Chemistry

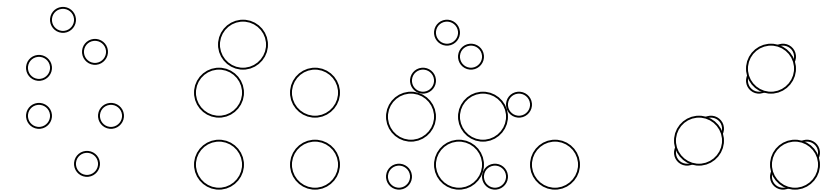
Atomic Structure and the Periodic Table
Lesson 4
Lesson Plan
David V. Fansler

Atoms

Objective: Summarize Dalton's atomic theory, Describe the size of an atom

- Atoms
  - Do you believe in things you cannot see?
  - Atom was first suggested in 4th century BC by Democritus
    - Indivisible and indestructible
  - John Dalton is credited with current beginning of understanding of the atom
    - Dalton's atomic theory
      - All elements are composed of tiny invisible particles called atoms
      - Atoms of the same element are identical. Atoms of any one element are different from those of any other element.
      - Atoms of different elements cane physically mix together or chemically combine with one another in simple whole-number ratios to form compounds.
      - Chemical reactions occur when atoms are separated, joined or rearranged. Atoms of one element, however, are never changed into atoms of another element as a result of a chemical reaction.
        - Alchemy – transmutation

-



Atoms of element A | Atoms of element B | Mixture of A & B | Compound of A&B by chemical reaction

  - Size of an atom
    - Imagine trying to grind up a penny – then cut up the fine grounds – you could never cut it down to an atom, blade too wide.
    - 100,000,000 atoms = 1cm
      - 10^8 atoms = 1cm
    - 1 penny has ~ 2.4×10^{22} atoms
    - The earth has 6×10^9 people
      - 1 penny contains 4×10^{12} more atoms than on the earth

- Structure of the Nuclear Atom
- *Objective: Distinguish among protons, electrons and neutrons in terms of relative mass and charge; Describe the structure of an atom, including the location of protons, electrons and neutrons with respect to the nucleus*
    - Change from Dalton's theory – atoms can be divided
    - There are 3 major sub-atomic particles – but there are dozens of kinds of sub-atomic particles
    - Electrons – negatively charged subatomic particles
        - JJ Thomson discovered electrons in 1897
        - Low pressure gas tube with a metal disk at each end
            - Metal disk called an electrode
            - Electrodes connected to high voltage
            - Anode became positively charged
            - Cathode became negatively charged
            - Glowing beam formed between the electrodes – traveling from the cathode to the anode – known as the cathode ray
            - Cathode rays would be attracted to metal plates with a positive charge, but repelled from plates with a negative charge.
            - Knowing that opposite charges attract and like charges repel, he proposed that the cathode ray was a stream of tiny negative charges moving at high speed .
            - He named them electrons
            - Proved that the type of gas or metal plates did not affect the production of electrons.
            - Concluded that electron was part of an atom
            - Mass of an electron is 1/2000 that of a hydrogen atom
        - Robert Millikan later determined the ratio of the charge to the mass of an electron
            - Electron is exactly 1 negative charge
            - Electron mass is 1/1840 of the mass of a hydrogen atom

    - Protons & Neutrons
        - If a cathode ray is electrons – what remains of the atom?
            - Hydrogen – strip electron, what is left behind?
    - 4 simple ideas to think through
        - Atoms have no charge (they are electrically neutral)
        - Electrical charges are carried by particles of matter
        - Electrical charges exists in whole numbers – no fractions
        - When a given number of negatively charged particles combine with an equal number of positively charged particles, an electrically neutral particle is formed.

- A positive particle was discovered in 1886 by Goldstein – observing a cathode ray and found a positively charge stream moving in the opposite direction as the cathode ray
  - Found to have charge of +1
  - Mass of 1840 times that of an electron
- 1932 James Chadwick confirmed the existence of the neutron
  - No charge
  - The same mass as a proton

Particle	Symbol	Relative Electrical Charge	Relative Mass Proton = 1	Actual Mass (g)
Electron	e^-	1-	1/1840	9.11×10^{-28}
Proton	p^+	1+	1	1.67×10^{-24}
Neutron	n^0	0	1	1.67×10^{-24}

- The Atomic Nucleus
  - 1911 Ernest Rutherford set about to determine the structure of the atom – sort of hard since you can not see an atom
  - Shot alpha particles at a sheet of gold foil (alpha particle is a helium atom without it's two electrons (2+ charge)
  - Since it was thought that electrons, neutrons and protons were evenly distributed in an atom and the alpha particle would pass through with a small deflection.
  - Some went straight through, some had a small deflection, some had a large deflection and some were bounced back
  - Conclusion – atom is mostly empty space (allowing the alpha particles to pass through. The positive charge and almost all the mass are concentrated in a small region that accounted for the large deflection of some of the particles
  - This region is know as the nucleus – the core of an atom
    - Composed of protons and neutrons
    - Small compared to the size of an atom

Distinguishing Between Atoms

Objective: How the atomic number identifies an element; Use atomic number and mass number of an element to find the numbers of protons, electrons and neutrons; How isotopes differ, why atomic masses of elements are not whole numbers; Calculate the average atomic mass of an element from isotope data

- Atomic Number
  - All atoms are composed of a nucleus of protons and neutrons surrounded by a large cloud of electrons – how do atoms of different elements differ?

