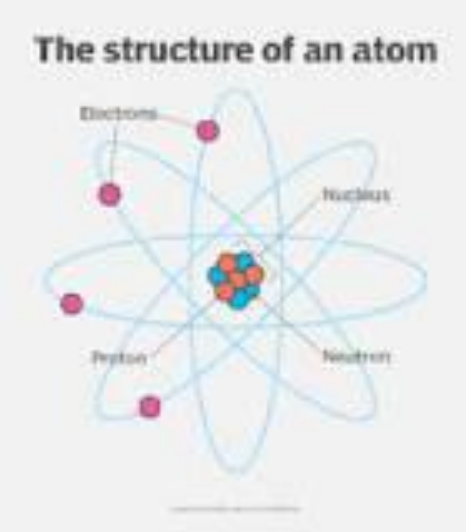
Material Science

The structure of solids: classify solids, Bonding of Solids, (Week 3)

What is an atom simple definition?

An atom is a particle of matter that uniquely defines a chemical element. An atom consists of a central nucleus that is surrounded by one or more negatively charged electrons.



Hydrogen atom is the smallest atom of all. The atomic radius of a hydrogen atom is 10^{-10} meter (0.1nm).

Bonding in solids

Solids can be classified according to the nature of the bonding between their atomic or molecular components. The traditional classification distinguishes four kinds of bonding:

- Covalent bonding, which forms network covalent solids

  (sometimes called simply "covalent solids")

- Ionic bonding, which forms ionic solids
- Metallic bonding, which forms metallic solids
- Weak inter molecular bonding, which forms molecular solids (sometimes anomalously called "covalent solids")

Typical members of these classes have distinctive electron distributions, thermodynamic, electronic, and mechanical properties. In particular, the binding energies of these interactions vary widely. Bonding in solids can be of mixed or intermediate kinds, however, hence not all solids have the typical properties of a particular class, and some can be described as intermediate forms.

Basic classes of solids

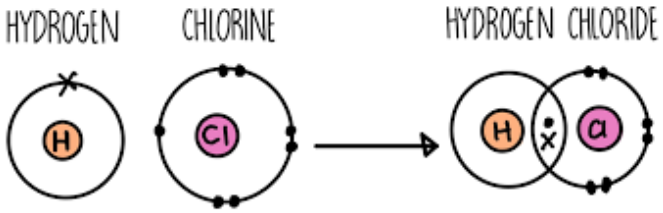
- Network covalent solids

A network covalent solid consists of atoms held together by a network of covalent bonds (pairs of electrons shared between atoms of similar electronegativity), and hence can be regarded as a single, large molecule. The classic example is diamond; other examples include silicon, quartz and graphite.

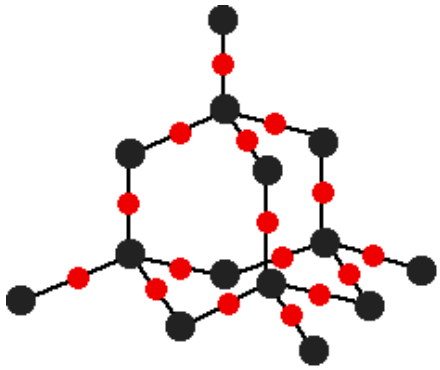
Properties

- High strength (with the exception of graphite)
- High elastic modulus
- High melting point
- Brittle

Their strength, stiffness, and high melting points are consequences of the strength and stiffness of the covalent bonds that hold them together. They are also characteristically brittle because the directional nature of covalent bonds strongly resists the shearing motions associated with plastic flow, and are, in effect, broken when shear occurs. Network covalent solids vary from insulating to semiconducting in their behavior.



Covalent Bond



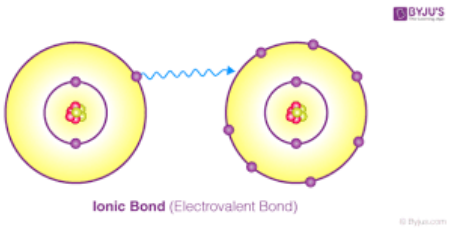
Covalent Structure

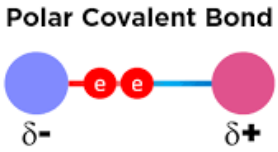
Ionic solids

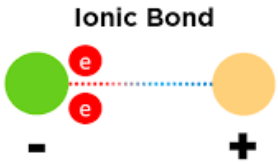
A standard ionic solid consists of atoms held together by ionic bonds, that is by the electrostatic attraction of opposite charges (the result of transferring electrons from atoms with lower electronegativity to atoms with higher electronegativity). Among the ionic solids are compounds formed by alkali and alkaline earth metals in combination with halogens; a classic example is table salt, sodium chloride.
Ionic solids are typically of intermediate strength and extremely brittle. Melting points are typically moderately high.

