英语版

全日制普通高级中学教科书（必修加选修）

CHEMISTRY

第三册

课程教材研究所
双语课程教材研究开发中心　组译

化学

人民教育出版社
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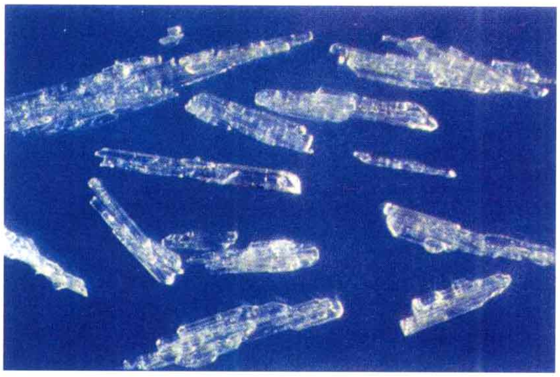
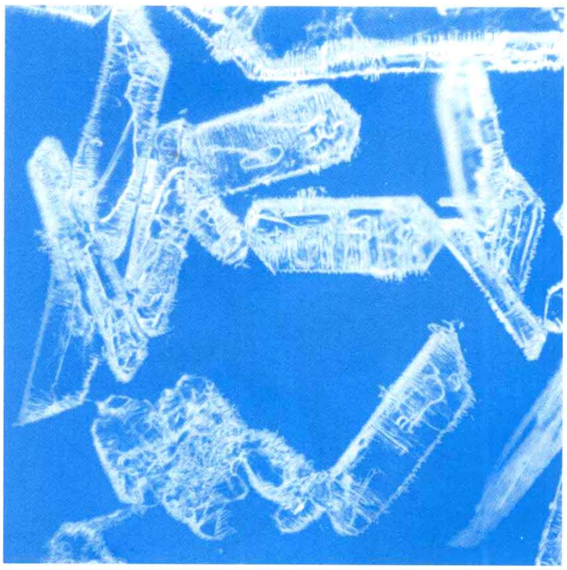

KNO_3 crystal


$K_2Cr_2O_7$ crystal


Alum crystal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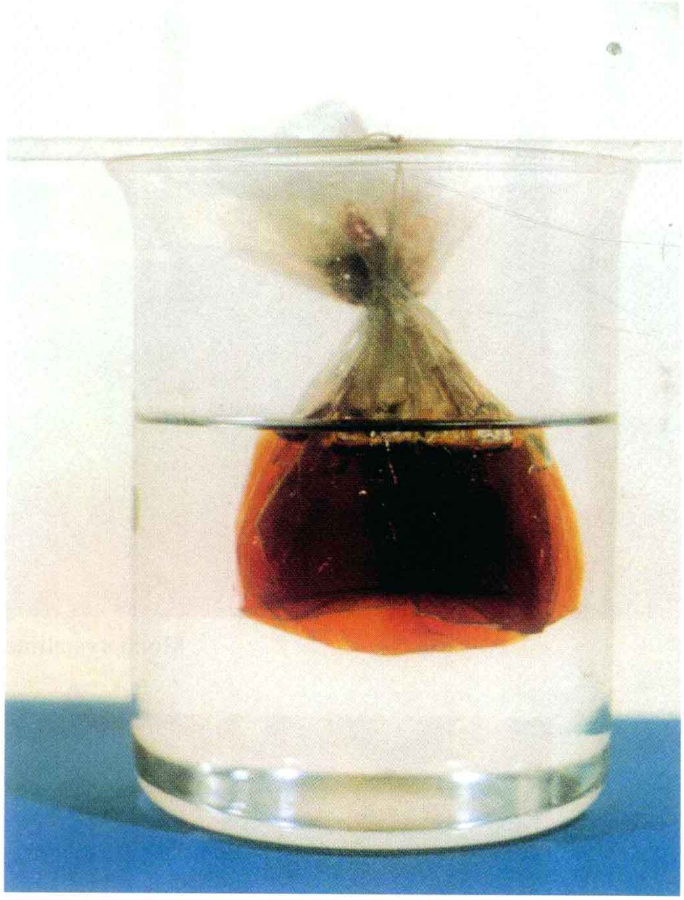
Dialysis


