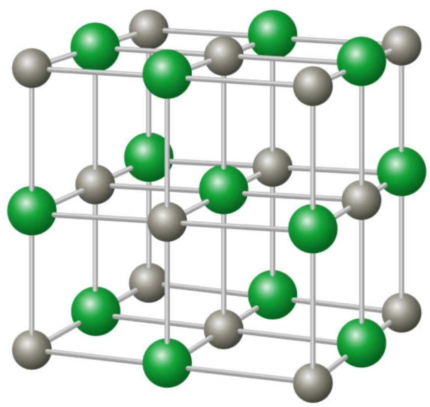
Structures and Types of Solids

There are many ways to classify solids, but the broadest categories are:

1. Crystalline Solids
    - solids with a highly regular arrangement of their components (atoms, ions, or molecules)

2. Amorphous Solids
    - solids with considerable disorder in their structures

The regular arrangement of the components of a crystalline solid produces the characteristic shapes of crystals. The positions of the components in a crystalline solid are usually represented by a **lattice** — a 3D system of points showing the positions of the components that make up the substance.



Types of Crystalline Solids

Crystalline solids are classified according to the type of component that occupies the lattice points. This leads to the following classifications:

1. Atomic Solids
    - atoms at the lattice points

2. Molecular Solids
    - molecules at the lattice points

3. Ionic Solids
    - ions at the lattice points

In addition, atomic solids can be divided into subgroups based on the type of bonding that exists between the atoms. These subgroups are: *metallic solids*, *network solids*, and *Group 18 solids*.

Metallic Solids

Metallic crystals can be pictured as containing spherical atoms packed together and bonded to each other equally in all directions. We can model such a structure by packing uniform, hard spheres in a way that most efficiently uses the available space.

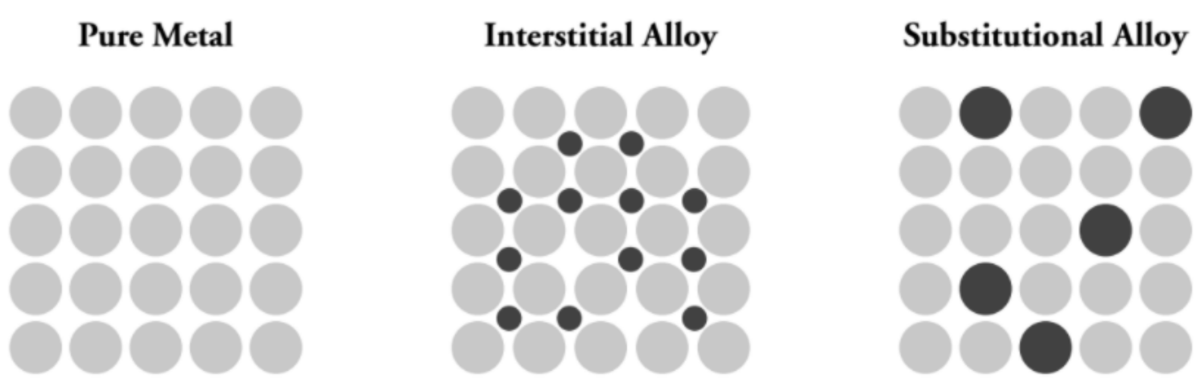
Metals have several properties in common: malleability, ductility, and the efficient conduction of heat and electricity. Though the shape of most pure metals can be easily changed, most metals are durable and have high melting points. To explain these properties, we adopt the electron sea model.

The **electron sea model** visualizes a metal as a regular array of metal cations (+) in a "sea" of valence electrons. The mobile electrons can conduct heat and electricity, and the metal ions can easily be moved around as the metal is hammered into a sheet or pulled into a wire.

