McGraw-Hill Ryerson

BC Science Connections 9

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Unit 2: The electron arrangement of atoms impacts their chemical nature

Topic 2.4: How do elements combine to form compounds?

- Compounds account for the huge variety of matter on Earth.
- Ionic compounds are made of ions.
- Covalent compounds are made of molecules.
- Covalent bonding also occurs in elements and network solids.

Concept 1: Compounds account for the huge variety of matter on Earth.

All the compounds that exist on Earth are built from elements

- 118 elements are on the periodic table; only 80 commonly form compounds
- 10 million known compounds; billions of possible

Figure 2.22: Hydrogen and carbon alone can be combined in millions of ways to make compounds with very different properties.

Discussion Questions

1. Distinguish between elements and compounds.

2. Compare the number of elements with the number of compounds on Earth.

Concept 2: Ionic compounds are made of ions.

Ionic compound: a compound made of oppositely charged ions

- Ions are held together with **ionic bonds** (a strong attraction between oppositely charged ions)
- Ionic bonds are very strong

Formation of Ionic Compounds

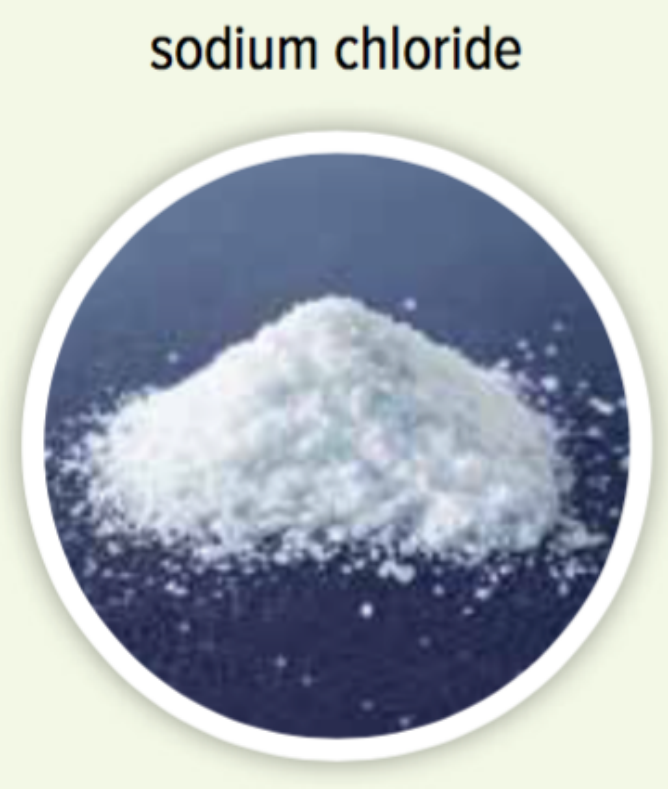
Binary ionic compounds:

- Contain two elements (metal and a non-metal)
- Form when atoms of the metal element each lose one or more electrons to atoms of the non-metal element
- Results in the formation of ions that have full valence shells
- Stability of a full valence shell dries the formation of compounds

Formation of Ionic Compounds: Sodium Chloride

Example: Sodium chloride (salt)

