Atomic Structure Foundations

Dr. R.

Welcome to AP Chemistry

Welcome to AP Chemistry!

A course that brings merit, credit, and extraordinary recognition from the college you apply for - those who have AP Chemistry Credit in their transcript are much sought after by the top colleges. Those who got admitted in top 10 colleges in the Engineering and Medical fields inevitably are those who had done AP Chemistry.

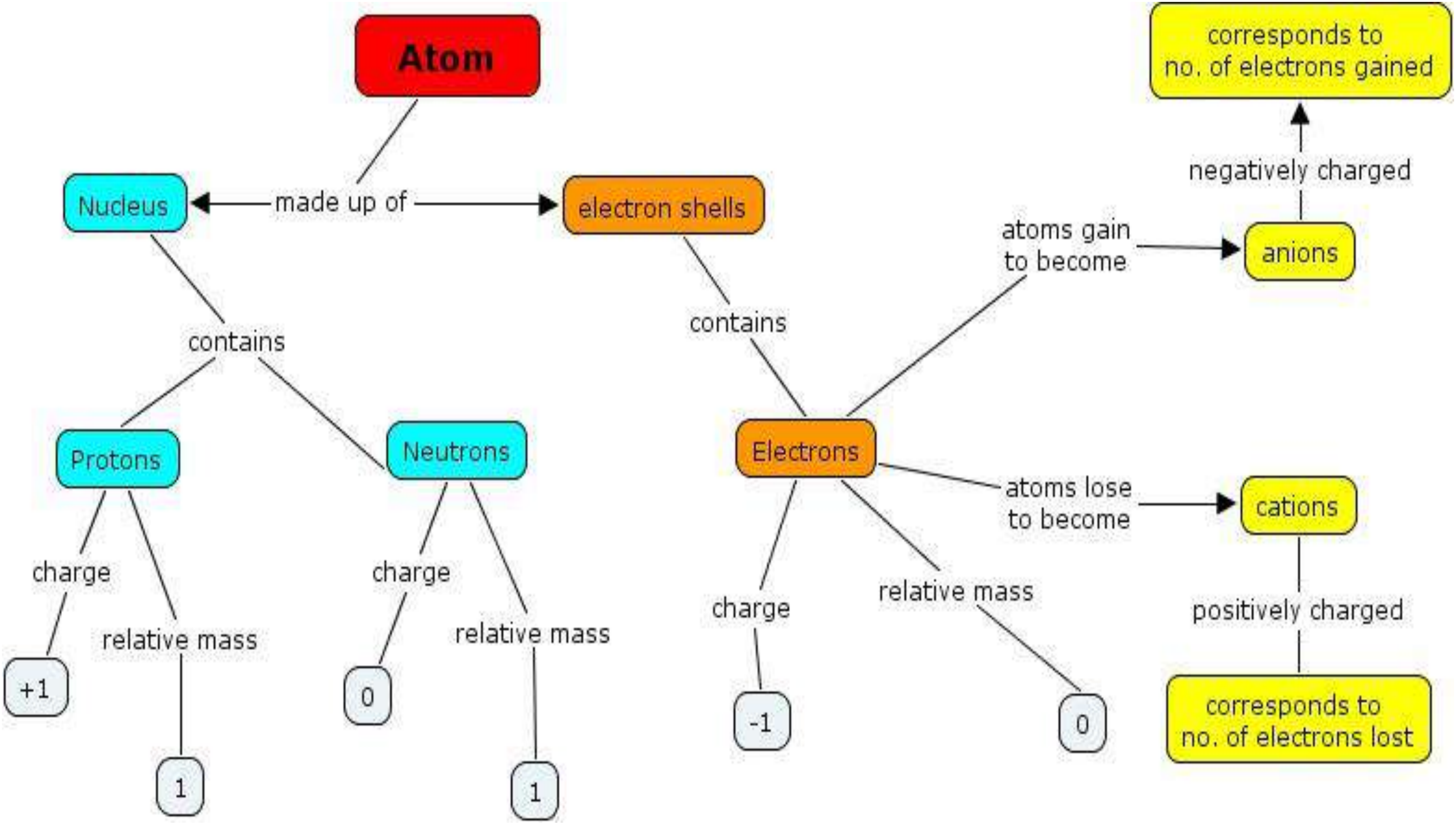
AP chemistry opens a new world for accomplishment not only in college but also in career, and in life.