Because of the nature and structure of metals, it is possible to introduce other elements into a metallic crystal to produce substances called alloys. An **alloy** is best defined as a substance that contains a mixture of elements and has metallic properties. Alloys come in two types:

1. Substitutional Alloy
    - some of the host metal atoms are replaced by other metal atoms of similar size
    - e.g. in brass, 1/3 of the copper atoms are replaced with zinc atoms
    - e.g. sterling silver (93% silver, 7% copper), pewter (85% tin, 7% copper, 6% bismuth, 2% antimony), solder (95% tin, 5% antimony)

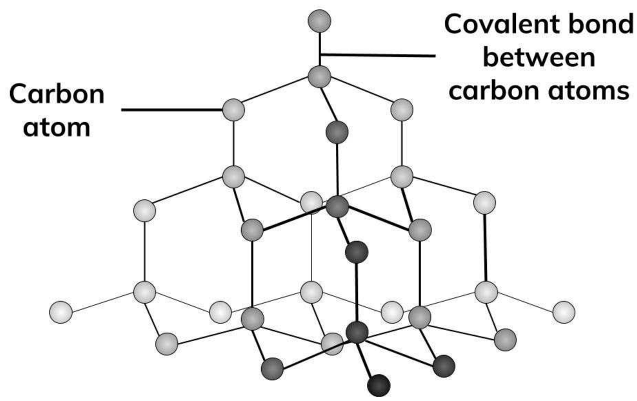
2. Interstitial Alloy
    - formed when some of the interstices (spaces) between the host metal atoms are filled in by small atoms
    - e.g. steel is an iron crystal with carbon atoms in the spaces



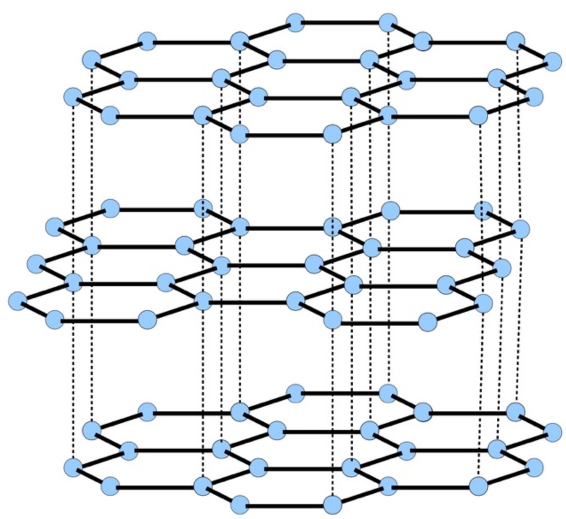
Network Atomic Solids

Network solids are formed by networks or chains of atoms held together by covalent bonds. They can be thought of as one giant molecule. Unlike metals, these solids are typically brittle and do not efficiently conduct heat or electricity.

Diamond and graphite are both network solids formed entirely of carbon atoms. In diamond, the hardest naturally occurring substance, each carbon atom is surrounded by a tetrahedral arrangement of other carbon atoms to form a huge molecule.



Graphite is very different from diamond. While diamond is hard, colorless, and an insulator, graphite is slippery, black, and a conductor. In contrast to the tetrahedral arrangement of carbon atoms in diamond, the structure of graphite is based on layers of carbon atoms arranged in six-atom rings.



