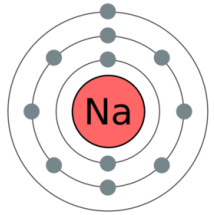
General Chemistry

Lecture 3

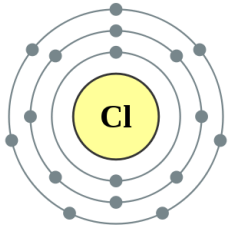
Electrons

- Protons and neutrons are found in the nucleus
- Electrons surround the nucleus in energy levels or shell at certain distances around the nucleus
- The number of electrons in an atom equals the number of protons
- The arrangement of the electron around the nucleus determine the chemical properties of and atom
  - The valence shell, or outer shell is of particular importance

11: Sodium 2,8,1



17: Chlorine 2,8,7

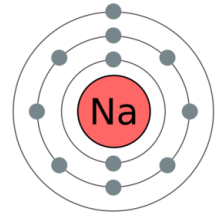


Electron Energy Shells

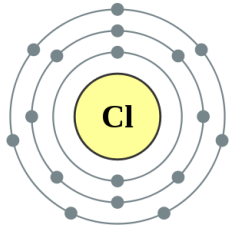
- 1st shell is closest to the nucleus
  - This shell hold a maximum of 2 e^-
  - H and He are the only elements with only one shell
- 2nd shell holds a maximum of 8 e^-
- 3rd shell holds a maximum of 18 e^-
- 4th shell holds a maximum of 32 e^-
- Up to 7 energy shells, the number of maximum electrons in the shell is $2(n^2)$ where n is the shell level

- Rule of Octet
  - Despite the fact that shells 3 and above can hold more than 8 electrons, there is an inherent stability to having 8 electrons in the valence shell
  - The octet rule says that atoms tend to gain, lose or share electrons so as to have eight electrons in their outer electron shell.
  - This is a very useful rule and will be adequate for us, but should also know that there are many bonding situations where it does not apply.

11: Sodium 2,8,1

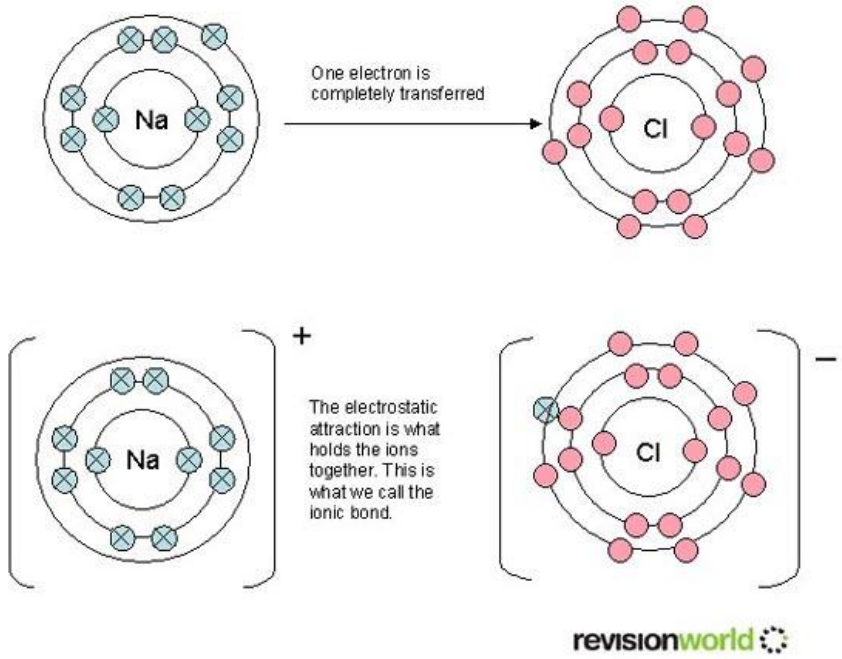


17: Chlorine 2,8,7



Ions

- To satisfy the rule of octet, atoms without 8 electrons in their valence shell will often gain or lose electrons
- Atoms that gain or lose are called ions
- If an atom gains an electron, it has a negative charge and it is referred to as a anion
- If an atom loses electrons, it has a positive charge and is called a cation