Please Read: Why study chemistry and feel proud for having made a decision to do AP Chemistry.

Time is an investment; you need invest quality time on studies in general and AP Chemistry in particular in order to receive high quality credentials and merit.

I am available for assistance all the time.

I am just away for a few days and you can reach me over email. I will respond o you as quickly as I could.

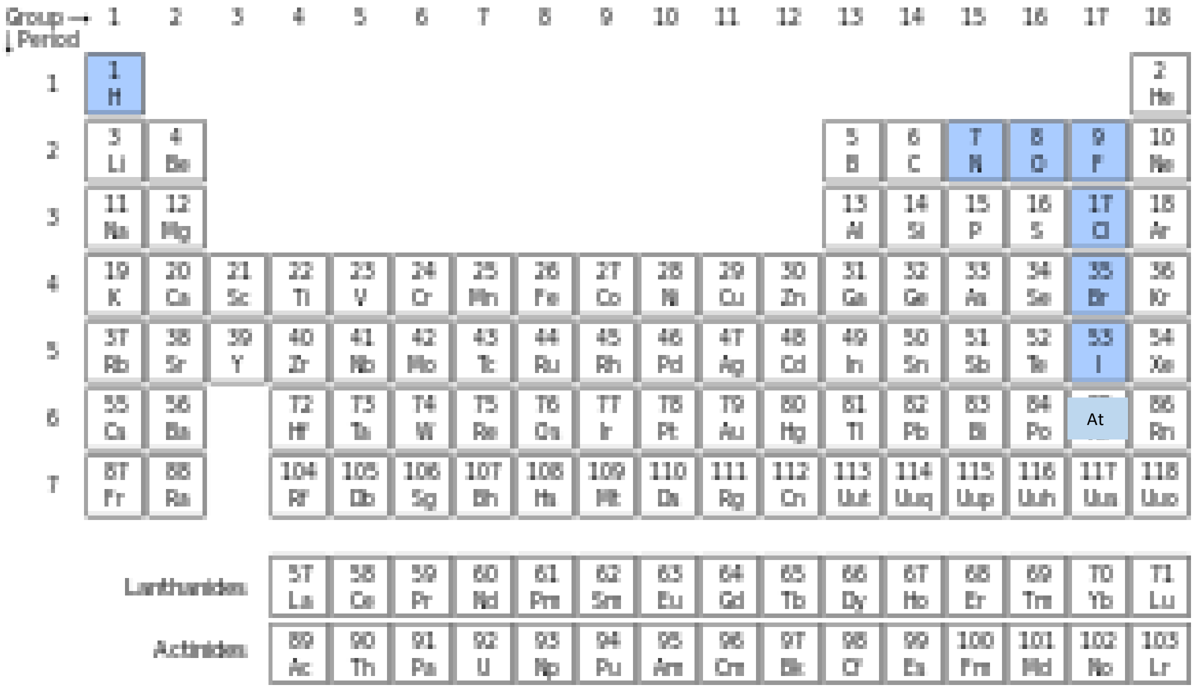

Atom
made up of
Nucleus
electron shells
contains
Protons
Neutrons
charge
+1
relative mass
1
charge
0
relative mass
1
contains
Electrons
charge
-1
relative mass
0
atoms gain to become
anions
negatively charged
corresponds to no. of electrons gained
atoms lose to become
cations
positively charged
corresponds to no. of electrons lost