Solar-energy powered car


Electroplated products

Monocrystalline silicon

Workshop for electrolyzing copper

Products of
alkali-chloride industry

说　明

随着改革开放的不断扩大，中国在经济、文化、教育等诸多方面与各国间的交往日益增强，中国人学习英语的热情也日趋高涨。当今社会，是否熟练掌握英语，已成为衡量一个人的知识结构甚至综合素质的一个重要方面。在这样的形势下，多角度、多渠道提高人们的英语水平，特别是提高基础教育阶段在校高中学生的英语水平，已经成为社会的迫切需要。

为了适应这种新的形势和需要，作为教育部直属单位的课程教材研究所着手研究开发这套英语版普通高中教材，包括数学、物理、化学、生物、历史、地理六门必修课程，由人民教育出版社出版。

这套英语版高中教材，根据经国家教育部审查通过、人民教育出版社出版的《全日制普通高级中学教科书（试验修订本·必修）》翻译而成，主要供实行双语教学的学校或班级使用，也可以作为高中生的课外读物，其他有兴趣的读者也可以作为参考书使用，使学科知识的掌握与英语能力的提高形成一种双赢的局面。

为了使这套新品种的教材具有较高的编译质量，课程教材研究所双语课程教材研究开发中心依托所内各科教材研究开发中心，在国内外特聘学科专家和英语专家联袂翻译，且全部译稿均由中外知名专家共同审校。

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2003年4月

高中《化学》教科书
说　明

《全日制普通高级中学教科书（必修加选修）化学　第三册》是根据教育部2002年颁布的《全日制普通高级中学课程计划》和《全日制普通高级中学化学教学大纲》，在《全日制普通高级中学教科书（试验修订本·选修）》第三册的基础上修订而成的。

普通高中教育，是与九年义务教育相衔接的高一层次的基础教育。高中教材的编写，旨在进一步提高学生的思想道德品质、文化科学知识、审美情趣和身体心理素质，培养学生的创新精神、实际能力、终身学习的能力和适应社会生活的能力，促进学生的全面发展，为高一级学校和社会输送素质良好的合格的毕业生。

教材中教学内容的编排严格按照教学大纲的要求，并充分考虑到我国高中化学教学的实际情况，分为必学和选学两部分。必学内容是全体学生在规定的课时内必须学习的，选学内容则是供学有余力的学生选用。此外，教材中还设有“资料”、“阅读”、“讨论”、“家庭小实验”、“研究性学习的课题”等栏目。“资料”主要是介绍一些知识性的常识；“阅读”主要是介绍与教学内容有关的化学史料或联系实际的知识，以扩大学生的眼界；“讨论”主要是根据教材的内容和教学过程的实际需要，提出一些具有一定启发性的问题，供学生在课堂上开展讨论；“家庭小实验”是为了进一步培养学生的实验能力，配合课堂教学而编写的，由学生在课外完成；“研究性学习的课题”主要是让学生联系社会实际，通过亲身体验进行学习，培养学生的创新精神和实际能力。为了更加充分地调动学生的学习积极性，教材中还编排了大量的插图，语言也力求生动活泼，以增强可读性。