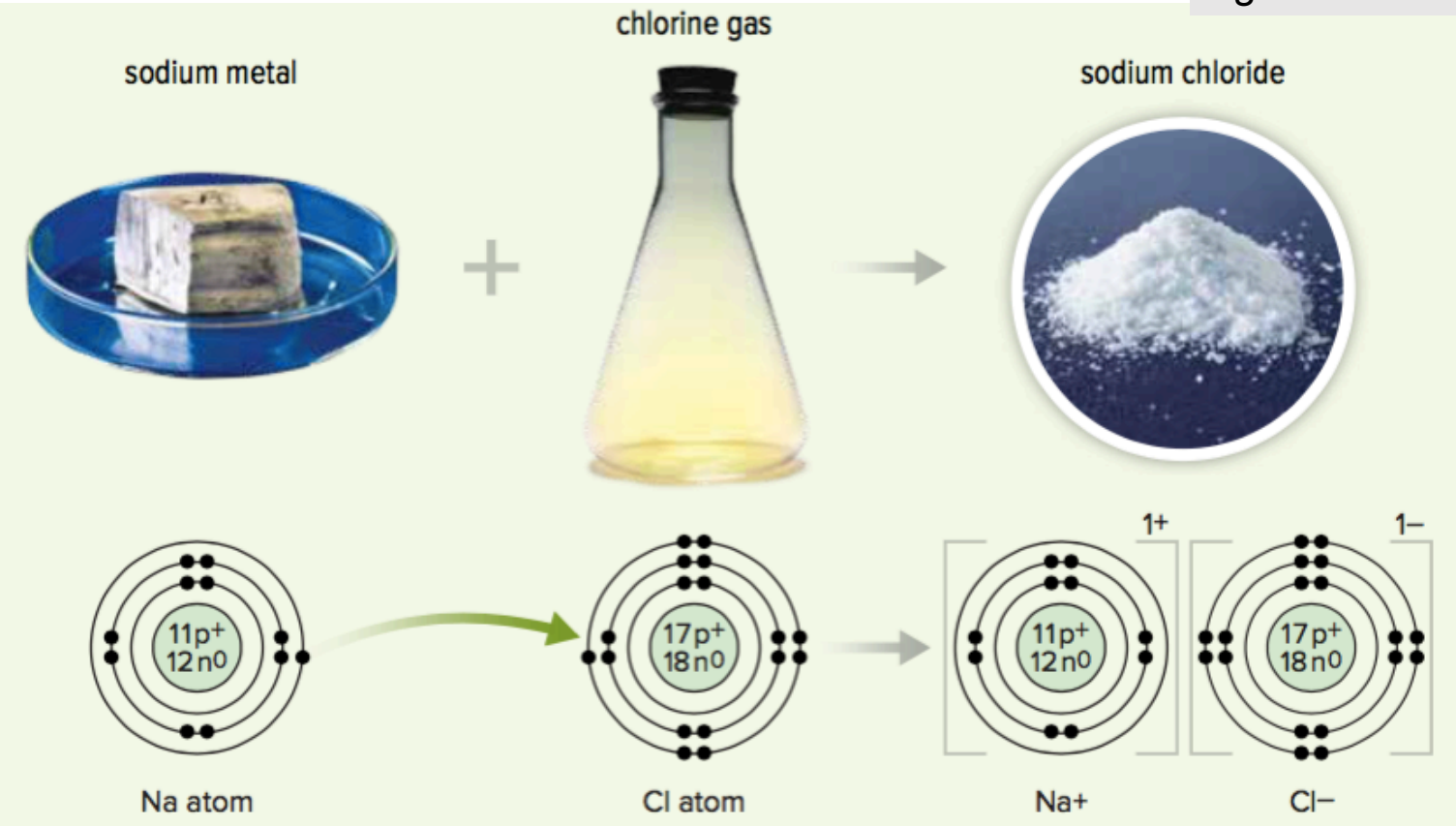
- Sodium (metal) reacts with chlorine (gas)
- Forms when sodium atoms each transfer one electron to chlorine atoms
- Each sodium atom becomes positive ion (Na^+)
- Each chlorine atom becomes a negative ion (Cl^-)



Formation of Ionic Compounds: Sodium Chloride (continued)

- Valence shells of both the sodium ion (Na^+) and chlorine ion (Cl^-) are full
- Recall: The stability of a full valence shell drives the formation of compounds

Figure 2.23



The Structure of Ionic Compounds

- Ionic compounds consist of positive and negative ions arranged in regular repeating patterns called *lattices*
- Example: Sodium chloride
  - Sodium chloride crystals consist of sodium and chloride ions arranged in a lattice

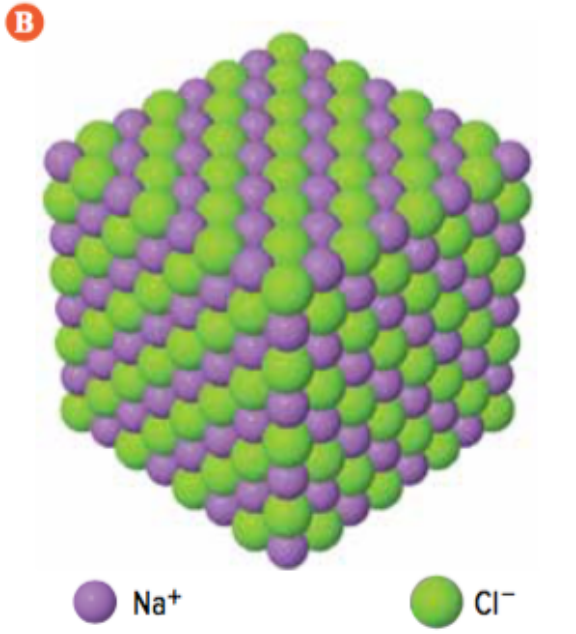


Figure 2.24: A) Cubic structure of sodium chloride crystals. B) Sodium chloride crystals consist of sodium and chloride ions arranged in a repeating pattern.