ATOM: THE BUILDING UNIT OF MATTER

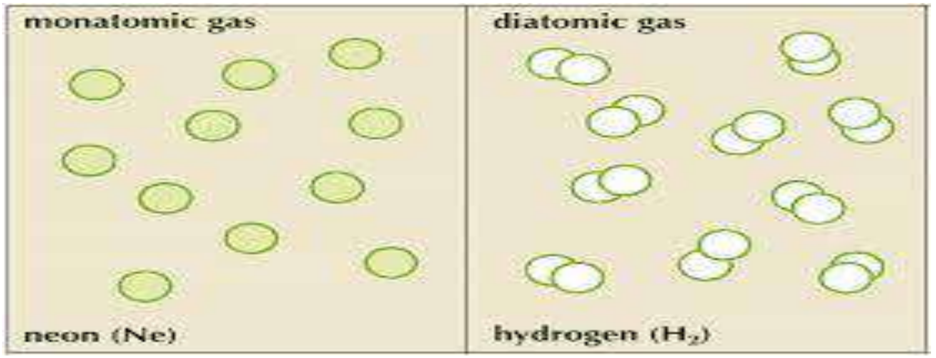
- Atoms are considered as tiny spherical bodies, that constitute matter.
- The diameter of an atom is: 0.1 to **0.5 nanometers** or 1 to 5 **Angstrom units,** Å; (nm = 1 × **10^{-9} m**; Å = 1 × **10^{-10} m; so 10** Å = 1 nm or 0.1 nm = 1 Å).
- The mass of an atom is expressed in atomic mass unit, a.m.u.
- 1 amu = 1/6.023 x 10^23 g.
- Or 6.023 x 10^23 amu = 1g
- 6.023 x 10^23 is the Avogadro Number.
- Avogadro Number represents the number of atoms in 1 mole of a monoatomic element.
- Therefore the mass of 1 mole of an element should be expressed in gram and not in amu, but the numeric will be the same. For example the mass of 1 atom of helium is 4.0026 amu. The mass of one mole of helium is 4.0026 g.
- For all practical purposes, Atomic Mass of elements are generally expressed as Molar Atomic Mass in grams.

Masses of Diatomic Elements

There are Eight Diatomic Elements



These Eight elements are Hydrogen, Nitrogen, Oxygen, Fluorine, Chlorine, Bromine, Iodine, and Astatine. They occur in nature as diatomic molecules when all other elements occur in the atomic state.



These Eight Elements have two masses: Atomic Mass and Molecular Mass. Since there are two atoms in a molecule,

Molecular Mass = Atomic Mass x 2

Masses of Diatomic Elements: Compare a Diatomic with a Monoatomic element

Example: Neon

- 1 atom of neon weighs 20.179 amu
- 1 mole of hydrogen atoms weigh
  20.179 g
- Neon does not form molecule – it is a monoatomic element
- Therefore, we do not have molecular mass for Neon.
- 1 mole of Neon atoms weighs: 20.179 g

Example: Hydrogen

- 1 atom of hydrogen weighs 1.008 amu
- 1 mole of hydrogen atoms weigh
  1.008 g
- Hydrogen is a diatomic molecule.
- 1 Molecule of hydrogen contains two atoms of hydrogen
- Therefore, 1 molecule of hydrogen weighs
  2 x 1.008 = 2.016 amu
- 1 mole of hydrogen molecule weighs 2.016 g

Masses of Allotropic Elements

- **Several Elements exist as allotropes.**
- **Allotropes are physical modifications of the same element, because of different molecules they form.**
- **Carbon, Phosphorus, Oxygen, Sulfur, and Selenium are elements very well known for their allotropic modifications.**
- **In your curriculum, you will be tested on whether you know how to apply the principles of atomic mass and molecular mass to the allotropes. You are expected to be very thorough with: Ozone, Tetra phosphorus, Octa sulfur, Octa selenium, and 60 carbon fullerene.**

The symbols of these famous allotropes are as follows:

O_3 Ozone (triatomic)