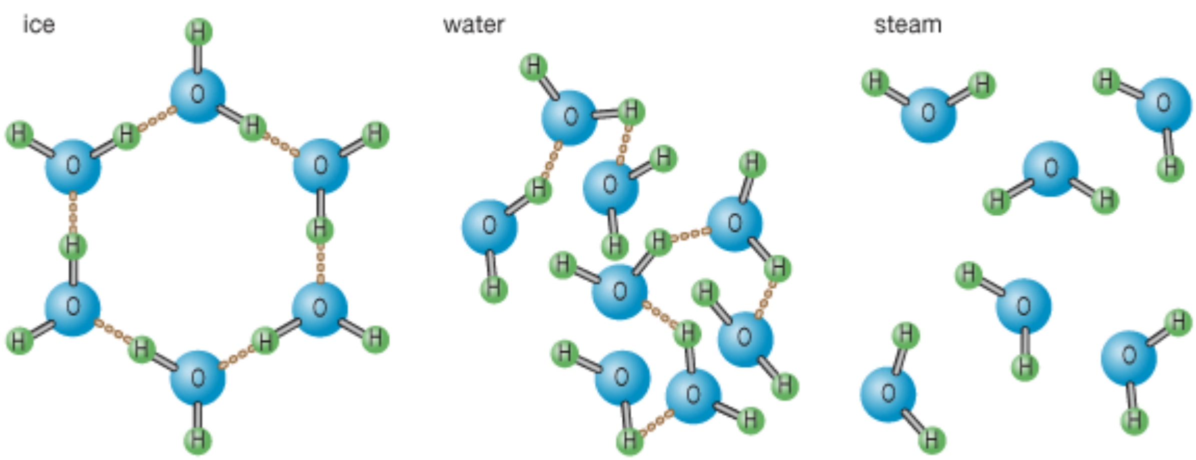
Graphite has very strong bonds *within* the layers of carbon atoms but much weaker bonds *between* the layers. This allows the layers to slide past one another quite easily, which accounts for graphite's slipperiness.

Group 18 Solids

When cooled below their melting points, the Noble Gases form an ordered solid. Because they have extremely low melting points, these solids are very rarely encountered outside of a laboratory.

Molecular Solids

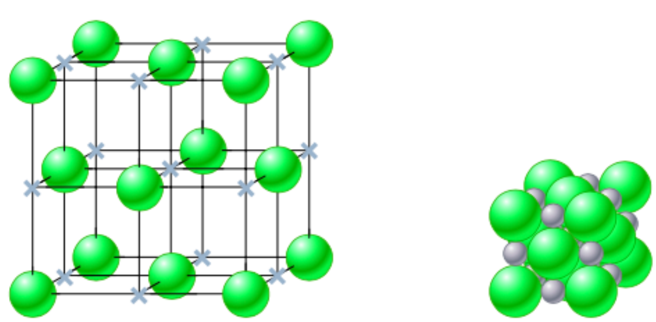
These are crystalline solids that have molecules at the lattice points, instead of atoms. A common example is ice, where the lattice positions are occupied by water molecules. Other examples include dry ice (solid carbon dioxide), certain forms of sulfur that contain S_8 molecules, and certain forms of phosphorus that contain P_4 molecules. These solids have strong covalent bonds *within* the molecules but relatively weak forces *between* the molecules.



Ionic Solids

Ionic solids are stable substances with high melting points. They are held together by strong electrostatic forces that exist between oppositely charged ions.

The structure of most binary ionic solids, such as sodium chloride, can be thought of as a crystal with the larger anions (–) at the lattice points and the smaller cations (+) in the spaces. The image below shows $NaCl$. The larger Cl^- ions occupy the lattice points, while the smaller Na^+ ions occupy the spaces.



Worksheet #2

1. Distinguish between the items in the following pairs.

    a) crystalline solid; amorphous solid
    b) ionic solid; molecular solid
    c) molecular solid; network solid
    d) metallic solid; network solid

2. Write a brief description of each of the following.

    a) metallic solid
    b) interstitial alloy
    c) substitutional alloy
    d) network solid
    e) molecular solid
    f) ionic solid

3. What type of solid will each of the following substances form?

    a) CO_2
    b) SiO_2
    c) Si
    d) CH_4
    e) Ru
    f) I_2
    g) KBr
    h) H_2O
    i) $NaOH$
    j) U
    k) $CaCO_3$
    l) PH_3

4. What type of solid will each of the following substances form?

    a) diamond
    b) H_2
    c) Mg
    d) KCl
    e) NH_4NO_3
    f) SF_2
    g) Ar
    h) Cu
    i) $C_6H_{12}O_6$