Properties of Ionic Compounds: High Melting Points

Ionic compounds have high melting points

- Melting requires breaking ionic bonds: the strong forces holding the ions together in the lattice structure
- A large amount of energy is required to break ionic bonds
- Example: Melting point of sodium chloride is 801°C

Properties of Ionic Compounds: Hard and Brittle

Ionic compounds are hard and brittle

- Ionic solids are hard because ionic bonds are very strong
- When enough force is applied, ions will shift
  - Causes ions with the same charge to be close together
  - Results in repulsive forces that break the solid apart

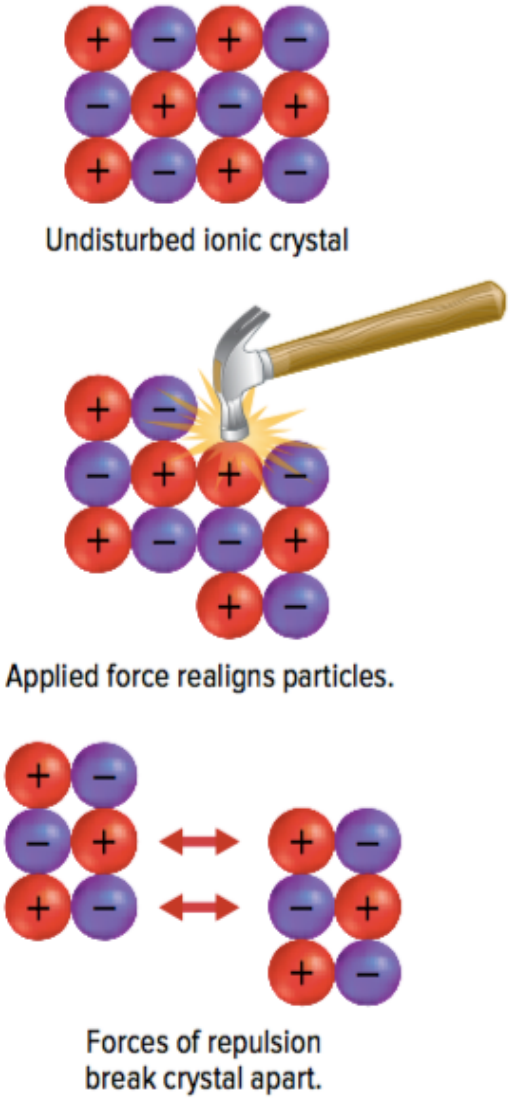


Figure 2.25: When a force strong enough to overcome the strong forces of attraction between oppositely charged ions is applied, ions with like charges come close together. They repel one another and the solid cracks.

Properties of Ionic Compounds: Conduct Electric Current

Ionic compounds conduct electric current when liquid or dissolved

- Electric current: the flow of charged particles
- Solid form: do not conduct electric current since ions are held rigidly in place
- Dissolved or liquid form: ions are free to move, and can conduct electric current

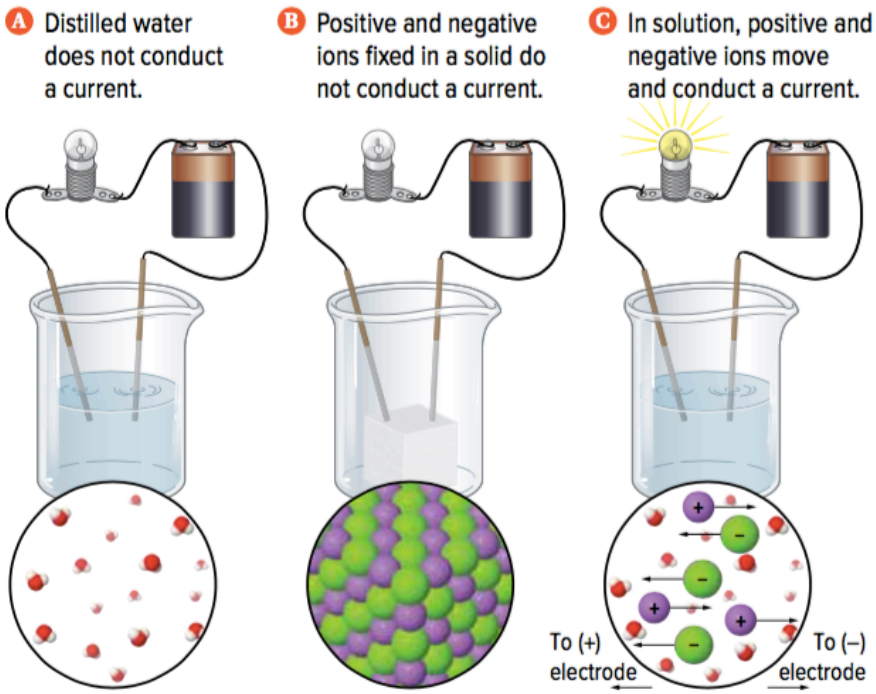


Figure 2.26

Properties of Ionic Compounds: Conduct Electric Current (continued)

