY

- British scientist John Dalton (1766-1848), proposed atomic theory of matter, some of these hypothesizes are true to this day.

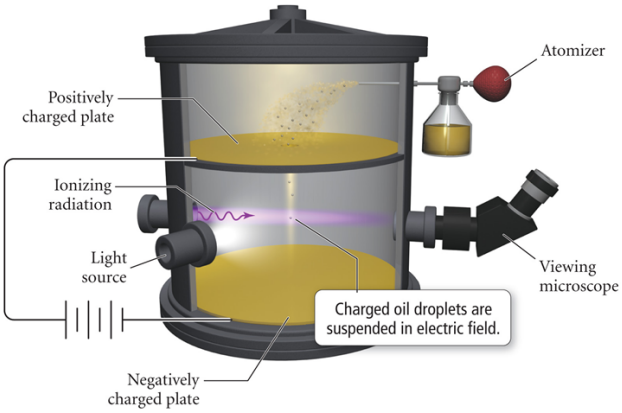
  (a) Atoms combine in a simple whole-number ratio to form compounds

  (b) A chemical reaction involves rearrangement of atoms. No atom is created or broken apart in a chemical reaction
- In 1870s British physicist William Crookes invented cathode ray tube.



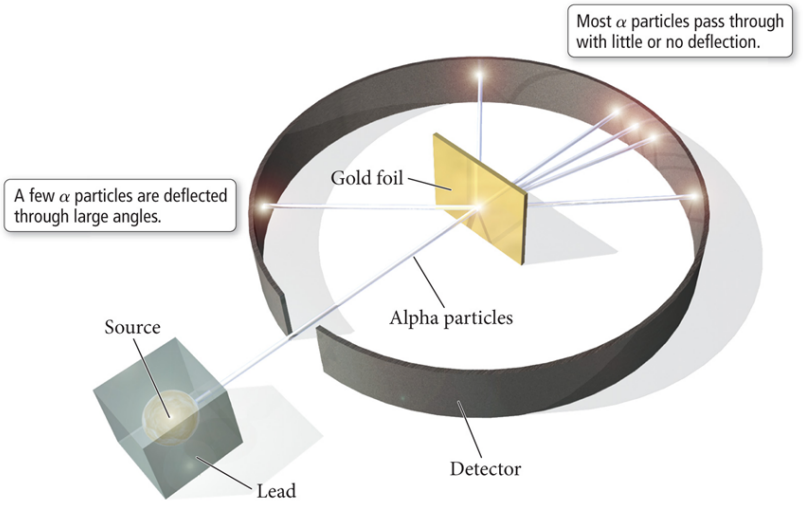
- The 1906 Nobel prize winner and the British physicist J. J. Thomson was the first scientist to prove that the cathode rays were negatively charged and called them as **electrons**.
- Thomson measured the charge to mass ratio of the cathode ray particle as, -1.76×10^8 coulombs (C) per gram.
- American physicist Robert Millikan did a series of experiments to find the mass of electrons.

Robert Millikan determined the mass and charge of an electron using the experimental procedure which in now called Millikan's oil drop experiment.



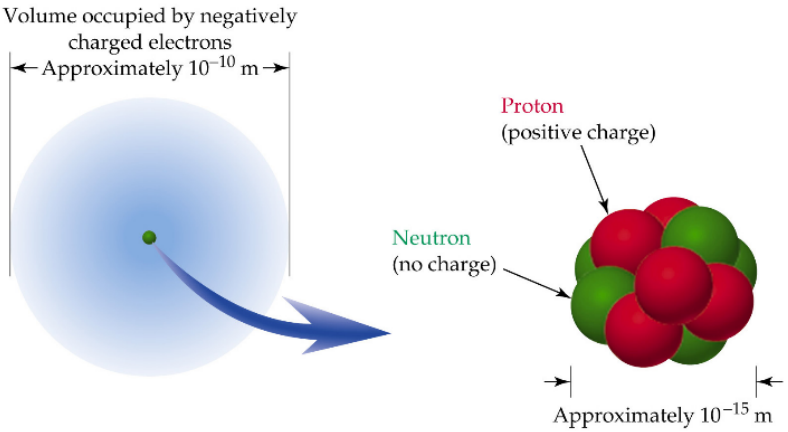
- Millikan measured the charge of an electron as -1.60×10^{-19} C. Since the mass to charge ratio of electron was already found by Thomson, using the newly found charge of an electron Millikan calculated the mass of an electron as 9.10×10^{-28} g.
- In the year 1923 Robert Millikan was awarded the Nobel Prize in Physics.
- Rutherford gold foil experiment: Ernest Rutherford proposed that, an atom has mostly empty space and it contains a dense particle (*later called a nucleus*) that was small in volume compared to the atom but large in mass.