本教材原试验本由武永兴、胡美玲主持编写，参加编写的有（按编写顺序）：王晶、冷燕平、胡美玲、李文鼎、何少华、戴健、陈晨。武永兴、胡美玲审读了全书。

参加本次修订的有（按编写顺序）：王晶、冷燕平、胡美玲、李文鼎、何少华、陈晨。

责任编辑为王晶。

责任绘图为李宏庆。

在本书的编写和试教过程中，得到了广大教师的支持，提出了不少建设性的意见，在此一并表示感谢。希望广大教师和教学研究人员在教材的使用过程中继续提出意见和修改建议。

人民教育出版社化学室

2003年2月

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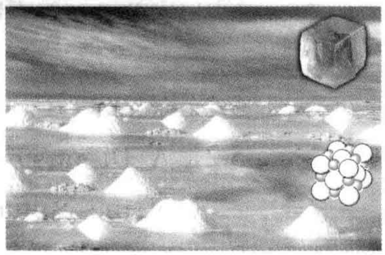
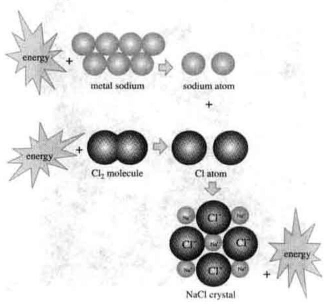
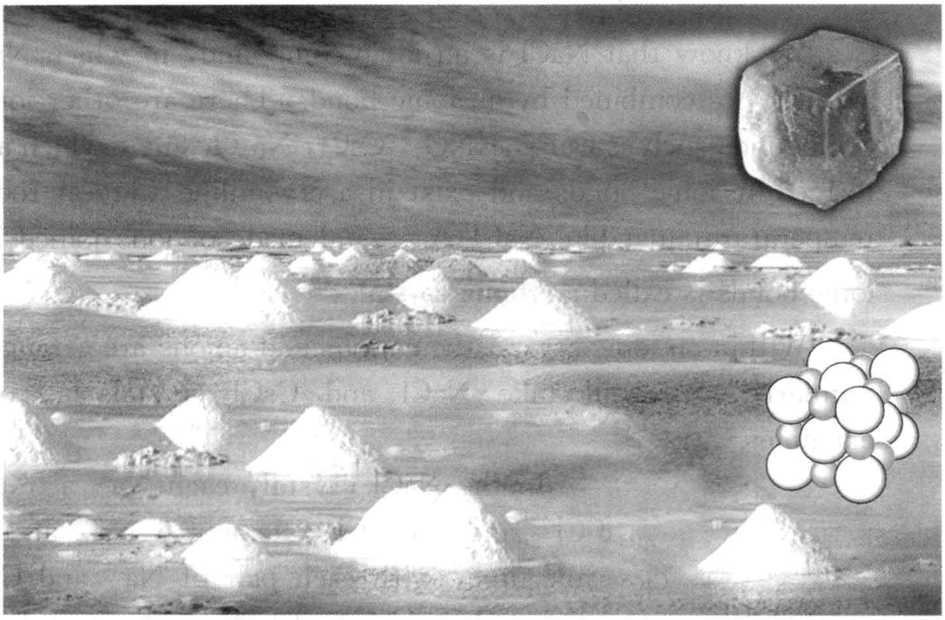




energy
metal sodium
sodium atom
energy
Cl_2 molecule
Cl atom
energy
NaCl crystal

Chapter 1

Types and Properties of Crystal



Crystal of sodium chloride and its structural model

In daily life we encounter and use various substances in their solid state, among which many are crystals, such as snow flakes or natural rock crystals, common salt, monosodium glutamate, and sugar in the kitchen, and so on. Although all these appear as crystals, they can be put into various groups which have different properties. Particles such as molecules, atoms or ions, are arranged regularly in a crystal. According to their types and their interactions of the particles, crystals can be divided into ionic crystals, molecular crystals, atomic crystals, metallic crystals, etc.

Studying the types and properties of crystal is significant for our understanding of matter in nature and to produce new substances. In this section some knowledge about crystals will be introduced.

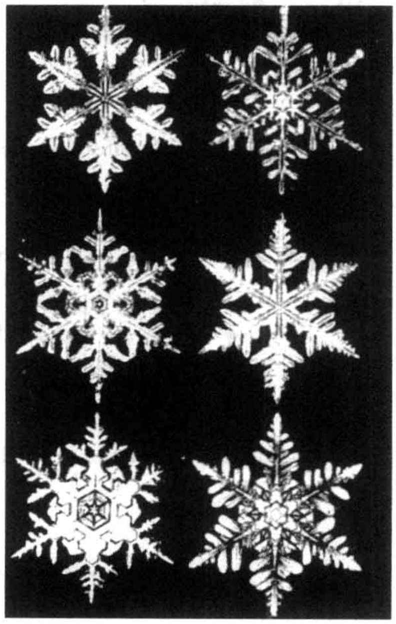


Fig. 1-1　Forms of snow crystal

1.1 Ionic Crystal, Molecular Crystal and Atomic Crystal

Ⅰ. Ionic crystal

We know that NaCl is an ionic compound, in which Na^+ and Cl^- are combined by an ionic bond. There are other ionic compounds such as CaF_2, KNO_3, CsCl, Na_2O, etc., which are formed by ionic bonds and exist in a crystalline state at room temperature, just like NaCl. A crystal made of ions joined by ionic bonds is called an **ionic crystal.** ❶

❶ *e*: If you want to know more, please visit: www.0-100.com.cn/5/23/1/0141.htm

Within an ionic crystal the cations and anions are arranged regularly. We will take NaCl and CsCl crystals as our examples.

In the NaCl crystal, each Na^+ attracts 6 Cl^- and each Cl^- attracts 6 Na^+ at the same time, with each pair of Na^+ and Cl^- connected by an ionic bond, as shown in Fig. 1-2. While in the CsCl crystal, each Cs^+ is surrounded by 8 Cl^- and each Cl^- is surrounded by 8 Cs^+ with an ionic bond connecting each pair of Cs^+ and Cl^-, as shown in Fig. 1-3. We can see that ions are the particles that make up ionic crystals.

