The Use of Scientific Models

Scientists are always making new discoveries and they often use models to support and demonstrate their research or ideas to others. Scientific models are representations of concepts or findings relating to science, usually three-dimensional and in a smaller or larger scale than the original. It can also be defined as a testable idea, one conjured from the human mind to explain certain aspects of nature. Models are mostly used in society in order to visually present complex notions or findings in a simplified manner, that is, to assist people in understanding and learning concepts. They aim to make a particular part or feature of the world easier to understand. They are used to help visualise or simulate, usually by referring to existing or commonly accepted knowledge. This makes models very important especially for scientists to present their findings or theories for others to understand. Models are especially useful in conveying concepts like ionic, covalent and metallic lattices as in nature, they are too miniscule to see with the naked eye, making them difficult to comprehend. Although all models have their limitations, they are a great way to express and understand concepts and findings. Models play a vital role in demonstrating scientific ideas and research.

Three Main Types of Chemical Bonding

There are three main types of chemical bonds. One of the main types of chemical bonding is ionic bonds. An ionic bond is when oppositely charged ions are drawn together by an electrostatic force of attraction. This happens when one atom completely transfers its valence electron(s) to another, resulting in a positive ion (cation) and a negative ion (anion) which attract each other. Ionic bonds usually form between metals and non-metals. The metal gives away its extra electron(s), therefore it becomes a cation and the non-metal accepts the electron(s), therefore it becomes an anion. These oppositely charged ions are attracted and form an ionic bond. For example, sodium chloride is an ionic compound, meaning that it is a compound that contains ions held together by ionic bonds. Sodium (metal) and chloride (non-metal) ions are bonded because they are oppositely charged ions which means they attract each other, forming an ionic bond. Sodium, which has a valency of +1, gives its extra electron to chloride, which has a valency of -1, so that each has a full outer shell. This results with a positive sodium ion and a negative chloride ion which attract each other.

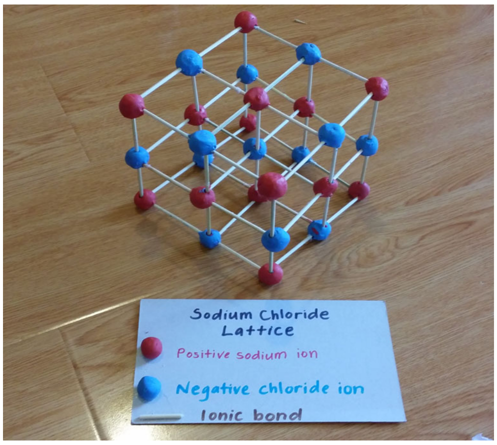
Another type of chemical bonding is covalent bonds. A covalent bond is the attractive force that results from atoms sharing one or more pairs of electrons. Atoms will share their electrons in order to fill their outermost electron shell and become stable. The shared pair(s) of electrons orbit the nuclei of both atoms and this holds them together. Covalent bonds usually form between non-metals, either with atoms of the same element or a different non-metal. The inert gases are an exception as they exist as monatomic molecules. An example of a covalent bond is a hydrogen molecule. A hydrogen molecule is a covalent molecule, meaning that a covalent bond binds the atoms together. Hydrogen has a valency of 1, meaning it can share its 1 electron with another hydrogen atom so that they both have a full outer shell and become stable.

Another type of chemical bonding is metallic bonds. A metallic bond is the attraction between delocalised valence electrons and positively charged metal ions. It is the chemical bonding that holds the atoms of a metal together. In a piece of metal, the outer shell electrons are not held to their own atoms but leave their atoms and wander from atom to atom. A sea of electrons is formed within the metal. The metal atoms become positively charged metal ions as its valence electrons leave them to wander from atom to atom. The electrons are shared by all the ions and the random movement of the sea of electrons provides the force that holds all these ions together, a metallic bond. An example of a metallic bond is copper. Copper is a metal that contains positively charged copper ions and a sea of delocalised electrons. The detached electrons wander from one copper ion to another as they are shared between the positive metal ions. The electrons act as the force and holds the ions together, therefore making it a metallic bond.

How Ionic, Covalent and Metallic Lattices are formed

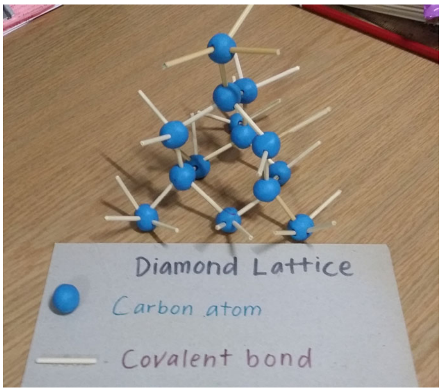
An ionic compound does not usually exist as isolated molecules. They exist as a part of a three-dimensional lattice, a large network of ions held together by ionic bonds which extends throughout the whole structure such as in sodium chloride. Its ionic bonds extend throughout the entire structure *(refer to Figure 1).* Ionic lattices are formed instead of ionic compounds because the ionic compounds join together to form a lattice, the anion of one compound is attracted to the cations of other compounds. In the case of sodium chloride, one negative chloride atom is surrounded by six positive sodium ions. It forms a giant ionic lattice as the arrangement is regular and repeated many times with large numbers of ions.

