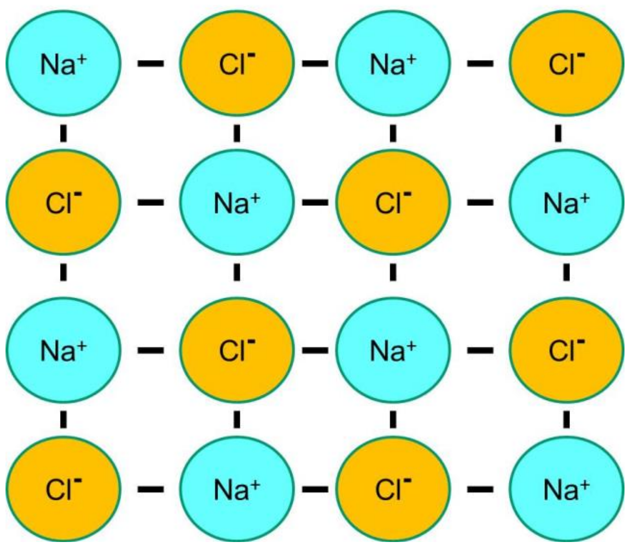
Chemistry Lecture #36: Properties of Ionic Compounds and Metals

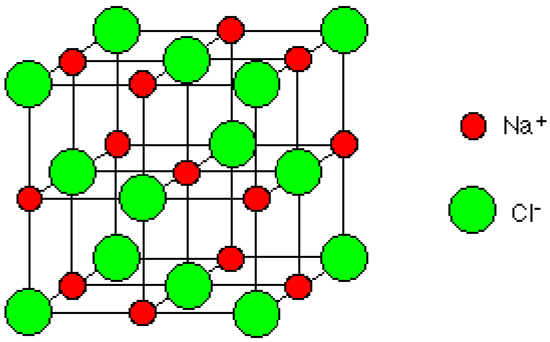
Ionic compounds are made of anions (negative ions) and cations (positive ions). The compound sticks together because opposite charges attract each other.

Table salt, or sodium chloride (NaCl) is composed of Na^+ and Cl^-. The ions in salt are arranged in an orderly pattern of alternating Na^+ ions and Cl^- ions. This pattern allows the opposite charges to be in contact with each other.

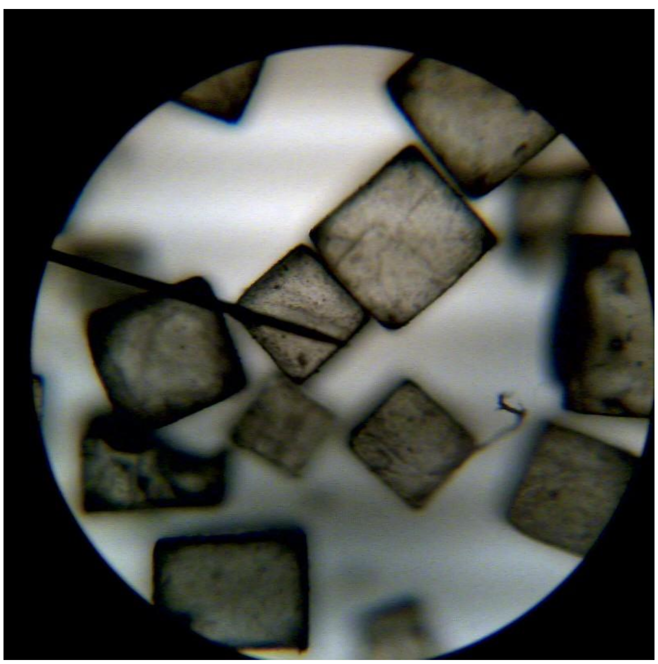
Crystal Lattice of NaCl (table salt)



The previous picture shows a two-dimensional diagram of alternating positive and negative ions. NaCl exists as a three-dimensional structure. Here's a picture showing alternating anions and cations in a three-dimensional structure.