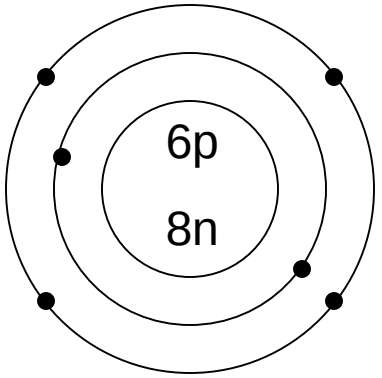


Questions

- Where are electrons found
  - In energy shells around the nucleus
- What is their atomic mass?
  - Negligible
- What is the charge?
  - Negative
- How many electrons fill the 1st energy shell
  - 2
- How many fill the 2nd – 7th shells?
  - 2(n^2): 8 for the 2nd, 18 for the 3rd, 32 for the 4^{th,} etc.
- What is the valence shell
  - The outer energy shell
- How many electrons will make the valence shell stable?
  - 8
- If there is more or less electrons in the valence shell, what might happen (if the opportunity arises)?
  - The atom will gain, lose or share electrons with another atom
- What is an ion?
  - An atom that gained or lost electron/s, it now has a positive or negative charge
- If an atom gained an electron, what would be its charge and what would it be called?
  - It would have a negative charge and be called an anion
- What if it lost an electron?
  - It would have a positive charge and be called a cation

For the Test

- Be able to draw a simple atom structure if given the isotope symbol
- For example if given $_{6}C^{14}$



Review Elements

- Each element is identified by one or two letter symbols (if two, the second letter is lowercase)
- Each element has an atomic number which indicates the number of protons contained in the nucleus of atoms of this element. This number is constant for this element and distinguishes it from other elements
- Elements are organized on the period table in vertical columns called groups and horizontal rows called periods.
  - These groups and columns indicate certain properties of the elements contained in them
  - *New info: This is just an example, you are not required to know this for the test*
    - Group IA is known as alkali metals (contains Li-Fr). These react rapidly with water to form products that are highly alkaline. Since they are highly reactive, they are never found in nature in the pure state, but only in combination with other elements
    - Group 8A contains inert gases. These have 8 electrons in their valence shell and therefore are inert, not reacting with other elements
    - Metals are on the left hand side of the period table, non-metals are on the right hand side and semi metals are in between
- Elements have a mass number which is the number of protons in the nucleus of atoms of this element plus the average number of neutrons in the nucleus.
- The number of electrons equals the number of protons in an atom
- Electrons do not contribute to significantly to the mass and do not effect the atomic mass number. However, they do contribute to the charge. They also contribute to the chemical characteristics of this element

Review Isotopes and Ions

- Protons have a positive charge, electrons have a negative charge and neutrons have a neutral charge
- Only protons and neutrons contribute to the atomic mass
- Isotopes
  - Atoms of the same element (same number of protons and electrons), but with a different number of neutrons are referred to as isotopes (example, carbon-12 and carbon-13)
- Ions
  - Atoms without 2 electrons in its first electron shell if it only has one, or 8 electrons in its valence shell will react with other atoms by either gaining, losing or sharing and electron
  - If it gains an electron, it is a negative ion called a anion
  - If it loses an electron, it is a positive electron called a cation

New Information

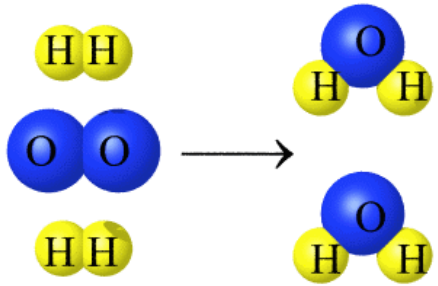
Bonds

Definitions: Compounds

- Compound
  - A substance that is formed when atoms of two or more different elements combine and create new materials
  - A compound has a constant composition with constituent units which are identical
    - Ex) Na and Cl react to form NaCl (table salt)
    - Ex) two atoms of H combine with one atom of O to form H_20
    - Such transformations are called chemical reactions

