

Section 4.8: The Structure and Properties of Solids

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Answers may vary. Sample answers:

A. If a 3-D photocopier could replicate any three-dimensional object, it could change our lives in many positive ways. For example, it could eliminate waiting for delivery of items that need to be shipped from far away and it could replace lost or broken items. A 3-D photocopier could reproduce valuable pieces of art quickly and inexpensively. It could improve health by creating healthy food and creating organs for transplant.

A 3-D photocopier could also have negative impacts on our lives. People who now work in manufacturing, repair, or delivery might find themselves out of a job if a 3-D photocopier could replicate any three-dimensional object. People who work in design might find that they were no longer paid for their work, since a 3-D photocopier could reproduce it with little effort.

In addition, many new technologies turn out to pose dangers to human health. A 3-D photocopier may also have unknown negative effects on our health.

B. The types of object that I would probably 3-D photocopy most often are objects that I often lose or need to replace such as keys, toiletries, clothing, and books. I also might use the machine to create new objects in the same way as I create collages using a photocopier.

C. Large objects or more complicated objects that have many interacting parts would be most difficult to 3-D photocopy.

D. There are many likely to be many objects that you could not make with a 3-D photocopier. Since this machine could only make objects from the constituent elements, it could not make gold objects unless it had some gold to work with, for example. It is unlikely that it could make biological material or living organisms.

E. This machine could promote green chemistry because it would promote the local generation of goods, thus reducing carbon dioxide emissions resulting from transportation of goods, and it would also reduce waste in the creation of objects, since only objects that are needed would be created.

F. There are many possible drawbacks to use of a 3-D photocopier, including the social, economic, legal, and ethical issues noted in part A. As one example, illegal copying and producing of goods will receive a large boost from a machine like this, and the regulation of production and tracking of goods will become a very important focus for government and industrial sectors. This could lead to a more repressive society.

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1. Properties of the Four Types of Solids

Type of solid	ionic crystal	metallic crystal	molecular crystal	covalent network crystal
Particles involved	oppositely charged ions	metal cations	molecules	C and Si
Primary force of attraction	ionic bonding (electrostatic attraction between opposite charges)	metallic bonding (electrostatic interactions of the metal cations for the “electron sea”)	intermolecular forces of attraction	covalent bonding (sharing of electrons)
Boiling point	high	high	low	high
Electrical conductivity: solid, liquid, solution	solution and liquid	solid and liquid	none	none (except semiconductors and graphite)
Other physical properties of crystal	hard, brittle	shiny, malleability, hardness	little hardness	hardness
Conditions necessary for formation	reaction of a metal with a non-metal	extraction from mineral ore	varies depending on the substance	high temperature
Examples	NaCl, NaF	Al(s), Fe(s)	CO ₂ (s), H ₂ O(s)	C ₆₀ , diamond

2. (a) A metallic crystal is the type of solid that would have the greatest electrical conductivity.
- (b) A molecular crystal is the type of solid that would have the lowest melting point.
- (c) An ionic crystal is the type of solid that would have the highest conductivity when dissolved in water.
- (d) A molecular crystal is the type of solid that would have the lowest hardness.
3. (a) Metallic crystals are one of the two solid conductors, and they conduct better than semiconductors.
- (b) Molecular crystals are held together by intermolecular forces, which are weak compared to the bonding in the other types of crystals, so molecular crystals would melt at a lower temperature.
- (c) Ionic crystals releasing ions as they dissociate to form a solution that conducts electricity. Some molecular substances like acids ionize to form conducting solutions.
- (d) Molecular crystals are the weakest of all the crystals because the bonds between the entities that make up these substances are weak.

- 4. (a)** Both CO_2 and H_2O form molecular crystal structures. $\text{CO}_2(\text{s})$ is a cubic lattice made up of the linear CO_2 molecules, and $\text{H}_2\text{O}(\text{s})$ is formed of stacks of hexagonal lattices that are made up of bent H_2O molecules.
- (b)** NaCl forms an ionic crystal and HCl forms a molecular crystal. $\text{NaCl}(\text{s})$ is a cubic lattice made up of the linear bonds between Na^+ and Cl^- ions, and $\text{HCl}(\text{s})$ has an orthorhombic lattice structure of linear $\text{H}-\text{Cl}$ molecules.
- 5.** Doping means adding a small amount of an additional element, such as boron or arsenic, to a semiconductor. This is done to change the conductive properties of the semiconductor.
- 6. (a)** A metallic solid conducts electricity and has a high melting point.
- (b)** An ionic solid does not conduct electricity as a solid but does when dissolved in heat.
- (c)** A covalent network solid does not conduct electricity and has a high boiling point.
- (d)** A molecular solid does not conduct electricity and has a low boiling point.
- 7. (a)** Answers may vary. Sample answer: To distinguish between an ionic crystal and a molecular crystal, raise the solids to a moderately high temperature. The molecular crystal will melt before the ionic crystal.
- (b)** Answers may vary. Sample answer: To distinguish between a metallic crystal and a covalent crystal, test for conductivity. The metallic crystal will conduct electricity and the covalent crystal will not.
- (c)** Answers may vary. Sample answer: To distinguish between a molecular crystal and a metallic crystal, test for malleability. The molecular crystal will break and the metallic crystal will bend.
- (d)** Answers may vary. Sample answer: To distinguish between an ionic crystal and a covalent crystal, dissolve both solids in water and test for conductivity. The ionic crystal will conduct electricity in solution and the covalent crystal will not.
- 8.** You could tell experimentally if titanium dioxide is an ionic solid or a molecular solid by melting TiO_2 testing for electrical conductivity. If there is conductivity, it is an ionic solid; if not, it is a molecular solid.
- 9.** The properties of salt and sugar are different because ionic solids (salt) and molecular solids (sugar) are very different in their hardness, conductivity, boiling points, and melting points. This is because ionic solids are held together tightly by ionic bonding between ions and molecular solids are held together more loosely by intermolecular forces between molecules. Salt will therefore dissolve in water and conduct electricity while dissolved. It has a high melting point and is hard and brittle like other ionic crystals.