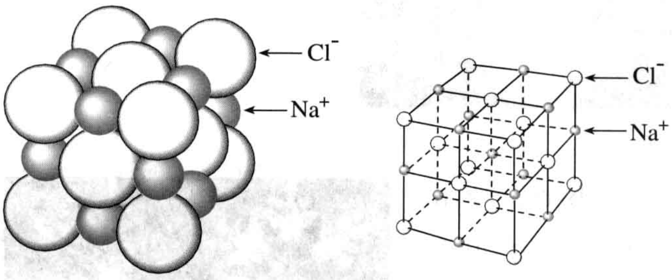


Fig. 1-2 Structural model of NaCl crystal

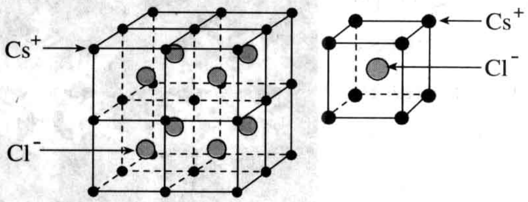


Fig. 1-3 Structural model of CsCl crystal

In NaCl and CsCl crystals there are no distinct molecules of NaCl or CsCl, while the ratio of cation to anion is 1 : 1 in both crystals. The chemical formulae NaCl and CsCl, therefore, are empirical formulae giving the whole-number ratio of the ions in the ionic crystals, rather than molecular formulae expressing the real molecular structure.

The ionic bonds existing between ions in the ionic crystals are relatively strong, making the crystals hard and difficult to compress. In addition, a lot of energy is needed to break up such strong ionic bonds, so the crystals can become liquid or gas from the solid state. In general, therefore, ionic crystals have a relatively high melting point and boiling point. For example, NaCl has a melting point of 801 ℃ and a boiling point of 1 413 ℃; and CsCl has a melting point of 645 ℃ and a boiling point of 1 290 ℃.

In junior middle school we all did experiments on electric conduction of substances, and we learnt that the crystal of NaCl is not conductive. But molten NaCl or its liquid solution is an electricity conductor. Why? After understanding the structure of ionic crystals, we should be able to make a simple explanation of such properties.

When an ionic crystal is heated and melted, the movement of ions increases due to the increased temperature, and the attraction between the anions and cations is overcome so that anions and cations will move freely. This is why the molten NaCl can conduct electricity.

NaCl crystal is soluble in water. When NaCl dissolves in water, the impact of the water molecules weakens the acting force between Na^+ and Cl^-, and NaCl is ionized into hydrated sodium ions and hydrated chlorine ions, which can move freely. This is why the liquid solution of NaCl also conducts electricity.

II. Molecular crystal

1. Intermolecular force and hydrogen bond

We have known there are strong interactions, i.e. the chemical bonds between adjacent atoms in molecule. Is there any interaction between molecules? It is the fact that gases NH_3, Cl_2, CO_2 and other gases condense into liquid or solid state when the temperature is lowered and the pressure is increased. In this process, the distance between gaseous molecules is getting shorter and the disorder state of irregular motion turns to be regular arrays. This fact proves there is indeed interaction between molecules. Such interactive force, holding molecules together, is **intermolecular force.** It is also called Van der Waals❶ force. Intermolecular force is much weaker than chemical bond. It affects the melting and boiling points.

In general, among substances with a similar composition

❶ J.D. Van der Waals, 1837—1923, Dutch physicist. He was the first person who studied intermolecular force. So this force is also called Van der Waals force.

and similar structure, the larger the relative molecular mass, the greater the intermolecular force and the higher the melting point and boiling point. Take the simple substance of halogen for example. With the increase of the relative molecular mass, the intermolecular force increases and the melting point and boiling point become correspondingly higher (Fig. 1-4). A similar situation exists for carbon tetrahalides (Fig. 1-5).