Chemical Reactions

- Chemical reactions are written in a standard format called a chemical equation which lists the starting substances (reactants) on the left and the final substances (products) on the right. The number and kinds of atoms are the same on both sides of the arrow
  - Ex) $O_2 + 2\ H_2 \rightarrow 2H_2O$



- A compound is written by giving its chemical formula. This formula lists the symbols of the elements that make it up and indicates the number of atoms of each element with a subscript
- If no subscript is given, it is understood to be 1
  - $C_{12}H_{22}O_{11}$, H_20, NaCl

Introduction to Bonds
Definition: Molecules

- When two atoms approach each other during a chemical reaction, the electrons form connections called chemical bonds
- Chemical bonds are classified as either covalent or ionic
  - Covalent bonds involve a sharing of electrons in the valence shell of two or more atoms
    - Covalent bonds generally occur between nonmetals (elements on the right of the periodic table)
    - **Molecules** are compounds that result from two or more atoms that form covalent bonds
    - *Note: Covalent bonds can form between atoms of the same element such as O_2. This would not be a compound, as compounds form between different elements.*
  - Ionic bonds involve the transfer of electrons and formation of ions. The resulting oppositely charged ions attract each other, forming ionic bonds
    - Ionic bonds generally occur between metals and nonmetals (metals are elements on the left side of the periodic table and nonmetals are on the right)
    - Metallic elements (such as Na, Mg) tend to give up electrons while nonmetals (such as Cl) tend to accept electrons

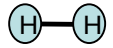
Covalent Bonds

Covalent Bonds

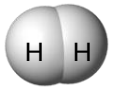
- Covalent bonds are the most common kind of chemical bond
- They occur when two atoms share one or more electrons
- Covalent bonds can occur between two atoms of the same element or two different atoms
- Covalent bonds still follow the rule of octet

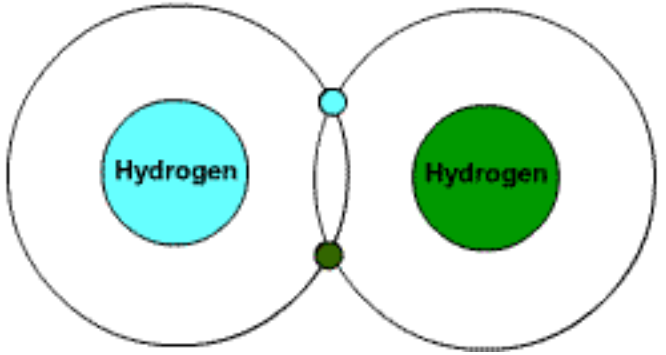
Single Covalent Bond

- An atom of hydrogen can form a single covalent bonds with another atom of hydrogen
- Hydrogen has one proton and one electron
- Two electrons are needed to fill the first electron shell and make it stable
- If two atoms of hydrogen come into contact, they can share the valence electron, thus filling the valence shell
- The electrons will orbit around both nuclei
- This can be represented several ways
  - As a name: Dihydrogen
  - As a chemical formula: H_2
  - As a structural formula: H—H
  - As a ball-and-stick model:

  - As a space filling model



Double Covalent Bonds

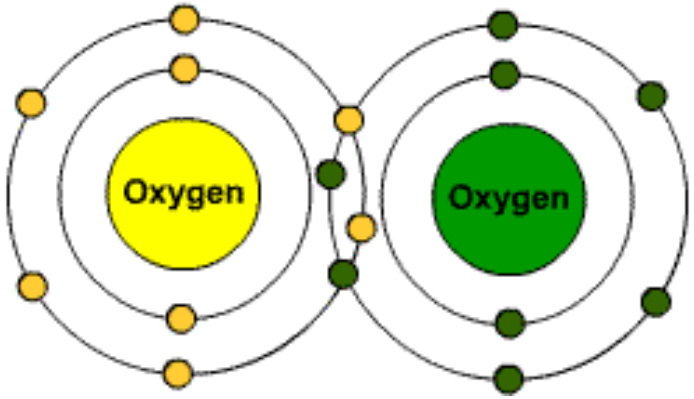
- An atom of oxygen can form a double covalent bond with another atom of oxygen
- Oxygen has 8 protons and 8 electron. 2 electrons fill up its first shell and it has 6 in its valence shell. It would need two more to fill up its valence shell and satisfy the rule of octet
- If two atoms of oxygen come into contact, they each share two electrons
- This can be represented several ways
  - As a name: Dioxygen
  - As a chemical formula: O_2
  - As a structural formula: O═O
  - As a ball-and-stick model:

