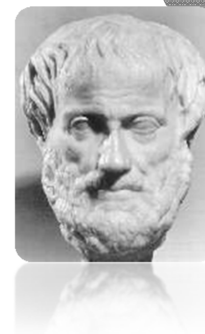
# THE ATOM: A TINY BIT FROM HISTORY

ATOMIC THEORY FROM THE GREEKS TO THE PRESENT

## The Early Greeks

- In the 4th century, Aristotle stated that “matter” had four possible properties:



•Moist •Dry
•Hot •Cold

- The four properties were contained in various proportions by four major elements which made up everything our senses could detect:
  - **fire, air, earth, water**

- With these ideas, the early Greek periodic table may have looked like…

| | | |
|---|---|---|
| Air | Moist | Water |
| Hot | | Cold |
| Fire | Dry | Earth |

## Medieval Chemist…

- developed the idea of "corpuscles" that were subject to attractive and repulsive forces.
- Any idea by the Greeks or Medieval chemists were mostly philosophical in nature (not based on scientific method)

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- At the beginning of the 19th century, three laws were accepted based on experimental results:

1. The Law of Definite Proportions
   - a chemical compound always contains exactly the same proportion of elements by mass
   - Ex. Water is always $H_2O$   (11% H and 89% O)
2. The Law of Multiple Proportions
   - when elements combine, they do so in the ratio of small whole numbers
   - Ex. CO and $CO_2$ not $CO_{1.5}$
3. The Law of Conservation of Mass
   - the mass of a closed system will remain constant, regardless of the processes acting inside the system.

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## Dalton's Atomic Theory

- In 1808, John Dalton based his model of the atom on solid experimental discoveries
- He stated:
  - Elements are made up of extremely small particles called *atoms (Greek word for uncuttable)*
  - All atoms making up an *element* are the same.
  - *Each compound is unique* and consists of particular atoms arranged in a particular way.
  - Chemical reactions involve *reshuffling* of atoms to form new compounds made from the old atoms.

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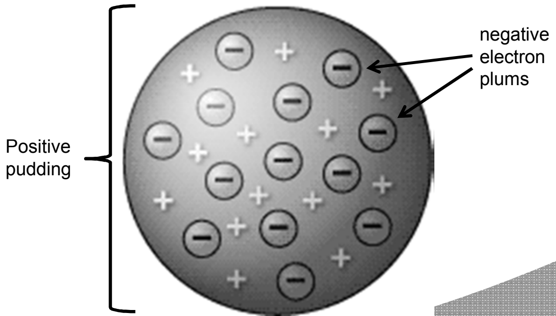
## The Thompson Atom

- By the middle of the 19th century, there was extensive evidence of atoms, but also smaller parts which make up the atom
- J.J. Thompson discovered and showed that atoms have negatively charged "electrons" (and so must have equal positive charged to cancel them out)

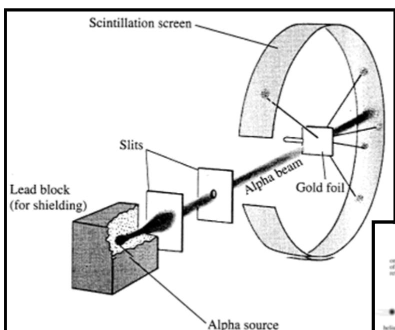
- His model was called the “Plum Pudding” model as it resembles the English dessert.

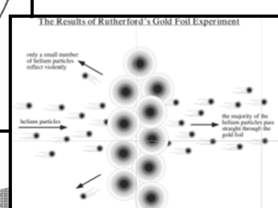



## The Rutherford Atom Model

- Rutherford proposed that the atom consists of a tiny, positively charged <u>nucleus</u>, surrounded by a “cloud” of negatively charged electrons
- First to use the word “proton”
- The protons are equal in number to the electrons thus making an electrically neutral entity
- The gold foil experiment.

## The Rutherford Atom Model



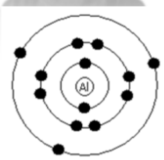

## Moseley

- Henry Moseley showed protons as individual particles with different numbers in each element. (assigned atomic numbers)

## Chadwick

- It was not until 1932 that James Chadwick discovered the <u>neutron</u> that was predicted by Rutherford.