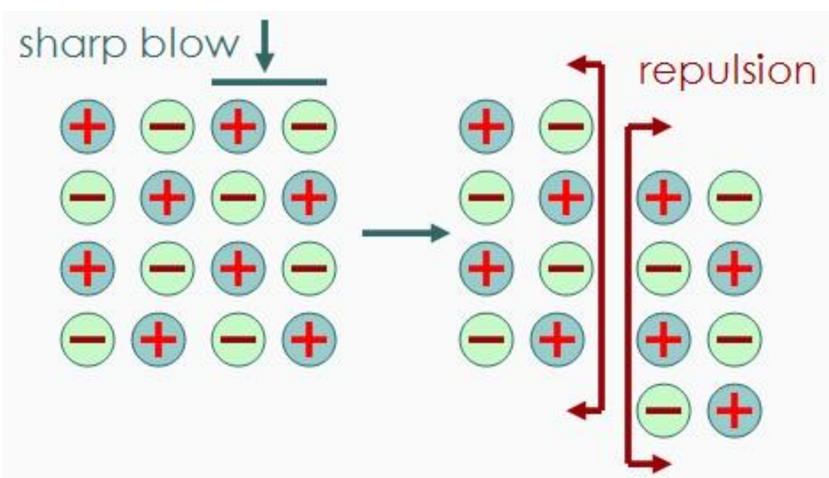
The structure is shaped like a cube. The NaCl ions form millions of cubes, which are all stacked on top of each other. This stack of cubes creates one gigantic cube, which we see as a salt crystal. Below is a picture of what salt crystals look like under a microscope.



The NaCl ions have formed a crystal lattice. A crystal lattice is a three-dimensional geometric arrangement of particles. Each positive ion is surrounded by negative ions, and each negative ion is surrounded by positive ions. The ions in an ionic compound are arranged in a crystal lattice.

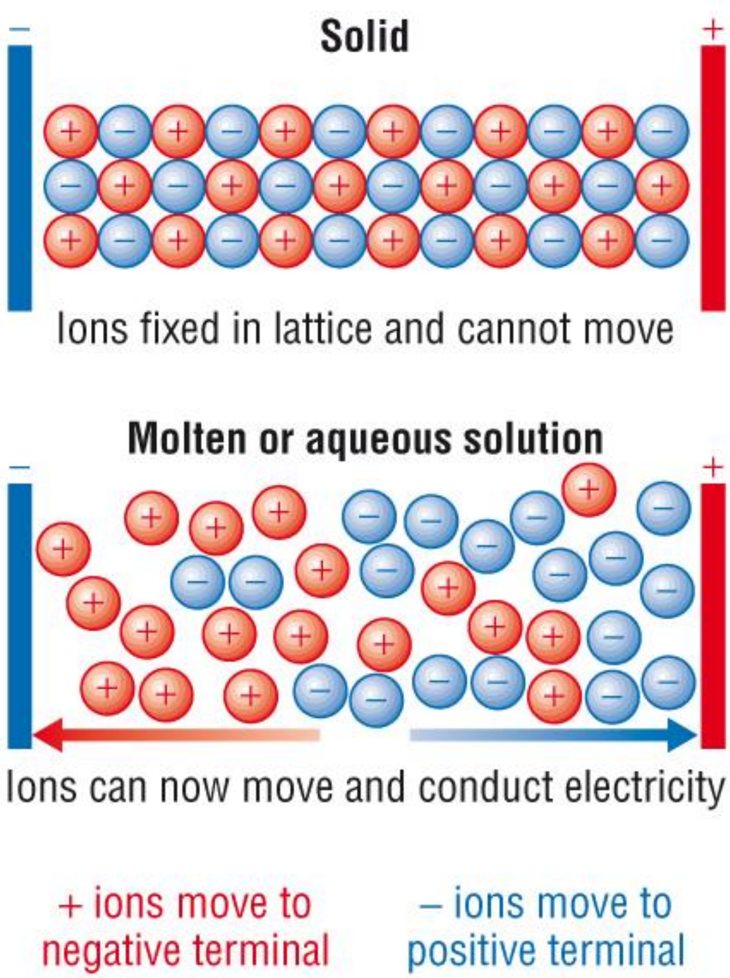
The crystal lattice gives ionic compounds certain properties. First, ionic compounds have a high melting point and a high boiling point. The electrostatic attraction between the anions and cations is strong, and it takes a lot of energy to break the ionic bonds and separate the ions. Does salt melt when you put it in a frying pan? Nope! Salt is an ionic compound with a high melting point!