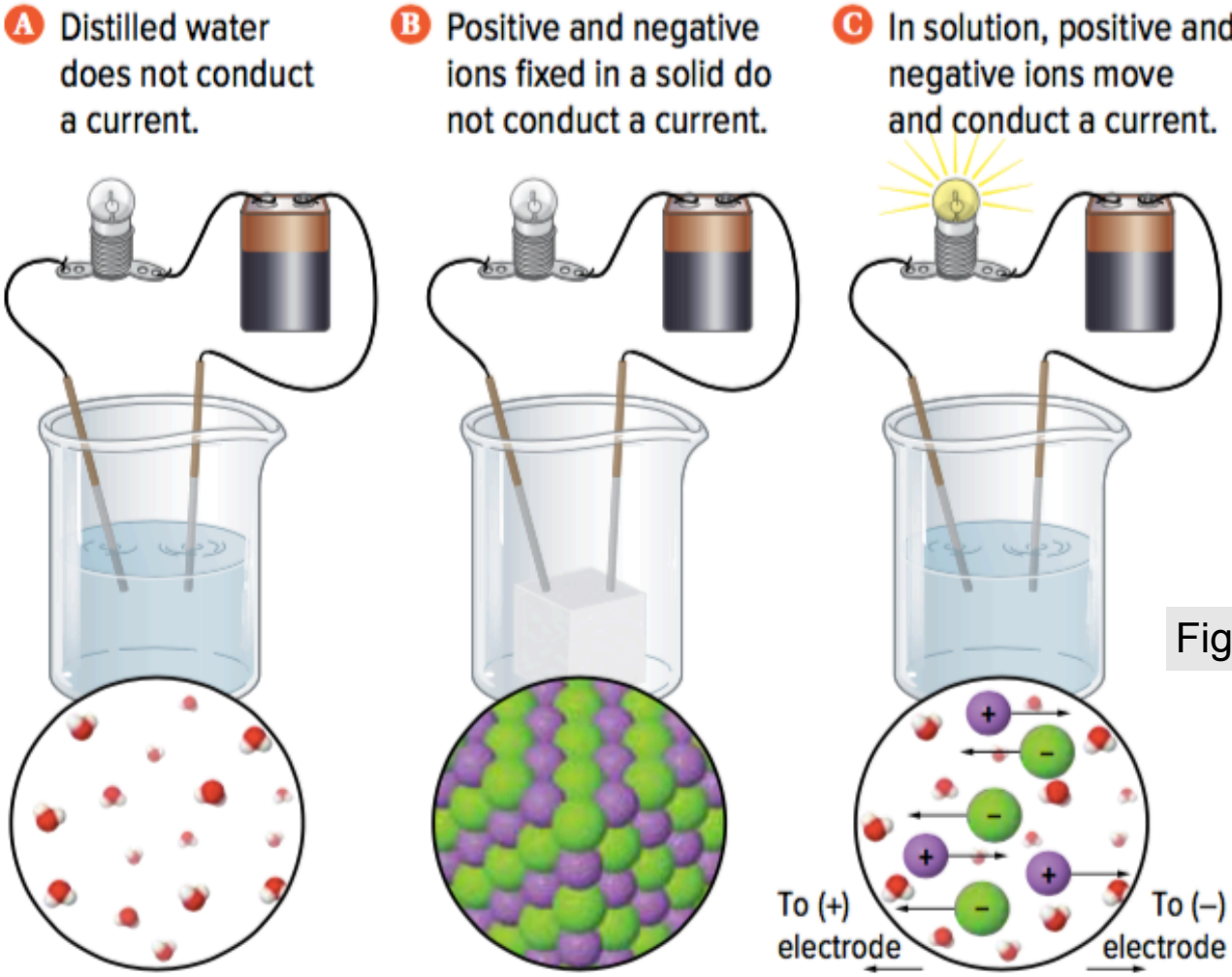


Figure 2.26

Discussion Questions

1. What is an ionic bond?

2. Describe the formation of sodium chloride from sodium and chlorine.

Discussion Questions

3. Binary ionic compounds form when which two types of elements react?

4. When do ionic compounds conduct electric current? Explain.

Concept 3: Covalent compounds are made of molecules.