  - As a space filling model

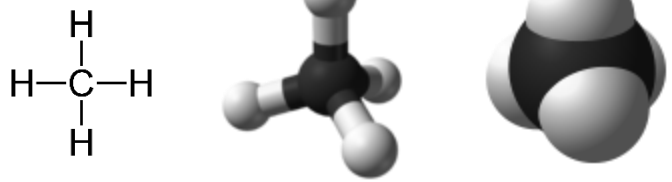
    

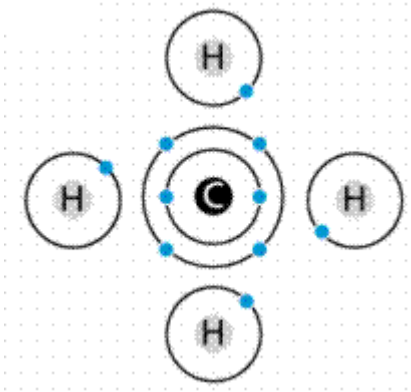
    Oxygen molecule

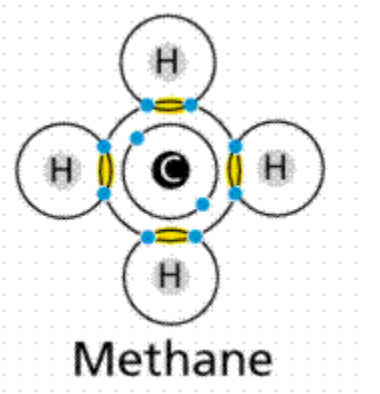


More Examples of Covalent Bonds

- Carbon has 6 protons and 6 electrons. 2 electrons fill up its first shell and 4 are in the valence shell
- Carbon would need 4 more electrons to satisfy the rule of octet
- Hydrogen has 1 electron and needs 1 more to fill its valence shell
- Carbon can form a single covalent bone with 4 hydrogen atoms
- This can be represented several ways
  - As a name: Methane
  - As a chemical formula: CH_4
  - As a structural formula, ball-and stick and space filling model:

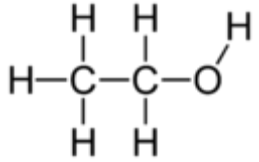






Rules

- Memory aid for number of covalent bonds for elements that form organic molecules
  - H – 1
  - O – 2
  - N – 3
  - C – 4
- How do you write the formula
  - CHONSP *(CHON are most frequently seen in organic molecules)*
  - List in this order
  - Put in number of atoms in the molecule as a subscript following the atom
  - A number preceding the molecule indicates how many of those molecules there are
  - Examples
    - $C_6H_{12}O_6$
    - $C_2H_5O_2N$
- Names of molecules with covalent bonds is memorization
  - Examples
    - C_2H_6O is ethyl alcohol



Polar and Nonpolar Covalent Bonds

- Nonpolar Covalent Bonds
  - Electrons are equally shared between atoms (i.e., they spends equal amounts of time orbiting both)
  - Nonpolar covalent bonds are formed between atoms of the same element
    - O2, H2
  - Between C and H
    - Called hydrocarbon chain

Polar and Nonpolar Covalent Bonds

- Polar Covalent Bonds
  - Electrons are unequally shared between atoms in the bond
  - One element is an ‘electron hog’ and has a stronger attraction for electrons
  - Polar covalent bonds are formed when oxygen bonds with anything else
  - Oxygen is an electron hog – it has a strong electronegativity
  - Because electrons spend more time around O, it has a partial negative charge and whatever it is bonded to has a partial positive charge
  - Partial charges are designated as δ^+ or δ^- (δ is the Greek letter delta)
  - Polar covalent bonds produce a partial charge
  - Between water molecules the partial negative charge of O of one water molecule is attracted to the partial positive charge of a H from another water molecule
  - This attraction is referred to as hydrogen bonding