## Bohr took the model a bit further…




- Bohr stated that electrons are restricted to a certain path called an "orbit", a fixed distance from the nucleus.
- Electrons can only emit or absorb energy when they move from one orbit to another.
- Only certain quantities of energy are emitted.

## Bohr Diagrams

- Bohr Diagrams are simplified pictures that show the arrangement of electrons in atoms and ions.
- Electrons are located in circular paths around the nucleus call orbits
- Orbits can contain up to
  2, 8, 8, 18, 18 electrons
- The electrons in the orbit farthest away from the nucleus are called **valance electrons** (which can be used in bonding)

## Bohr Diagrams…

- Just follow the steps:
  - find # of protons, neutrons and electrons
  - write "P=" and "N=" for the number of protons and neutrons in the nucleus
  - Draw circles around the "nucleus" and fill them up with electrons until all the electrons are accounted for in the pattern 2, 8, 8, 18, 18

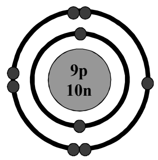
## Remember…

- # of protons = Atomic number
- # of neutrons = Mass number – Atomic number
- # of electrons = # of protons for an atom
- # of electrons = # of protons – (charge) for an ion

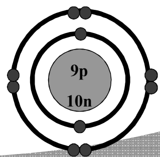
Note: mass number and atomic mass are NOT the same – mass number tells us the mass of one specific atom, atomic mass tells us the average mass of all the isotopes of the element

## Bohr Diagram

- Ex. Bohr Diagram for Fluorine atom

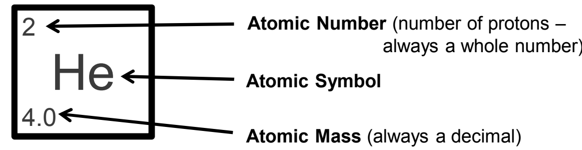



- Ex. Bohr Diagram for Fluoride ion ($F^-$)




## Atomic Number and Atomic Mass…

- There are three pieces of information usually shown for each element on the periodic table:




- Since both neutrons and protons have a mass of 1.0 amu, the mass number (NOT atomic mass) of an atom will be found by their combined totals

## Electrons and Ions

- What about the mass of an electron? ~0 amu
- Note: If electrons are added to or subtracted from an atom, the resulting particle is called an ION
  - For example:
    - How many electrons are possessed by the following?
      Re: #$e^-$ = atomic # – (charge)
      - a) $N^{3-}$ #e = 7e – (-3e) = 10 e
      - b) $Ca^{2+}$ #e = 20e – (+2e) = 18 e

## Atomic particles

- Some examples
  - Find the number of protons, neutrons and electrons for the following:
  - a) $^{27}_{13}Al^{+3}$ p = 13, n = 14 and e = 10
  - b) $^{75}_{33}As$ p = 33, n = 42 and e = 33

## Isotopes

- Species having the same atomic number, but different atomic masses (same # of protons, different # of neutrons)

Ex: ${}^{1}_{1}H$ = H = ordinary Hydrogen (called "protium")

${}^{2}_{1}H$ = D = Deuterium (sometimes called "heavy" hydrogen)

${}^{3}_{1}H$ = T = Tritium (called "radioactive" hydrogen)

## Molar Masses

- molar masses are calculated based on the isotope masses and their relative abundances (what percentage they occur in nature)
- For example: Potassium has the following isotopes distribution: K-39 (93.3%), K-40 (0.0117%), K-41 (6.7%). What would the molar mass of this sample be (to 1 decimal place)?

| | | |
|---|---|---|
| K-39: | 0.933 x 39 g/mol | 36.387 g/mol |
| K-40: | 0.000117 x 40 g/mol | 0.00468 g/mol |
| K-41: | 0.067 x 41 g/mol | 2.747 g/mol |
| | | 39.1 g/mol |

## Examples continued…

- Experiments show that chlorine is a mixture which is 75.77% Cl-35 and 24.23% Cl-37. If the precise molar mass of Cl-35 is 34.966653 g/mol and of Cl-37 is 36.965903 g/mol, what is the average molar mass of the chlorine atoms in such a mixture?

| | | |
|---|---|---|
| Cl-35 | 0.7577 x 34.966653 g/mol | 26.49423298 g/mol |
| Cl-37 | 0.2423 x 36.965903 g/mol | 8.95683829 g/mol |
| | | 35.45 g/mol |