- **Covalent bond**: a strong attraction between atoms that forms when atoms share valence electrons
- **Covalent compound**:
  - Made of molecules
  - **Molecule**: a particle made up of two or more neutral atoms bonded together by covalent bonds

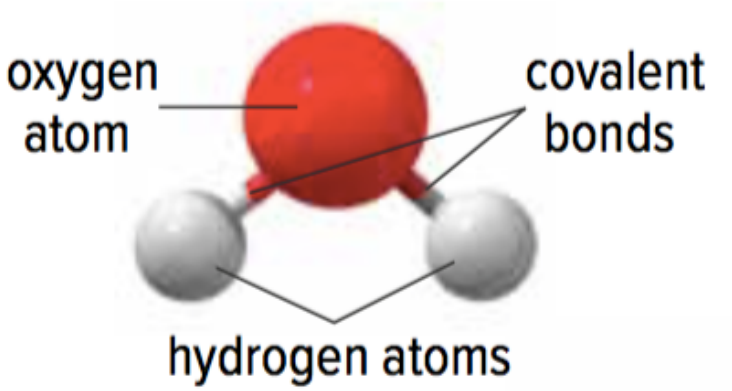


Figure 2.27: Water molecules consist of two hydrogen atoms bonded to one oxygen atom.

Covalent Bonds: Tug of War

Covalent bonds are similar to a game of tug of war

- Each team (atom) tries to pull the rope (shared electrons) toward itself
- Neither side wins, and the bond is the rope that connects them

Figure 2.28

Achieving Stability by Sharing Electrons

Formation of a covalent compound is based on achieving stability with a full valence shell

- Non-metals in covalent compound share electrons to get a full valence shell

Achieving Stability by Sharing Electrons (continued)

Example: Water

- Covalent bond is formed from a single pair of shared electrons
  - Each hydrogen atom contributes a single electron to the shared pair of electrons
  - Each oxygen atom contributes a single electron to the shared pair of electrons
- Hydrogen atoms achieve a full valence shell of 2 electrons
- Oxygen atom achieves a full valence shell of 8 electrons

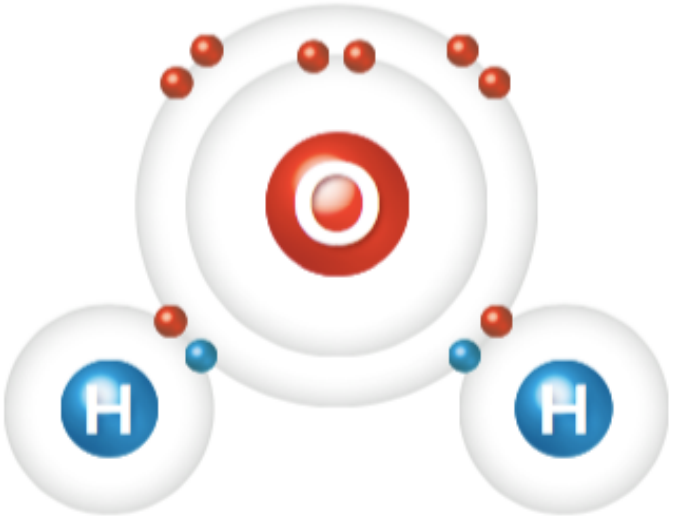


Figure 2.30: Each hydrogen atom contributes a single electron to the shared pair of electrons in its covalent bond with oxygen.

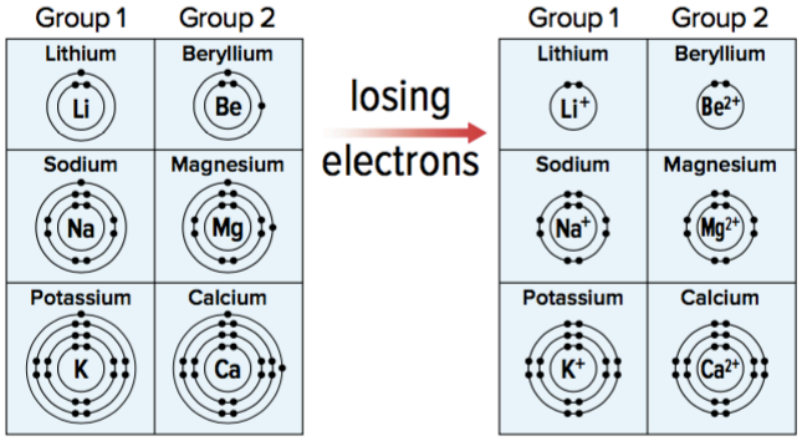
Three Ways That Atoms Become Stable (Achieve a Full Valence Shell)

- Metal atoms can lose electrons to achieve a full valence shell
- Non-metal atoms can gain electrons to achieve a full valence shell
- Non-metal atoms can share electrons with other non-metal atoms to achieve a full valence shell