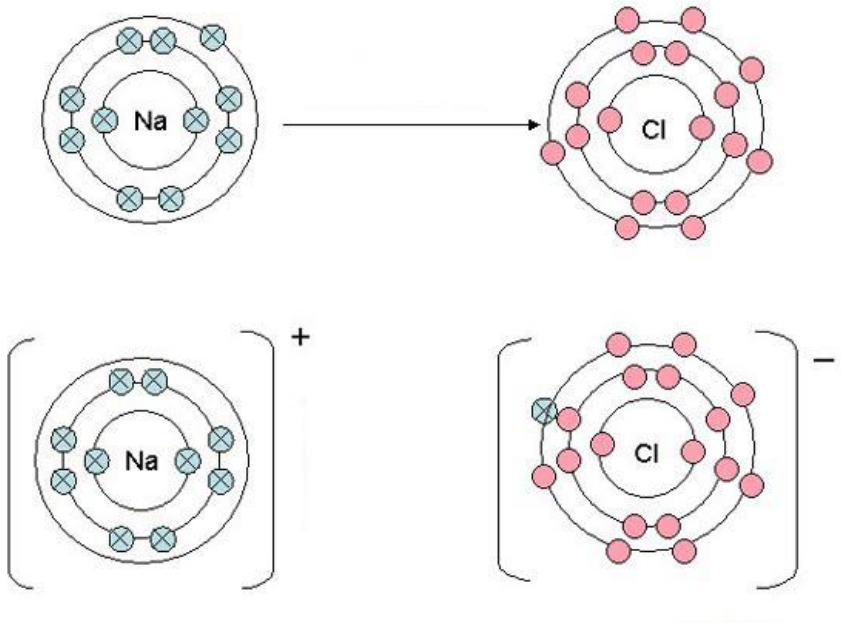
Review Questions for Covalent Bonds

- Do covalent bonds involve atoms that gain, lose or share electrons?
  - They involve bonds with atoms that share electrons
- Do covalent bonds form between two atoms of the same element or atoms of different elements?
  - Both
- How many covalent bonds can form between H, O, N, and C
  - H – 1
  - O – 2
  - N – 3
  - C – 4
- Which type of covalent bonds form molecules with partial charges?
  - Polar covalent bonds

Ionic Bonds

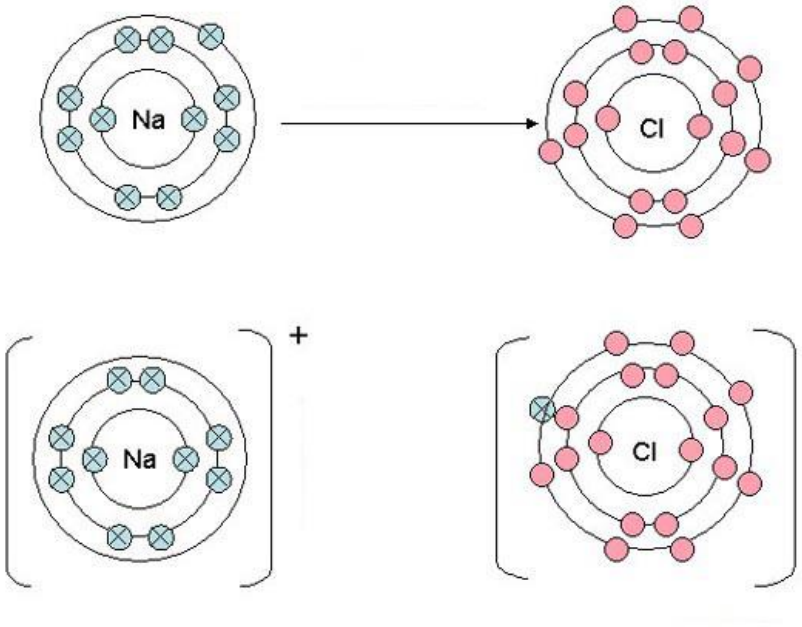
Electron Energy Shells

- Recall
  - Energy shell one can hold a maximum of 2 electrons
  - Energy shell 2 can hold a maximum of 8 electrons and it is most stable when it has all eight electrons
  - Despite the fact that shells 3 and above can hold more than 8 electrons, there is an inherent stability to having 8 electrons in the valence shell
  - The octet rule says that atoms tend to gain, lose or share electrons so as to have eight electrons in their outer electron shell.
- In the example to the left
  - Sodium has one electron in its valence shell and chlorine has seven electrons
  - If these two come into contact, sodium gives its electron to chlorine
  - The number of electrons gained or lost is its valency, thus Na and Cl have a valency of 1
  - After transfer. they both now have eight electrons in their valence shell