Atoms of the First Ten Elements

			Composition of nucleus			
Name	Symbol	Atomic #	Protons	Neutrons*	Mass #	# of electrons

Hydrogen	H	1	1	0	1	1
Helium	He	2	2	2	4	2
Lithium	Li	3	3	4	7	3
Beryllium	Be	4	4	5	9	4
Boron	B	5	5	6	11	5
Carbon	C	6	6	6	12	6
Nitrogen	N	7	7	7	14	7
Oxygen	O	8	8	8	16	8
Fluorine	F	9	9	10	19	9
Neon	Ne	10	10	10	20	10

* Number of neutrons is most abundant isotope

    - As can be seen, the number of protons always equals the number of electrons to be electrically neutral.
    - Atomic Number = number of protons = number of electrons for a neutral atom

- Mass Number
    - Most of the mass of an atom is in the nucleus (protons & neutrons)
    - Mass Number is the total number of protons & neutrons in an atom
        - Proton & neutron have been assigned a mass number of 1
        - He has 2 protons & 2 neutrons, mass number is 4
        - C has 6 protons & 6 neutrons, mass number is 12
    - The difference between the mass number and the atomic number is the number of neutrons (# 0f Neutrons = mass number – atomic number)
        - H mass number of 1, atomic number of 1, neutrons = 1-1 = 0
        - O mass number of 16, atomic number of 8, neutrons = 16-8=8
    - Shorthand for showing atomic number and mass number
        - $^{mass\_number}_{atomic\_number}Symbol$
        - $^{16}_{8}O \quad ^{56}_{26}Fe \quad ^{238}_{92}U$

- Isotopes
    - Neutral atoms of a single element will always have the same number of protons and electrons – however the number of neutrons can vary - **isotopes**
    - Example – Neon-20, Neon-21, Neon-22

      Neon –20 Neon-21 Neon-22
      10 protons 10 protons 10 protons
      10 neutrons 11 neutrons 12 neutrons
      10 electrons 10 electrons 10 electrons
    - Chemical behavior is determined by electrons & protons

    - Isotopes contradict Dalton's theory, since all atoms of an element are not identical
- Atomic Mass
    - Most of the mass of an atom comes from the nucleus – neutrons & protons
    - Scientists have been able to determine the mass of an atom since the 1920's
        - Fluorine – 3.55×10^{-23}g
        - Arsenic – 1.244×10^{-22} g
    - Such numbers are too small to work with
    - Carbon-12 was chosen as the standard and given an atomic mass of 12 (6 neutrons & 6 protons make up the mass – electrons are neglible)
        - Carbon-12 has 12 amu
        - 1 amu = 1/12 Carbon-12 and since there are 6 neutrons and 6 protons in a Carbon-12 atom, 1 proton or 1 neutron has a value of about 1 amu
    - If a proton and neutron have a mass of 1 amu, why do elements not have whole number atomic mass?
        - Isotopes – elements naturally occur with different isotopes
            - Chlorine
                - Chlorine-35 accounts for 75% of all chlorine, Chlorine-37 is the other 25%
                - Taking the weighted average of the two chlorines we find the atomic mass is 35.5 amu
    - Atomic Mass of an element is a weighted average mass of the atoms in a naturally occurring sample of the element
    - Weighted average mass reflects the mass and relative abundance of the isotopes as they naturally occur
- Periodic Table

Objective: Describe the origin of the periodic table; Identify the position of groups, periods, and the transition metals in the periodic table

    - In the mid-1800's 70 elements had been discovered
    - Russian Dmitri Mendeleev was the first person to arrange the elements in columns so that elements with similar properties were side by side
        - For missing elements, blanks were left and predications were made of their physical and chemical properties – which turned out to be true
    - In 1913 a Brit, Henry Moseley determined the atomic number (# protons) of the elements and arranged them in a table by atomic number instead of atomic mass – still holds today
    - Horizontal rows are called **periods**
        - 7 periods
        - 2 elements (period 1) to 32 elements (period 6)

        - Properties of a period change as you move across
        - Pattern of properties repeat
            - **Periodic Law** – when elements are arranged by increasing atomic number, there is a periodic repetition of chemical and physical properties
            - Elements with similar chemical and physical properties end up in the same column
    - Vertical rows are called a **group**
        - Groups have similar chemical and physical properties
        - Groups are identified by a number and either an **A** or **B**
        - Group 1A – all but H react vigorously with water
        - Group 2A, skip across to Group 3A – 7A
            - Group A elements are **representative elements**
                - Wide range of physical and chemical properties
    - Group A can be divided into 3 broad classes
        - Metals
            - Highly electrically conductive
            - High luster (shine) when clean
            - Ductile – can be drawn into wire
            - Malleable – beat into thin sheets
            - Most all elements on the far left (except H)
            - Group 1A are **alkali metals**
            - Group 2A are **alkaline earth metals**
            - Most of the Group B elements are metals
                - **Transition metals**
                    - Cu, Ag, Au, Fe
                - **Inner transition metals**
                    - Two rows below main body of table
                    - Rare earth metals
            - 80% of all elements are metals
                - only one metal is not solid at room temperature – Mercury
        - Non-Metals
            - Are in the upper right of the table
            - Poor conductors of electricity
            - Generally are non-lustrous
            - Some are gaseous at room temperature, some are brittle solids
            - Two special groups of non-metals
                - **Halogens** – group 7A
                - **Noble Gases** – group 0
                    - Also know as inert gases since they rarely undergo chemical reactions
        - Metalloids

- Elements that border the staircase
- Have properties of both metals & non-metals
    - Silicon, Germanium