**Alkali: An alkali is a chemical that can dissolve in water, combine with acids to form salts, and make acids less acidic.

**Halogens are nonmetals. At room temperature, fluorine and chlorine are gases and bromine is a liquid. Iodine and astatine are solids. Halogens are very reactive, the reactivity decreases from fluorine to astatine



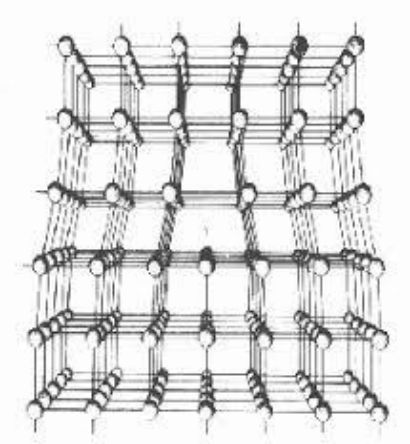




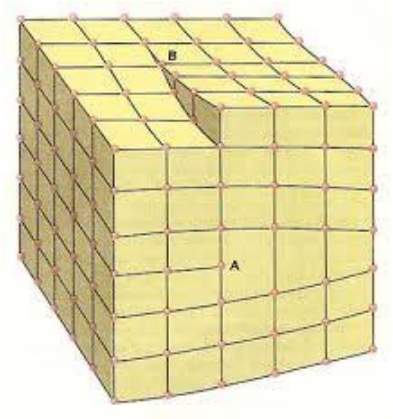
Metallic solids

Metallic solids are held together by a high density of shared, delocalized electrons, resulting in metallic bonding. Classic examples are metals such as copper and aluminium.
Metallic solids are conducting.
Solids with purely metallic bonding are characteristically ductile and, in their pure forms, have low strength; melting points can be very low (e.g., Mercury melts at 234 K (−39 °C). These properties are consequences of the non-directional nature of metallic bonding, which allows atoms (and planes of atoms in a crystal lattice) to move past one another without disrupting their bonding interactions.
Metals can be strengthened by introducing crystal defects (for example, by alloying) that interfere with the motion of dislocations that mediate plastic deformation.

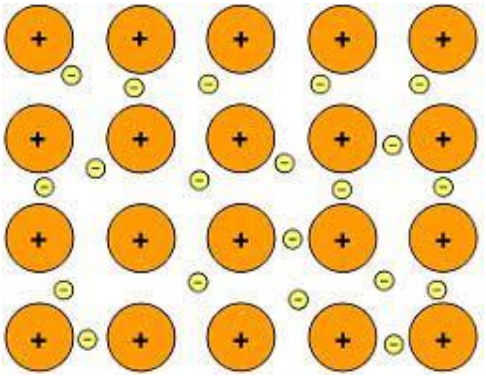
Dislocation: is **a linear crystallographic defect or irregularity within a crystal structure which contains an abrupt change in the arrangement of atoms.

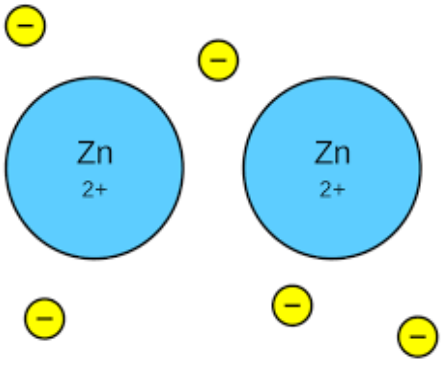


dislocations



Transition metals: **any of various metallic elements (such as chromium, iron, and nickel) that have valence electrons in two shells instead of only one.





Metallic Bond

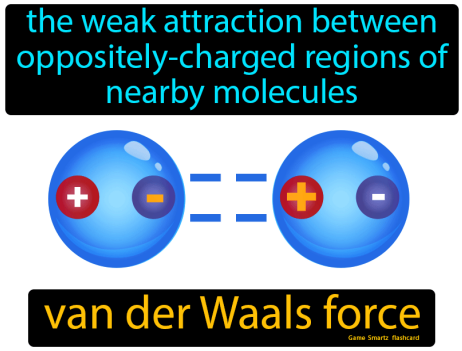
Molecular solids

A classic molecular solid consists of small, non-polar covalent molecules, and is held together by van der Waals

forces; a classic example is paraffin wax. These forces are weak, resulting in pairwise interatomic binding energies on the order of 1/100 those of covalent, ionic, and metallic bonds. Binding energies tend to increase with increasing molecular size and polarity.
Solids that are composed of small, weakly bound molecules are mechanically weak and have low melting points; an extreme case is solid molecular hydrogen, which melts at 14 K (−259 °C). The non-directional nature of dispersion forces typically allows easy plastic deformation, as planes of molecules can slide over one another without seriously disrupting their attractive interactions. Molecular solids are typically insulators with large band gaps.