Rutherford's Gold Foil Experiment



- Later it was found that the nucleus contains positively charged protons and electrically neutral neutrons.

- The atoms of all elements consist of positively charged protons, neutral neutrons and negatively charged electrons. Exception, the isotope hydrogen-1 has no neutrons.



THE LAW OF DEFINITE AND MULTIPLE PROPORTIONS

- The French chemist **Joseph Louis Proust** (1754-1826), observed that copper carbonate ($CuCO_3$) occurs in nature (a) as the mineral malachite, (b) as a patina on copper roofs and bronze statues, (c) and can also be synthesized in the laboratory. Regardless of its source, the chemical compound, copper carbonate, has the same composition.
- **The Law of Definite Proportions**: All samples of a given compound, regardless of their source or how they were prepared, have the same proportions of their constituent elements.
- This statement is true for any compound and not just for copper carbonate. For example, a sample of water found in any part of the world has the sample composition (H_2O).
- **Dalton theory multiple proportions:** Elements can combine with each other in more than one set of proportions.
- For example, hydrogen and oxygen combine with each other in two different proportions and form two entirely different compounds.

$$2H_2 + O_2 \rightarrow 2H_2O$$

Water

$$2H_2 + 2O_2 \rightarrow 2H_2O_2$$

Hydrogen peroxide

Practice Problems

1. From the Millikan's oil drop experiment charge of an electron was determined as -1.60×10^{-19} C. J. J. Thomson found that charge to mass ratio of an electron as -1.76×10^{8} coulombs (C) per gram. Based on these facts calculate the mass of an electron and verify that it matches will the literature value.

2. One of the postulates of Dalton's atomic theory is 'All atoms of a given element are identical', why this aspect of his theory was proved to be incorrect later?

3. Carbon dioxide found in Earth and in the planets Mars and Venus determined to have the same molecular formula, CO_2, this observation validates which one of theories we learned in this module?

4. A nucleus of an atom has a charge of 8.32×10^{-18} **C,** how many protons are present in this atom?

5. In the year 2010, physicist Randolf Phol determined the radius of a proton as 0.84 fm (fm = 10^{-15} m). The atomic radius of the hydrogen is 53 pm (pm = 10^{-12} m). Based on these data, comment on the volume of hydrogen nucleus with respect to the total volume of a hydrogen atom. How your discussions relate to Rutherford gold foil experiment?

6. What is the nuclear charge of an atom of selenium (Se)?

7. Total mass of protons in an atom is found to be 5.3381×10^{-22} g. If the mass of a proton is 6.6726×10^{-24} g, identify the element.

8. Which of the following pairs of compounds can be used to illustrate the law of multiple proportions?

(A) H_2O and HCl (B) NO and NO_2

(C) NH_4 and NH_4Cl (D) ZnO_2 and $ZnCl_2$

9. An analytical chemistry lab received three containers with unknown chemical samples in them. When analyzed, it was found that each sample was comprised of only two elements, namely, uranium and fluorine, with the masses given in the table. The molecular formula of the sample in the first container was determined as UF_4. Do all three samples have the same molecular formula or different molecular formulas.

	Mass of Uranium	Mass of Fluorine
Container-1	52.0 g	16.6 g
Container-2	22.0 g	7.02 g
Container-3	85.0 g	27.1 g