P_4 White Phosphorus (tetraatomic)

S_8 Cyclo Octa Sulfur (octaatomic)

Se_8 Octaselenium (octaatomic)

C_{60} Fullerene

So you have to calculate the molar mass by taking into account the number of atoms in each of these allotropes

Atomic Structure Concepts

For most part, atomic structure is generally discussed using Bohr's Model as the main reference. However, the contribution of several other individual scientists is liberally embedded into Bohr's Model in all our discussions. Be very familiar with:

Dalton's atomic theory

JJ Thomson's Plum Pudding or Water Melon Model

Rutherford's famous Gold Foil Experiment

Hund's Rule of Maximum Multiplicity

Pauli's Exclusion Principle

Aufbau diagram

Heisenberg's Uncertainty Principle

Huygen's Wave Nature of Electron

de Broglie's Wave-Particle Dualism of the electron - Matter Waves and Stationary Orbits

Schrodinger's Wave Equation

Sommerfeld's Elliptical Orbits

Quantum Mechanical Model – Electron Cloud Model

Einstein's Photoelectric Effect

Atomic Spectra

Photoelectric Effect

Mass Spectrometry

Ring Diagram

Box Diagram

Valence Shell Dot Diagram

Long Hand and Shorthand Electronic Configuration Formulas

Octet Rule

Exceptions to Octet Rule

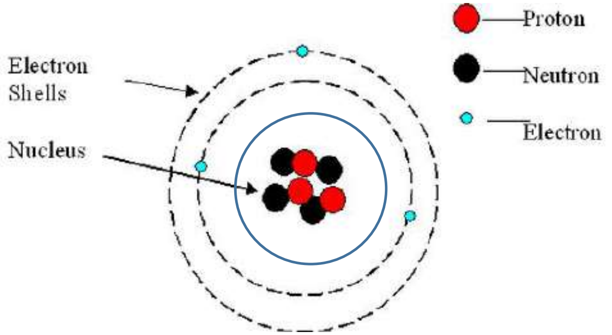
Exceptions to aufbau

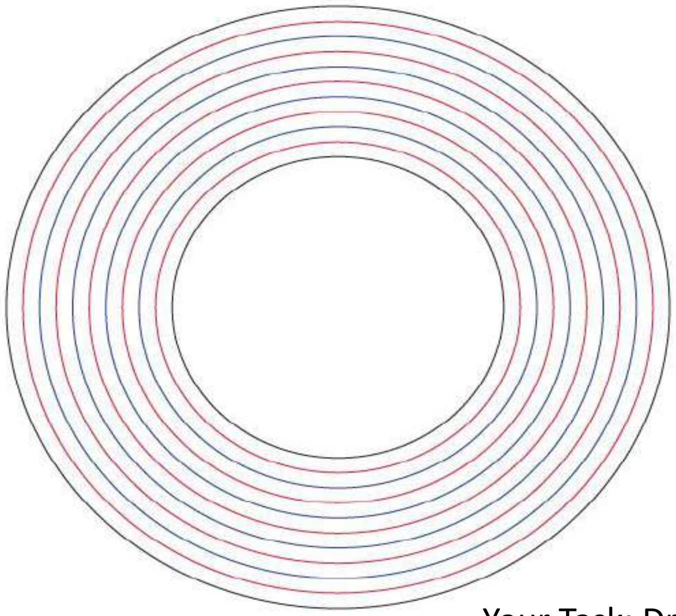
The Fundamentals of Atomic Structure

1. Atoms are the fundamental building units of matter.
2. Atom has two major parts: Nucleus and Shells. The nucleus is the small sized, dense body found at the center of the atom; shells are the circular orbits found around the nucleus.
3. There are three types of particles (generally called subatomic particles) inside an atom. They are: Electrons, Protons, and Neutrons. Electrons are negatively charged. Protons are Positively charged; Neutrons are Neutral. The mass of electron is negligible. The mass of a proton is the same as the mass of a neutron = 1 a.m.u. (atomic mass unit). 1 amu = 1/6.023 x 10^23 g. Or 6.023 x 10^23 amu = 1g; 6.023 x 10^23 is the Avogadro Number.
4. Avogadro Number represents the number of atoms in 1 mole of a monoatomic element.