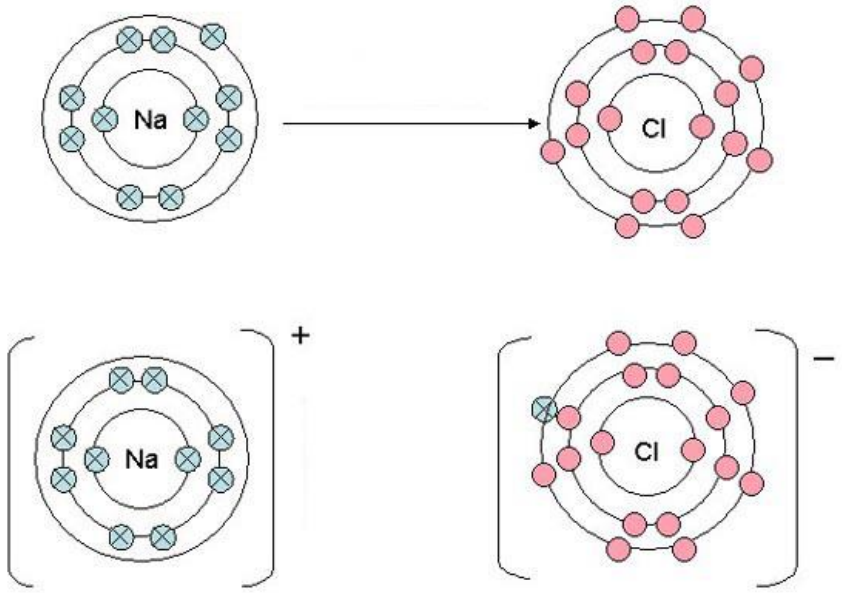
Ions and Ionic Bonds

- As stated, sodium gave its electron to chlorine
- Both are now ions
  - Since sodium gave its electron to chlorine, it now has a positive charge and is called a cation
  - Since chlorine gained an electron, it now has a negative charge and is a anion
    - Cations and anions can be listed with their element symbol and a superscript + or – denoting charge
      - Na^+
      - Cl^-
    - If an atom gave or lost more than one electron, this number would be written before the charge sign
      - Ca^{2+}
- Since positive and negative attract, these two ions have an attractive force and will bond with each other, forming a molecule
- By conventional nomenclature, the anion is listed after the cation and the -ine is changed to –ide
  - The molecule is now called sodium chloride and would be listed as NaCl or Na^+Cl^-



Ionic Bonds in Aqueous Solutions

- In aqueous solutions molecule such as NaCl are surrounded by water molecules
- Na+ and Cl- disassociate and can move freely and independently of each other
- These ions are listed as follows
  - $Na^+(aq)$
  - $Cl^-(aq)$
- $Na^+(aq)$ and $Cl^-(aq)$ are present in cells along with many other ions such as $K^+(aq)$, $Mg^{2+}(aq)$, $Ca^{2+}(aq)$, $H^+(aq)$
- Trace quantities of other ions are founds such as $Fe^{2+}(aq)$, $Fe^{3+}(aq)$, $Cu^{2+}(aq)$, $Zn^{2+}(aq)$, $Co^{2+}(aq)$
- Ions can contain more than one element in which case they are called compound ions
  - Examples
    - Hydroxide ion - OH^-
    - Ammonium ion - NH_4^+



Review Questions for Ionic Bonds

- Do ionic bonds involve atoms that gain, lose or share electrons?
  - They involve bonds with atoms that gain and lose electrons
- What holds ions together in ionic bonds?
  - Opposite charges
- What is a negatively charge ion called?
  - A anion
- What is a positively charge ion called?
  - A cation