Identifying Unknown Solids

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Abstract

The general properties of ionic, non-polar, polar, covalent network, and metallic crystals have been well studied. Given an unknown solid, tests can be done to determine its physical properties, which can then be compared to those of the five crystals. This experiment identified four unknown solids using the known properties of various types of solids. Each of the solids were put through a variety of tests for physical properties, such as conductivity, solubility, and melting point, as well as properties like texture, lusture, colour, etc.. These properties and behaviors were then compared to those of the five types of crystals. Through these comparisons it was determined that the unknown solids labelled K1 through K4 were non-polar covalent, metallic, covalent network, and ionic respectively.

Introduction

The purpose of this experiment was to determine the type (ionic, non-polar, polar, covalent network, or metallic) of unknown solid by comparing both quantitative and qualitative physical properties of the unknown to the general characteristics of such solids. The qualities compared were those expected of each type of compound.

Ionic compounds would generally show properties such as being non-conductive in solid form, but conductive when submerged in water, while being hard and brittle with a high melting point[1]. Ionic crystals are made of ionic bonds, which have very strong intermolecular forces, caused by the full transfer of electrons. These oppositely charged ions are held together by strong forces of attraction. This strong bond requires a lot of energy to break, contributing to a high melting point. The full transfer of electrons also creates full valence shells, which does not allow electricity to flow. When the ionic compound is submerged in water, the partial charges on water molecules can pull with ions in the ionic compound apart. In such a situation the ions can move from one site to another, thus conducting electricity.

A metallic solid would show a range of properties but mostly a lustrous finish as well as being conductive and non-soluble[1]. In a metal, the electrons are shared and can move freely from one nucleus to another. This movement allows the solid to conduct electricity. However, it is not soluble, because the sea of electrons is attracted more towards the large group of metal cations than the partial charges on the water. The other properties of a metallic vary greatly depending on the number of unfilled orbitals. A small number of valence electrons means less electrons in the electron cloud, resulting in weaker forces of attraction. On the other hand, a large number of valence electrons means that there are more electrons in the electron cloud, resulting in stronger forces of attraction.

Polar covalent solids will be soluble in water, while having a relatively low melting point, and being non-conductive in solution and as a solid[1]. Because the polar molecules have a partially positive and partially negative end, when arranged in a crystal, there will be small attractie forces in between them. This force of attraction is less than that of an ionic compound as the difference in charge is not as great (full electron transfer vs. partial charges). This means that they will have a relatively low melting point. When submerged in water, the polar molecules are attracted to the polar molecules of water, and therefore dissolves. In both solid form and in solution, there is no way for the electrons to transfer between molecules, which makes it unconductive.

Non-polar covalent solids will have a very low melting point, and will be non-soluble and non-conductive[1]. Non-polar covalent solids are only held together by London dispersion forces, which are very weak. This means that it takes very little energy to break them apart, making it have a very low melting point. This little force of attraction means that there will also be no attraction to water, which makes it non-soluble. Similar to the polar covalent bond, there is no way for electrons to transfer between molecules, which makes it unconductive in solid form and in solution.

The last type is covalent network solids, which are very hard, with a very high melting point, and generally non-conductive[1]. In a covalent network solid, there are many covalent bonds which bond the entire solid together. With so many bonds, a very large amount of energy is required to break the bonds apart, giving these types of solids a very high melting point. These bonds also hold the molecules together very strongly, making it very hard. Covalent solids are non-soluble, due to their large size and their symmetrical, non-polar nature. They are also generally non-conductive, due to the lack of delocalized electrons. Graphite is an exception, since each carbon is only bonded to three other carbons, creating a delocalized electron.

Materials

- 4 unknown solids
- Multimeter
- Distilled water

- 4 beakers
- Bunsen burner
- Scoopula
- 4 watch glasses
- Stirring rod
- 4 small ladles

Procedure

Small samples of each unknown solid was transported via a scoopula onto a watch glass. The appearance of each substance was recorded, keeping track of properties such as texture, lusture and colour. A multimeter was used to measure the resistance of the solid, with the probes placed on the smallest unit possible (size dependant). In between each measurement, the probes of the multimeter were rinsed with distilled water, and wiped with a piece of paper towel. Then four beakers were filled with distilled water, each about halfway, into which the samples were poured in individually. The mixtures were then stirred, and the appearance of the resulting mixtures or solutions were recorded. Another conductivity test was done by placing the probes into each of the mixtures at a similar depth and distance apart. The procedure for cleaning the multimeter probes between measurements was identical to previously described. In addition to the mixtures, the resistance of distilled water was also measured. A bunsen burner was set up and samples of the four unknown solids were transfered into each of the four small metal ladles. The ladles were held on top of the burner flame, with the physical changes (changes in appearance) and relative speed of change recorded. After the burning, K2 was tested again for conductivity.