5. Atoms are electrically neutral even though they have charged particles inside of them. This means that the positive and the negative charges inside an atom are equal and they cancel out each other. Therefore, the number of Protons should be equal to the number of electrons.
6. Nucleus contains both the Protons and Neutrons. Therefore, the positive charge of the atom is entirely concentrated only in the Nucleus. Similarly the mass of the atom is concentrated only in the nucleus.
7. The negatively charged particles namely electrons revolve around the nucleus in shells. This is similar to the planetary motion Electrons also spin on their own axis like the planets.
8. Every shell can have only a definite number of electrons. (See Right)

Q Shell – maximum of 8 electrons only
P Shell – maximum of 18 electrons
O Shell – maximum of 32 electrons
N Shell - maximum of 32 electrons
M Shell –maximum of 18 electrons
L Shell -maximum of 8 electrons
K Shell –maximum of 2electrons

Your task: Position Protons and Neutrons





Your Task: Draw Nucleus, Label Shells, Fill electrons, label valence shell, penultimate shell, antepenultimate shell, kernel, and valence sheath

The Fundamentals of Atomic Structure

9. The shells are arranged concentrically with nucleus at the center.

10. Each shell has a fixed diameter and energy. The shell is also called Energy Level.

11. The diameter as well as the energy of the shell increases as move from inside to the outside. The diameter of an atom is: 0.1 to **0.5 nanometers** or 1 to 5 **Angstrom units,** Å; (nm = 1 × **10^{-9} m**; Å = 1 × **10^{-10} m so 10** Å = 1 nm).

12. There are infinite number (countless) of shells in an atom.

13. We count shells from interior to the exterior. Shells are named K, L, M, N, O, P, Q, respectively from shell 1.

14. The last shell to have electrons is called the Valence Shell or the Outermost Shell

15. The shell immediately inner to the Valence Shell is called the Penultimate Shell

16. The shell immediately inner to the Penultimate shell is called the Antepenultimate shell.

17. The electrons present in the valence shell are called Valence Electrons.

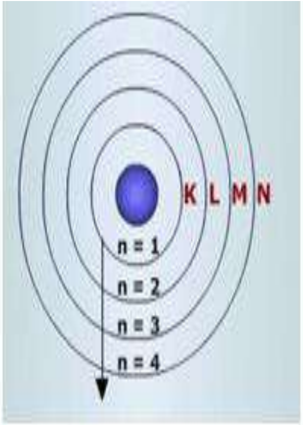
18. All electrons other than the valence electrons are called inner electrons are core electrons.