Three Ways That Atoms Become Stable: Metal Atoms Can Lose Electrons

Metals can lose electrons to achieve a full valence shell

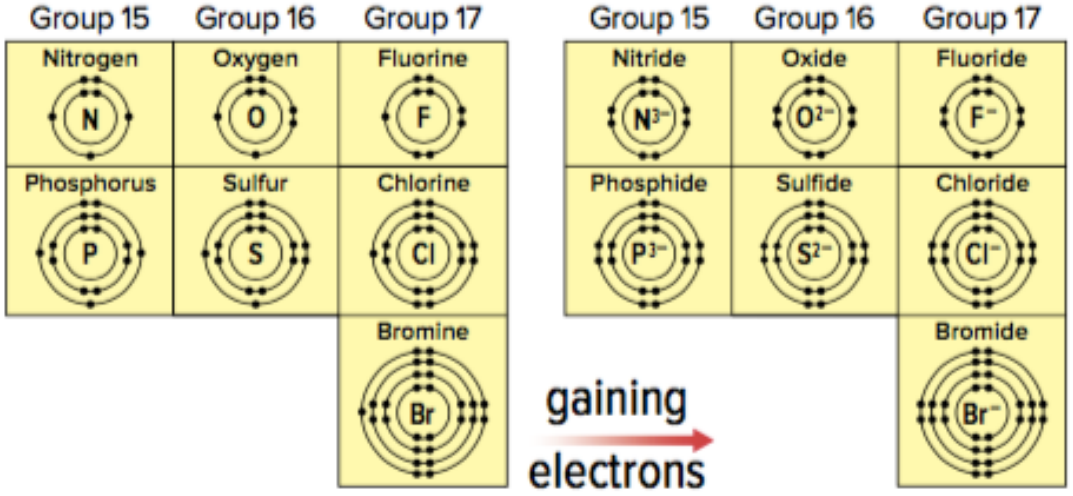
- Form positive ions because they lose electrons
- Retain the same number of protons in the nucleus
- Example:
  - Group 1 metal ions have a 1+ charge because they have lost one electron
  - Group 2 metal ions charge: 2+
  - Group 3 metal ions charge: 3+



Three Ways That Atoms Become Stable: Non-metal Atoms Gain Electrons

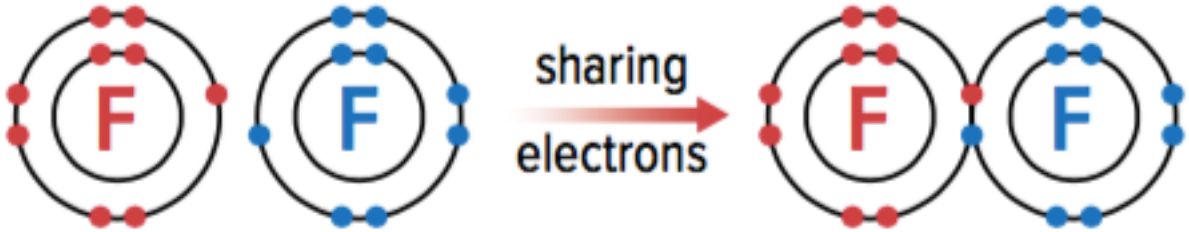
Non-metal atoms can gain electrons to achieve a full valence shell

- Form negative ions because they gain electrons
- Non-metal ions end in *–ide*
- Example:
  - Group 17 non-metals ion charge is 1- because they have gained one electron
  - Group 17 non-metal ions charge: 2-
  - Group 18 non- metal ion charge: 3-



Three Ways That Atoms Become Stable: Non-metal Atoms Share Electrons

- Non-metal atoms can share electrons with other non-metal atoms to achieve a full valence shell



Properties of Covalent Compounds

Have low melting points:

- Forces holding atoms together in a molecule are strong
- Bond that attract molecules to one another are relatively weak; therefore, not as much energy is needed to "break" the weak bond melt at low temperatures