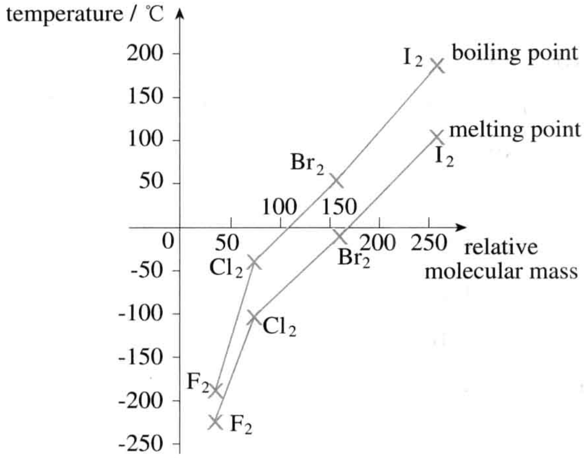


Fig. 1-4 Relationship of melting point and boiling point with the relative molecular mass of a simple substance of halogens

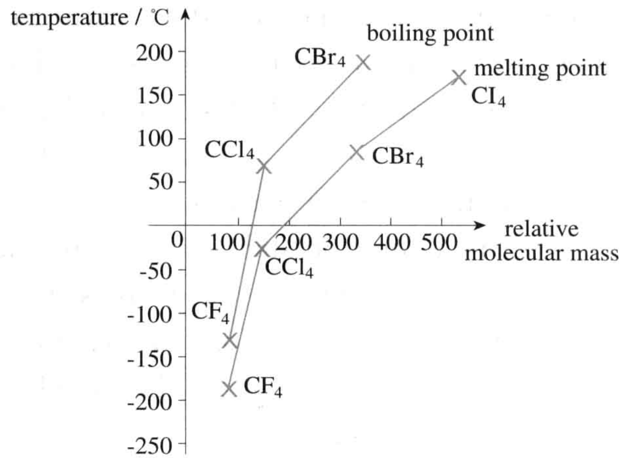


Fig. 1-5 Relationship of melting point and boiling point with the relative molecular mass of carbon tetrahalides

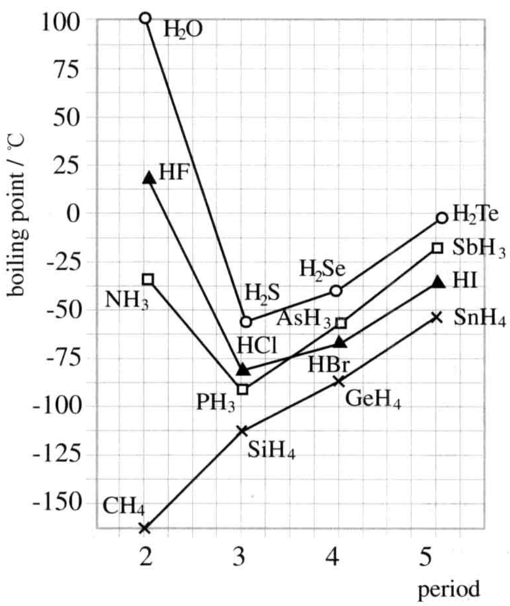


Fig. 1-6 Boiling points of certain hydrides

However, the variation in the melting point and boiling point of some hydrides is not consistent with these rules. We can see from Fig. 1-6 that the boiling points of NH_3, H_2O, and HF are inconsistent. For example, the boiling point of HF is actually 20 ℃ rather than below −90 ℃ as it should be according to the descending curve, while the boiling point of H_2O should be below −70 ℃ instead of actually being 100 ℃.

Why are the boiling points of HF, H_2O and NH_3 inconsistent? This is because of another interaction between their molecules, which is slightly stronger than the intermolecular force and makes them evaporate at a higher temperature. Scientific research shows that such an interaction between molecules is created by what is called a hydrogen bond.

How is a hydrogen bond formed? Consider HF as an example. In a HF molecule, the H—F bond has a strong polarity, because the F atom strongly attracts the electrons, making the shared electron pair strongly deviate toward the F atom. Namely the electron cloud of the H atom is pulled off by the F atom and the H atom becomes a nearly "naked" proton. Such a H nucleus with small radius and certain positive charge will attract the negatively charged F atom of an adjacent HF molecule. Such electrostatic attraction is called the hydrogen bond. It is much weaker than a chemical bond but slightly stronger than the intermolecular force. Usually we consider the hydrogen bond as a relatively strong intermolecular force. The hydrogen bond between molecules makes the melting point and boiling point of substances increase, for more energy is needed to break the hydrogen bonds for solids to melt or for liquids to evaporate. The symbol "…" is used in Fig. 1-7 to represent a hydrogen bond in order to distinguish it from a chemical bond.