Next, ionic compounds are hard and brittle. Ionic crystals are hard because the positive and negative ions are strongly attracted to each other and difficult to separate. However, when pressure is applied to an ionic crystal then ions of like charge may be forced closer to each other. The electrostatic repulsion can be enough to split the crystal, which is why ionic solids are brittle. The picture below shows how layers of a crystal can be realigned to cause repulsion between identical charges.

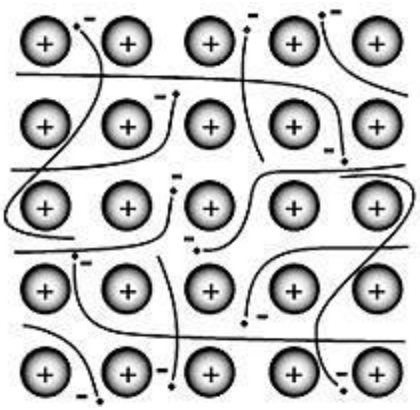


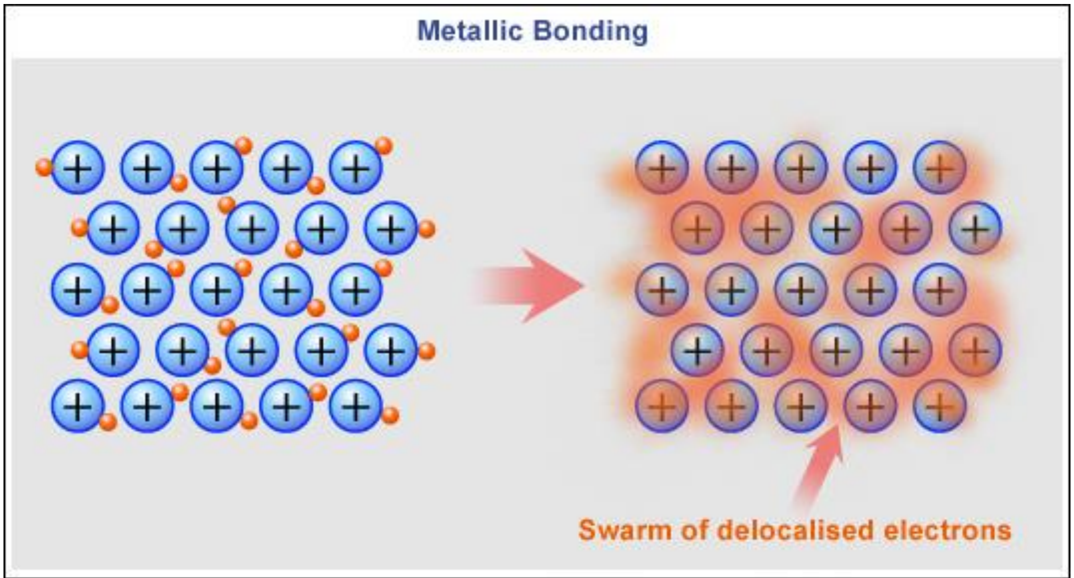
If you do manage to apply enough heat to melt an ionic solid, it is capable of conducting electricity. Ionic compounds in the molten state are electrical conductors because the ions are free to move. Ions dissolved in water are also free to move. Thus, ionic compounds dissolved in water also conduct electricity.