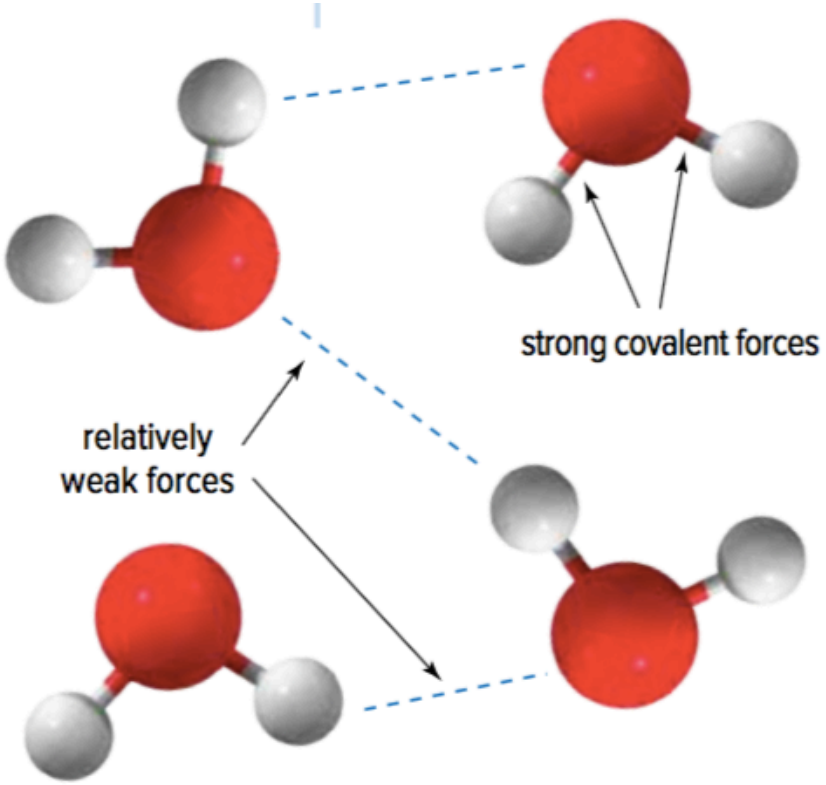


Figure 2.31

Properties of Covalent Compounds (continued)

- Relatively soft: Weak forces between molecules mean that it's easier for molecules to move and shift
- Poor conductors: covalent compounds do not have free electrons, and they are poor conductors of electric current and heat

Figure 2.32: Covalent compounds are poor conductors of electric current. This makes them useful as insulating covers for computer cables.

Discussion Questions

1. What type of bond is formed when two non-metal atoms share electrons?

2. What is a molecule?

3. Why do covalent compounds tend to have low melting points?

Concept 4: Covalent bonding also occurs in elements and network solids.

Seven elements are made up of molecules held together with covalent bonds under normal conditions:

- H_2, F_2, Cl_2, Br_2, I_2: Two atoms share one electron in a covalent bond
- O_2: Two atoms share two pairs of electrons to form two covalent bonds (*double bond*)
- N_2: Two nitrogen atoms share three pairs of electrons to form three covalent bonds (*triple bond*)

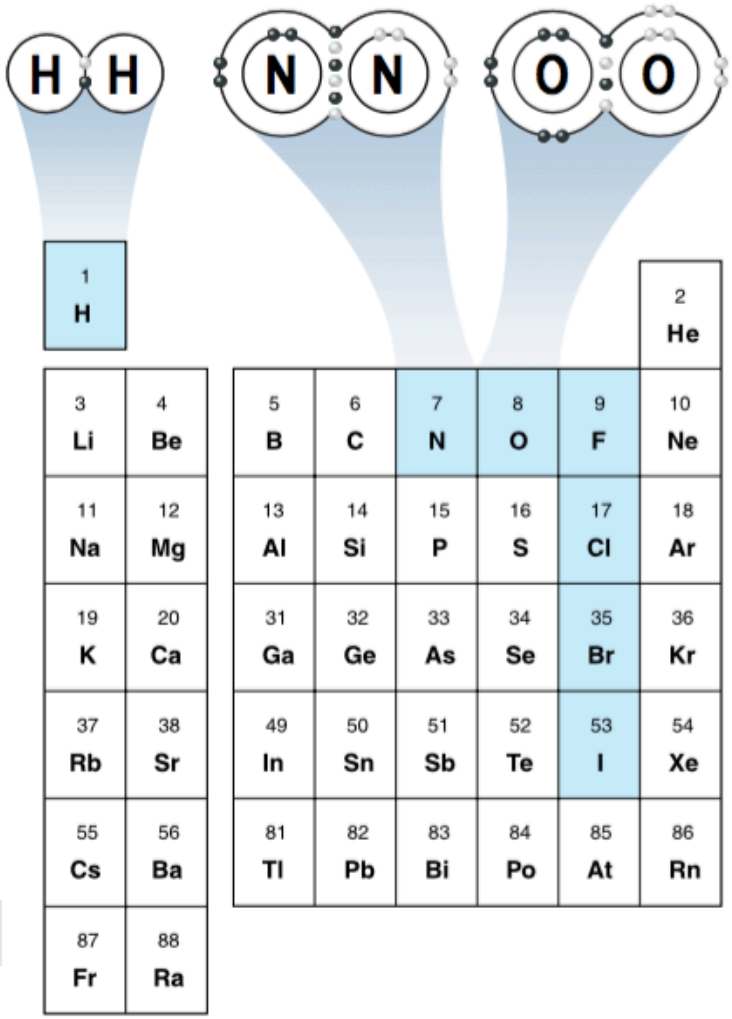


Figure 2.33

Network Solids

Network solid:

- Consists of non-metal elements containing covalent bonds that connect their atoms in one large network; essentially consist of one giant molecule
- Example: Silicon dioxide (SiO_2)
- Figure 2.34: (A) Atoms are bonded in a regular, repeating structure by covalent bonds (B) In real quartz crystals, billions of atoms are bonded together in the same repeating structure, forming one giant molecule.