19. Valence shell together with all the empty shells outside of the valence shell is called the Valence Sheath

20. Nucleus together with all the shells from K up to the Penultimate shell is called the Kernel.

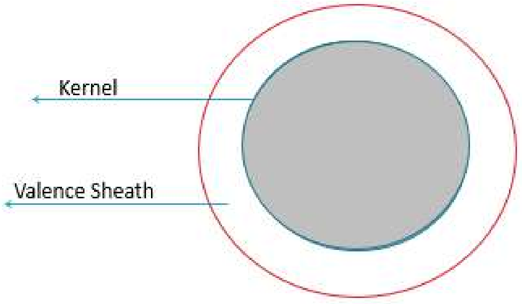
Energy →

Diameter →

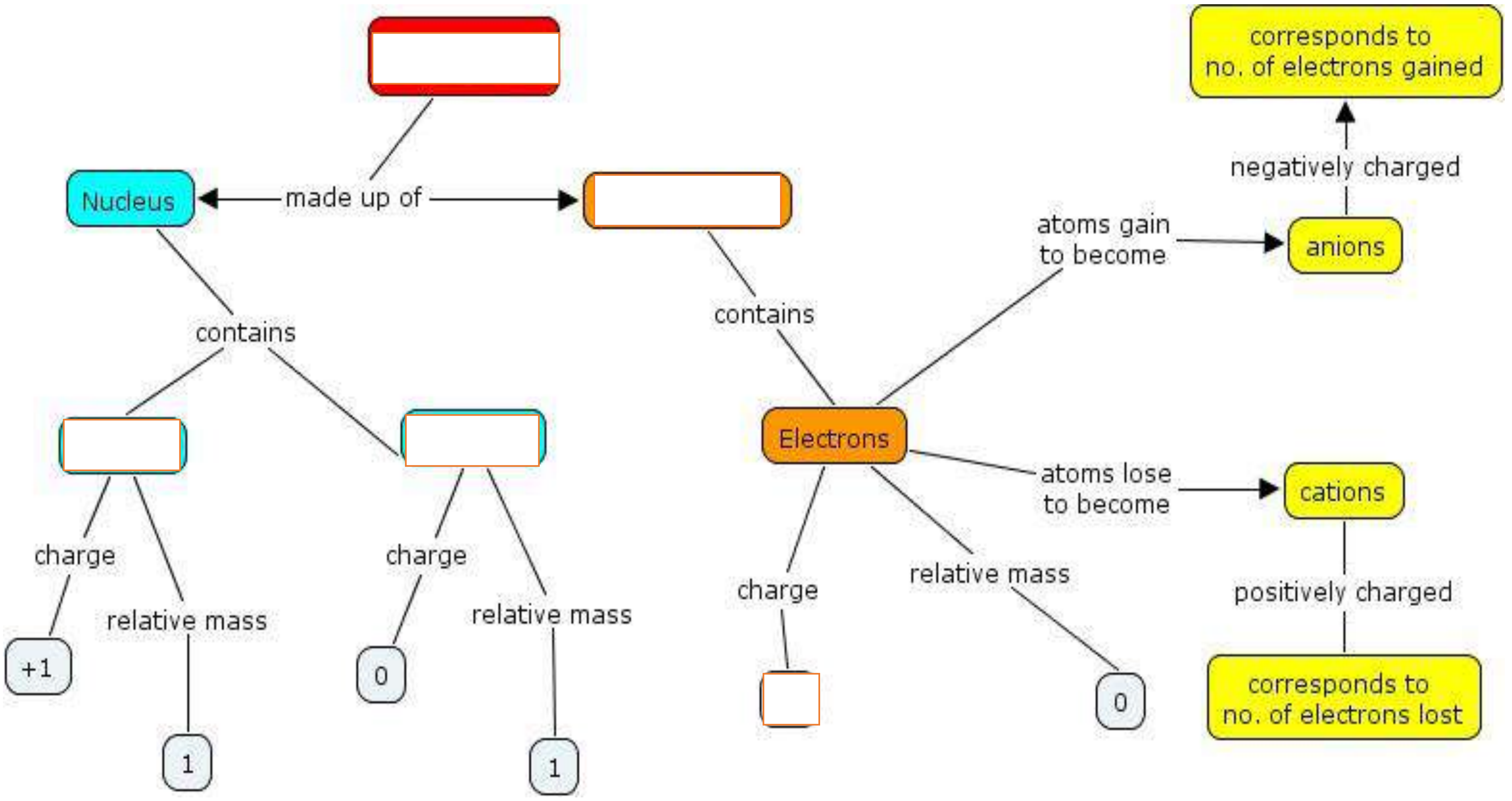


There are infinite number od=f shells in an atom. Shells are named from inside to outside. Shells are named as K, L, M, N, O, P, Q shells