In the solid state, however, ionic compounds do not conduct electricity. In a solid, the ions are held rigidly in a fixed position, so they cannot move, thus prohibiting the flow of electricity. Compounds that do not conduct electricity are called insulators.



Metals, however, are solids that can conduct electricity. This is due to the nature of metallic bonding. Metallic bonding occurs when the loosely held valence electrons of metal atoms move freely from one metal atom to another. This moving sea of negative electrons acts like a glue that holds the positive nuclei of the atoms together.





The outer electrons are so weakly bound to metal atoms that they are free to roam across the entire metal. Having 'lost' their outer electrons, individual metal atoms are more like positive ions in a swarm of communal electrons.

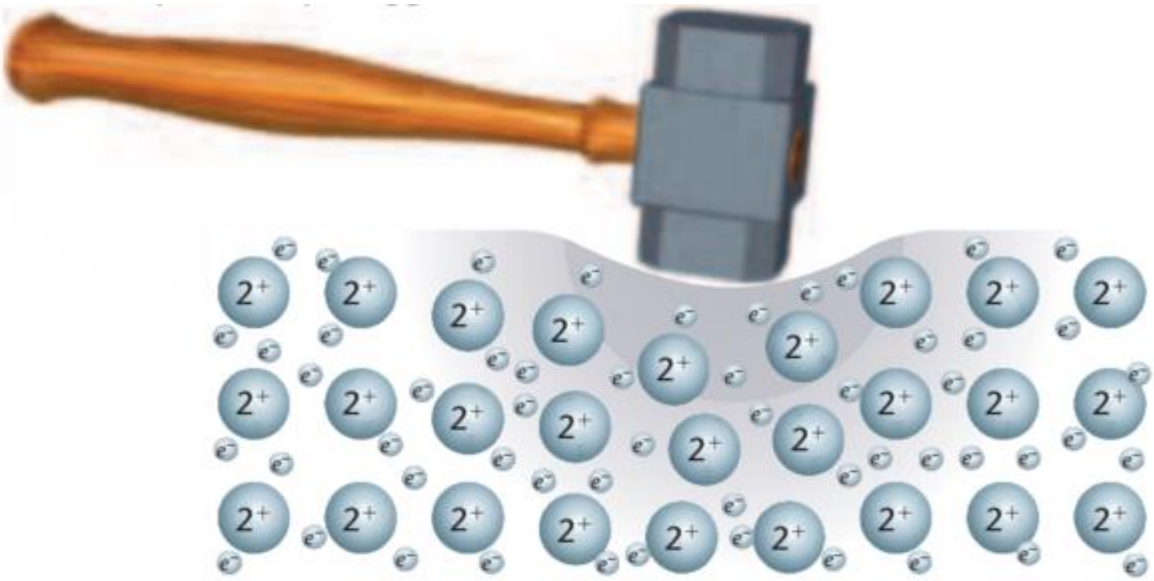
Thus, metals conduct electricity because the electrons move freely from one nucleus to another. Mobile electrons can also transmit heat from one place to another. Consequently, metals can also conduct heat.

These mobile electrons are also called delocalized electrons. Delocalized electrons interact with photons by absorbing and releasing their energy. We observe this absorption and release of photons when we see metals reflect light. When metals reflect light, we are seeing the release of visible photons. Thus, metals are shiny and reflect light.

Finally, metallic bonding makes metals malleable and ductile. Ductile means that a substance can be drawn into a thin wire. Malleable means that a substance can be hammered into thin sheets without breaking. This is the opposite of being brittle.

A flattened penny is an example of the malleability of metal.

Metallic bonding makes metals malleable and ductile because the moving electrons are in continuous contact with the metal nuclei. Putting stress on the metal by hammering or pulling on it will not separate the negative electrons from the positive nuclei. Thus, the attraction between ions is preserved.



Bonding in metals is not rigid. As a metal is struck by a hammer, the atoms slide through the electron sea to new positions while continuing to maintain their connections to each other. The same ability to reorganize explains why metals can be pulled into long, thin wires.