A non-polar covalent bond: is **a type of chemical bond that is formed when electrons are shared equally between two atoms.

****Van der Waals forces**: **relatively weak electric forces that attract neutral molecules to one another in gases, in liquefied and solidified gases, and in almost all organic liquids and solids**.



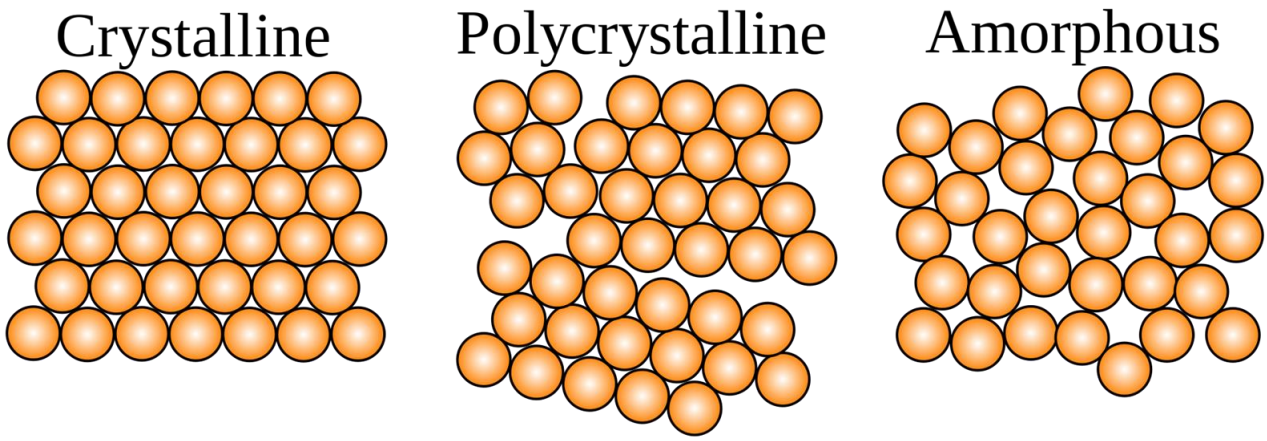
Crystalline solids

Crystalline solids have regular ordered arrays of components held together by uniform intermolecular forces, whereas the components of amorphous solids are not arranged in regular arrays. With few exceptions, the particles that compose a solid material, whether ionic, molecular, covalent, or metallic, are held in place by strong attractive forces between them. When we discuss solids, therefore, we consider the positions of the atoms, molecules, or ions, which are essentially fixed in space, rather than their motions (which are more important in liquids and gases). The constituents of a solid can be arranged in two general ways: they can form a regular repeating three-dimensional structure called a crystal lattice, thus producing a crystalline solid, or they can aggregate with no particular order, in which case they form an amorphous solid (from the Greek amorphous, meaning "shapeless").

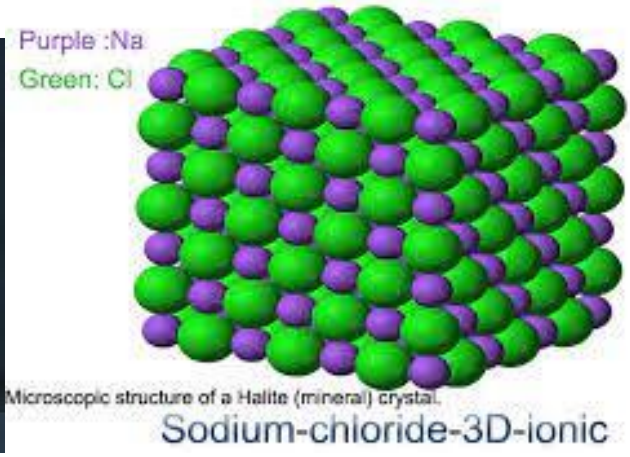
A crystalline structure is any structure of ions, molecules, or atoms that are held together in an ordered, three-dimensional arrangement. Crystalline structure is one of two types of structural ordering of atoms, the other being the amorphous structure.

An amorphous structure is any non-crystalline structure in which the atoms and molecules are not organized in a definite lattice pattern. Such solids include

glass, plastic, and gel. Solids and liquids are both forms of condensed matter; both are composed of atoms in close proximity to each other.







Halite , commonly known as rock salt, is **a type of salt, the mineral (natural) form of sodium chloride (NaCl)**. Halite forms isometric crystals.