Sodium atom with 11 electrons

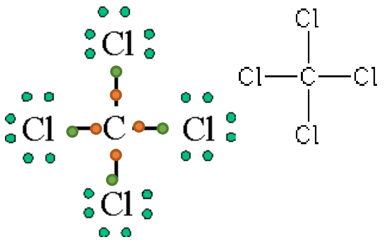


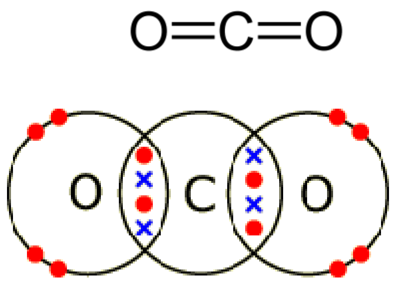
Daily Formative Assessment – 1: Complete the Concept Map



Four Pairs of Electrons and Four Bonds: The True Drive of Chemical Reactions

We are aware that the valence shell is the last shell to have electrons and it can hold a maximum of eight electrons. So the fully filled state of **A VALENCE SHELL MEANS EIGHT ELECTRONS OR FOUR PAIRS OF ELECTRONS**. Chemical reactions involve electrons. Atoms gain or lose electrons in order to attain the noble gas configuration – that is the octet configuration in the valence shell. Therefore, through chemical reactions atoms attain the fully filled state of the valence shell, which represents eight electrons or four bonds (remember: a bond requires two electrons). See below: Carbon tetra chloride (left) and carbon dioxide (right)





Four single bonds or two double bonds make four bonds. In carbon tetrachloride both carbon and chlorine attain the octet configuration in the valence shell. Similarly, in carbon dioxide bot carbon and oxygen attain the octet configuration of the valence shell.

Valence Shell is like the Front Office of the Atom

Thus it is clear that in chemical reactions, only the valence shell and the valence electrons are directly involved – loss or gain of electrons take place at the valence shell only. It is the valence electrons, which are lost or gained, to attain the nearest noble gas configuration. The inner electrons are never directly involved in chemical reactions. Similarly, the nucleus never participates in chemical reactions.

This gives us a picture of valence shell functioning like the front office of the atom. The valence shell takes care of the atomic correspondences and communications and relationship between different atoms and actual bonds are formed only at the valence shell.

Not All Can Form the Octet in Chemical Reactions: Three Inevitable Exceptions

However, attaining octet configuration is difficult for some atoms and they make less than four bonds. On the other hand, some atoms are able to make more than four bonds.

These two conditions of (i) making less than or (ii) making more than four bonds constitute **EXCEPTIONS TO THE OCTET RULE.**

Case 1: Less than four bonds is due Reduced Octet or Electron Deficiency (Elements up to Boron are electron deficient)

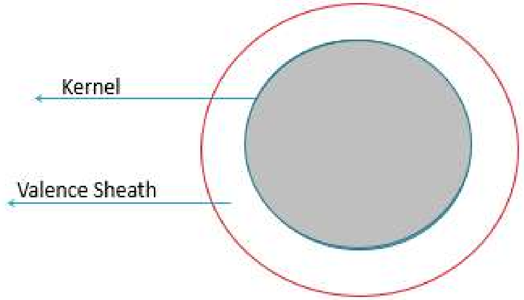
Case 2: More than four bonds is due to Expanded Octet or Electron Richness (Elements such as Phosphorus and Sulfur are electron rich).

Case 3: SEEN IN FREE RADICALS, WHICH CONTAIN ODD NUMBER OF ELECTRONS RESULTING FROM HOMOLYTIC BOND CLEAVAGE. Actually, this is a case of Electron Deficiency but in Electron Deficient atoms there are even number of electrons and bonds whereas free radicals contain odd electrons and odd number of bonds, with one solitary electron.

Valence Shell and Valence

Valence shell (the last shell to have electrons) together with the outer empty shells makes what is called a Valence Sheath

The nucleus together with all the inner shells makes the k



You can visualize t

f t

s

c is the kernel or core

of the atom.