Figure 1: Sodium chloride lattice



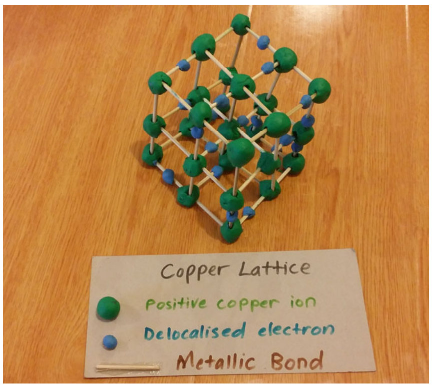
Most covalent compounds exist as small molecules as most atoms of non-metals can combine with each other by sharing electrons, forming covalent molecular compounds. However, in other instances, non-metals form giant covalent lattices. Covalent lattices can occur in both elements and compounds. Group IV contains elements that have four electrons in their outer shell, meaning that they can share their electrons with other atoms of the same element. For example, diamond is made up of carbon atoms that have covalent bonds *(refer to Figure 2)*. The carbon atoms join together in a very large lattice and all the atoms are held tightly by the strong covalent bonds that extend throughout the structure. Carbon has a combining power of four and in diamond, each carbon atom shares electrons with four other carbon atoms - forming four single bonds. Each carbon atom makes four covalent bonds with four of the carbon atoms around it.

Figure 2: Diamond Lattice



Positive metal ions surrounded by delocalised electrons actually exist as a three dimensional network (lattice) of ions. The outer shell electrons leave their metal atoms and wander from atom to atom. The electrons are shared by all the ions and the random movement of the sea of electrons provides the force that holds all these ions together, a metallic bond. This metallic bonding only occurs in metals and exists as a lattice in nature like in the case of a copper lattice. Copper is a metal and contains metallic bonds. The random movement of the valence electrons throughout the entire lattice structure of the metal provides the bond that holds all the copper ions together *(refer to Figure 3)*. This creates a very strong bond, meaning that a lot of energy is required to break it.

Figure 3: Copper Lattice



Properties of Ionic, Covalent and Metallic Lattices

Each type of lattice has its own properties from their unique structure and bonding. An ionic lattice has a variety of physical properties. They have high melting and boiling points due to their strong ionic bonds that extend throughout the entire structure. A lot of energy is required to break these bonds. They are poor conductors of electricity when they are solids because ionic substances do not have any free electrons due to the fact that they are held firmly by the ions. However, they are good conductors of electricity when they are molten. This is because when you heat an ionic compound, the ions vibrate faster and if enough energy is used, the ionic bonds break apart, leaving ions that are free to move and carry charge. They are also good conductors of electricity when they are dissolved in a solvent. This is due to the solvent's molecules coming between the ions and breaking the structure of the lattice. The ions are then free to move about and carry current. Ionic lattices have a range of properties.

A covalent lattice has many physical properties that can be explained in terms of it structure. They have extremely high melting and boiling points as their strong covalent bonds extends throughout the entire lattice. Similarly, they are hard because of the strong covalent bonds extending throughout the lattice. However, they are all poor conductors of heat and electricity as they do not have moving ions or mobile electrons. Graphite is an exception. A covalent lattice has many properties.

A metallic lattice has a range of physical properties. Its structure and bonding plays an important part in explaining these properties. Metals have high melting and boiling points due to the strong metallic bonds between the positive metal ions and the sea of electrons. This means that a lot of heat energy is required in order to break these metallic bonds so that it can change state. They are good conductors of electricity due to the outer shell electrons being free to move around. The electrons moving about allows the metal to carry an electric current. Metals are malleable and ductile as the rows of metal ions are able to slide over each other without their bonds breaking apart. Metals also have a shiny lustre due to the sea of electrons able to reflect light. Metallic lattices have a variety of properties.

Limitations of Models

Models help make scientific notions easier to comprehend but all models will have its own flaws. No model can possibly express and explain every detail of a certain scientific concept as a model is only a mere 'representation' of the actual thing. Models are limited as some properties cannot be recreated like in the metallic copper lattice (*Diagram 3*). The electrons in this model are supposed to be delocalised and able to move around freely, wandering from one metal ion to another. These mobile electrons are unable to be expressed like so in the model as it is difficult to make the electrons imitate this behaviour. The electrons in the model look fixed but in fact it is not and this can be misleading for people if they do not refer to the key/label. This is one limitation for models.

Another limitation is that the size ratio of the model can be misleading. Sometimes, it is just not possible for models to be created in the exact same size of the actual thing. In the case of ionic, covalent and metallic lattices, they are all minuscular structures but the models are, understandably, in an extremely larger proportion than it really is. After all, you cannot construct a model that is the actual size of a lattice. This may lead to warped interpretations. This is another limitation of models.

Yet another limitation is that models can give false impressions. Models are designed to be as accurate as possible but some aspects of the model can unintentionally give off false details. For example, the models of the lattices contain sticks that represent the types of bonds present. They seem like a tangible entity in the model but in fact are actually supposed to be imperceptible. They are only bonds or attractions and are entirely intangible. This feature can be deceptive and is a limitation of the model as it is not entirely possible to keep the atoms of the model suspended in the air and nothing to represent which atoms/ions bond with which.

Sometimes, models are oversimplified and this can lead to misconceptions but if it is too complex, it defeats the whole purpose of creating a model as it is to help people understand. A balance is to be found between the two. In the covalent diamond lattice structure (*Diagram 2*), it seems as if the lattice ends like shown but in fact, it is only showing a bit of the whole structure. The structure in fact continues on and on in three dimensions and is completely variable to the size of the diamond. Simplifying too much can sometimes be misleading. No one model is perfect, but in understanding its limitations, people can gain a fuller understanding of the theory or finding expressed with the model.

In conclusion, scientific models are extremely important in society to help people understand concepts or findings, especially those that you cannot physically see such as ionic, covalent and metallic lattices. Models play a vital role in demonstrating scientific ideas and research. They greatly assist in scientific progress and understanding.

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