Results and Observations

The resistance of distilled water was measured to be $800\,\mathrm{k\Omega}$, and the resistance of K2 after heating was measured to be $0.2\,\Omega$. General observations are listed in Table 1.

Compound	K1	K2	K3	K4
Appearance Before	• Reflective • White • Medium particle size • Sticks to side of container	• Ball-shaped, large particles • Dull, black-greyish colour • Dense	• Fine powder, small particle size • White	• White, slightly translucent • Small particle size
Resistance Before	$> 2000\,\mathrm{k\Omega}$	$> 2000\,\mathrm{k\Omega}$	$> 2000\,\mathrm{k\Omega}$	$> 2000\,\mathrm{k\Omega}$
Submersion in Water	• Dissolved after a few minutes • Particles initially sank	• No change • Sank to bottom	• Formed white translucent layer on top of water	• Dissolved after a few minutes • Initially sank
Resistance in Water	$670\,\mathrm{k\Omega}$	$1440\,\mathrm{k\Omega}$	$> 2000\,\mathrm{k\Omega}$	$270\,\mathrm{k\Omega}$
Heating	• Initially turned brown, then into a clear liquid • Turned into a caramel coloured, bubbling liquid • Caught on fire • Cooled into black solid • Fastest change	• Blackened • Particles melted and fused together to form one solid • Increased in lusture • Fast change	• No change	• Powder turned brown in colour • Flame colour turned to green • Slow change

Table 1: General observations

Analysis

One of the unique features of a metallic crystal is its ability to conduct electricity in solid form. During the experiment, none of the solids were able to conduct electricity in its original form. However, after heating and letting it cool down, K2 was able to conduct electricity extremely well. As well, the surface of the solid became more lustrous, matching the phyiscal properties expected of a metallic crystal. Because the melting points of metallic crystals vary greatly, the relatively fast melting of K2 can be expected. These similarities lead to the conclusion that K2 is a metallic crystal. The initial observations not matching were most likely due to an oxide layer which was mostly removed due to the melting and reforming of the metal.

Out of the four unknown solids, only K3 did not show any change after being heated by the bunsen burner flame. This high melting point indicates very strong intermolecular forces, such as ionic or covalent bonds in a covalent network structure. Ionic compounds would dissolve in water and conduct electricity in solution, but K3 did neither of these. Thus, K3 is a covalent network crystal.

K1 and K4 are both very similar in terms of solubility, but their differing melting points lead to the conclusion that K1 is a polar covalent crystal, and K4 is an ionic crystal. Both of these compounds dissolved in water, and gave resistances in the hundreds of kiloohms. When subjected to a bunsen burner flame, K1 reacted with the heat very quickly, changing from a white powder to a brown powder, then melting into a clear liquid. This very low melting point in conjunction with its solubility means that K1 is therefore a polar covalent compound. It was also flammable, which may mean that it is an organic compound, with the browning possibly indicating a caramelization reaction, with K1 being some kind of sugar. K4 on the other hand did not change much while being heated, with only a slight browning, otherwise staying the same, without melting. Although the resistance of the solution was pretty high, it was still the lowest of the 4 solids in solution. The high resistance can be attributed to the proportionality of concentration of ions to the conductivity. If a larger sample was dissolved, a more representative measurement of resistance could have been made. The presence of a green flame indicates the presence of ions (B^{2+}, Ba^{2+}, Ca^{2+}, Cu^{2+}, etc.) [3]. However, because the metal ladles were not cleaned throughly, these ions may have not originated from K4. Regardless, the high melting point and solubility provide overwhelming evidence that K4 is an ionic crystal.

There were a few anamolies with the conductivity tests, mostly due to the deionized water still possessing some ions. Ideally, the deionized water should be very unconductive, with over $18.2\,\mathrm{M\Omega/cm}$ of resistance [2]. However, the deionized water used in the experiment had a resistance of only $800\,\mathrm{k\Omega}$. Regardless, the measured resistance generally follows what is expected of the compound, even if only considering other characteristics.

Conclusion

Various physical properties of the unknown substances were used in comparison with those expected of the five types of crystals to identify the unknown substances K1-4 as polar covalent, metallic, covalent network, and ionic respectively.

Bibliography

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