- There are indefinite number (countless) of shells in an atom.
- We count shells from interior to the exterior. Shells are labeled K, L, M, N, O, P, Q. There are only 7 shells that have been found with electrons. We have not yet found elements that have electron in Shell 8 or above.
- The last shell to have electrons is called the Valence Shell or the Outermost Shell
- The shell immediately inner to the Valence Shell is called the Penultimate Shell
- The shell immediately inner to the Penultimate shell is called the Antepenultimate shell.
- The electrons present in the valence shell are called Valence Electrons.
- All other electrons are called inner electrons are Core electrons or Inner electrons.
- Effective Nuclear Charge is a measure of the influence of the nucleus on the valence shell, which is determined by the inner or core electrons. Effective Nuclear Charge is = Number of protons minus Number of Inner Electrons. Effective Nuclear Charge has the symbol: Z_{eff}

Daily Formative Assessment 2: Fill in the Blanks

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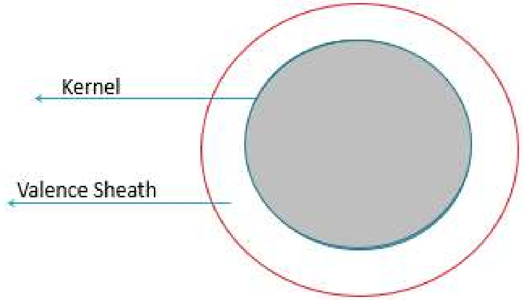
The nucleus together with all the ---- shells makes the -



You can visualize t

fr t

s -

t ruit is like the ------- or core of the atom.

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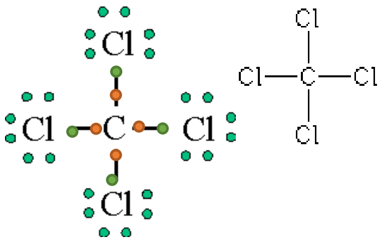

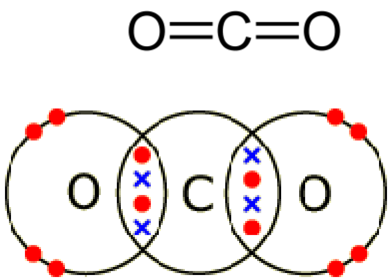

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VALENCE OR VALENCY: COMBINING CAPACITY OF ATOMS

Valence shell is where chemical reactions take place.

Inner shells and inner electrons are not involved in chemical reactions

Elements gain or lose electrons so as to attain the octet configuration in the valence shell.

How many electrons are lost or gained represents the combining capacity of atoms, called Valence or Valency.

So valence or valency is a whole number and can never be in decimal, because full electrons are lost or gained.

Valency can be easily determined from the position of an element on the periodic table relevant to the nearest Noble Gase.

VALENCE SHELL: OCTET RULE and EXCEPTIONS TO OCTET RULE

- Shells contain electrons. The maximum capacity of a shell for electrons is given by $2n^2$ where n represents which shell – first, second, third, fourth, etc.
- Thus, the maximum number of electrons in shells are as follows”
- Shell 1 or K shell: 2 x 1x 1 = 2
- Shell 2 or L shell: 2 x 2x 2 = 8
- Shell 3 or M shell: 2 x 3x 3 = 18, --- etc.
- **However, the valence shell of an atom cannot hold more than 8 electrons.**
- **This is called the famous Octet Rule.**

- The Octet Rule is a very important rule and guides the force behind most of the chemical reactions.
- Octet configuration of the valence shell represents Stability. In order to understand the stability aspect, let us have a look at the noble gases. All the noble gases have the octet configuration. They are therefore quite stable, inert, and unreactive.
- All other elements undergo chemical reactions to attain the noble gas configuration of the valence octet.
- For example sodium attains neon configuration by losing one electron and fluorine gains one electron to attain neon configuration. However, there are exceptions to the Octet Rule. **Read the content in the Handout on Octet Rule**.

Empty Shell Structures for Practice