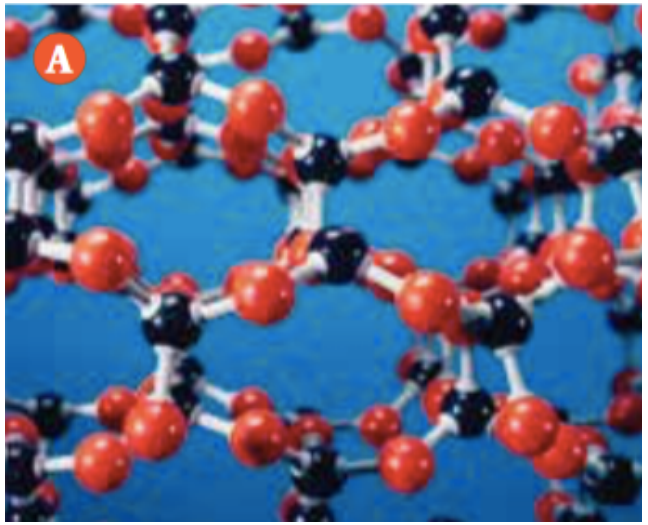


Figure 2.34

Network Solids: Carbon (Diamond Form)

Carbon (diamond form – network solid):

- Each carbon atom is bonded to four other carbon atoms by covalent bonds
- Forms strong 3-D structure

Carbon (graphite form – not a network solid):

- Each carbon atom forms covalent bonds with three other carbon atoms, forming sheets
- Sheets are weakly attracted to each other and can slide around
- As you write on paper, layers of graphite slide off the pencil tip and onto the page

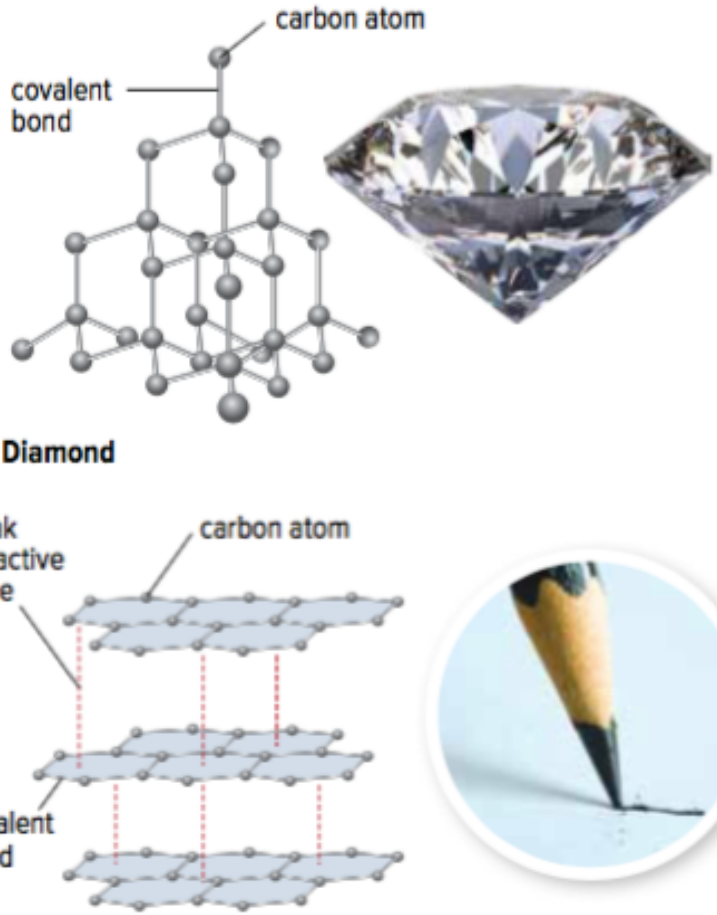


Figure 2.35: Diamond and graphite both contain covalent bonds but have very different properties due to their structure.

Discussion Questions

1. Describe a molecule of hydrogen.

2. Why does neon gas consist of individual, unbonded neon atoms while chlorine exists as diatomic chlorine molecules?

3. What is a network solid?

Topic 2.4 Summary: How can atomic theory explain patterns in the period table?

- The structure of atoms can be represented using simple diagrams.
- Elements in chemical groups have similar electron arrangements.
- The periodic table shows how properties of elements change in predictable ways.