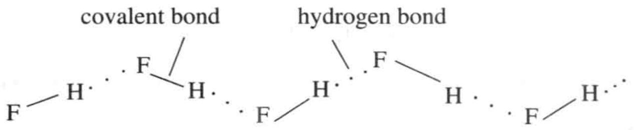


Fig. 1-7 Hydrogen bonds between HF molecules

Water has another inconsistent property which is that its volume expands while its density decreases when it is frozen. This can also be explained by the hydrogen bond.

Water exists in vapor as separate H_2O molecules. But in its liquid state, several H_2O molecules are usually combined together by hydrogen bonds to form $(H_2O)_n$ (Fig. 1-8). And in its solid state (ice) the molecules are extensively connected to each other by hydrogen bonds to form rather loose crystals, leaving many openings in the structure. That makes the volume increase and density decrease so that ice can float in water (Fig. 1-9). This property of water has important implications for the survival of aquatic animals.

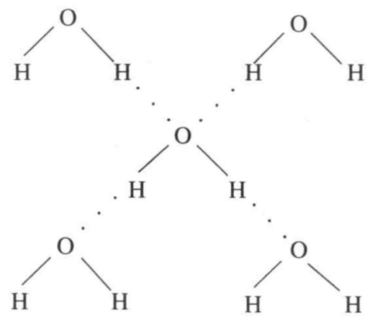


Fig. 1-8 Hydrogen bonds between water molecules

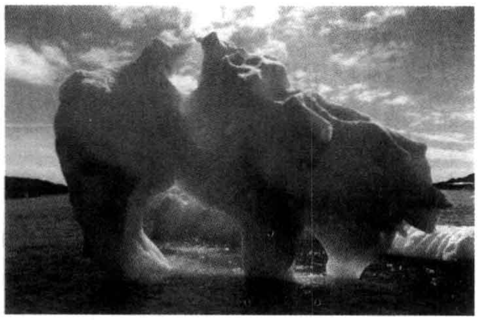


Fig. 1-9 Ice floating in water

DISCUSSION

What would the earth look like if no hydrogen bond exist between water molecules?

2. Molecular crystal

H_2O, CO_2, NH_3, CH_4 etc. have an intermolecular force between their respective molecules, and they appear as crystals in their solid state. Such crystals, whose constituent particles are molecules combined by a intermolecular force, is referred to as a **molecular crystal.** Fig. 1-10 shows the structural model of CO_2 crystal. In addition, halogens, rare gases, O_2, CO etc can also form molecular crystals.

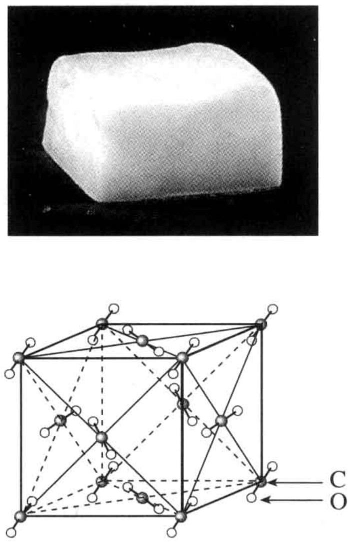


Fig. 1-10 Dry ice and the structural model of its crystal

Because the intermolecular force is very weak and easy to break, it is relatively easy for the crystal to change into liquid or gas. Thus molecular crystals have a relatively low melting point and boiling point. For example, the melting point and boiling point of CO are −199 ℃ and −191.5 ℃ respectively. Moreover, molecular crystals have a relatively low hardness. The magnitude of the intermolecular force influences the melting point, boiling point, and other properties of molecular crystals. For example, the greater the intermolecular force, the more energy is needed for the molecular crystals to melt or to evaporate, and the higher its melting point and boiling point.

Because a molecular crystal is composed of molecules, it is not an electric conductor either in its solid state or in its molten state.

REFERENCE

Similar are Soluble

The properties of molecular crystals are different depending on different constituent molecules. For example, some molecular crystals differ in their solubility, and that the same molecular crystal has quite different solubility in various solvents. We can see that sucrose and phosphoric acid are easily soluble in water but hardly at all in carbon tetrachloride, whereas naphthalene and iodine are easily soluble in carbon tetrachloride but hardly at all in water.

We can learn from a structural analysis of these crystals and solvents that sucrose, phosphoric acid and water are composed of polar molecules, but iodine, naphthalene and carbon tetrachloride have non-polar molecules. Through observation and study of many experiments, people have made the empirical rule of "similar are soluble": a non-polar solute is in general soluble in a non-polar solvent, while a polar solute is usually