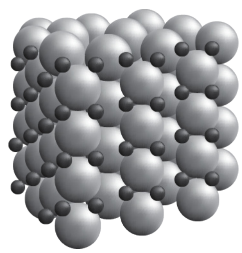
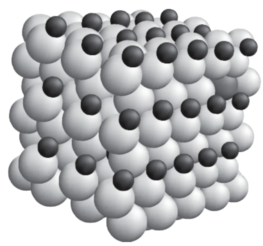
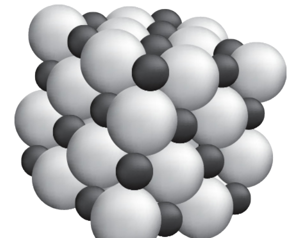
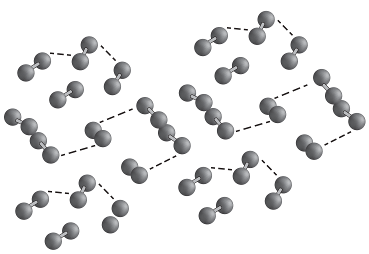
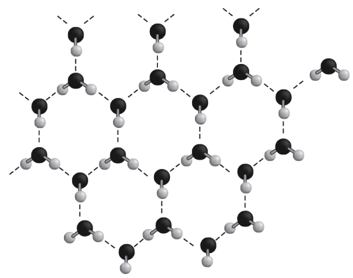
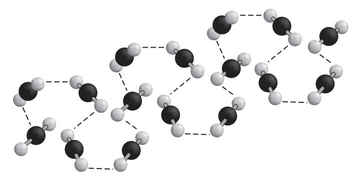
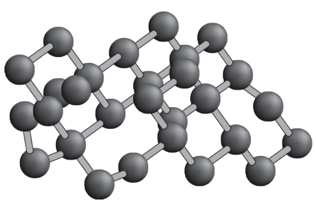
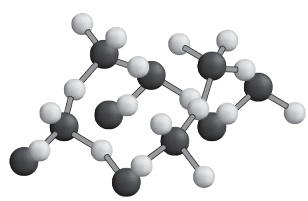
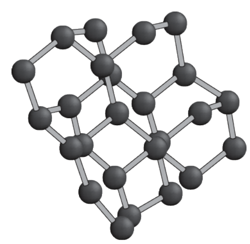
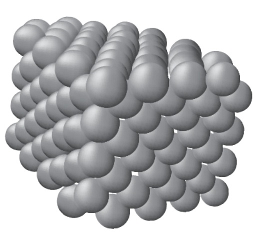
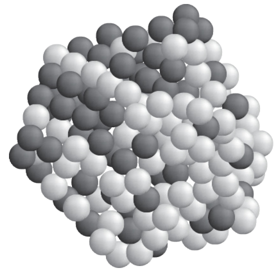
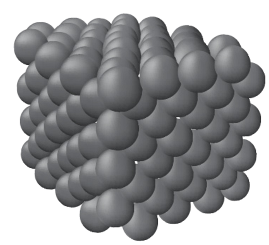
Types of Solids

What are some common categories of solids, and their properties?

Why?

Not all solids are the same. Solid substances have a tremendously wide range of melting points. Helium melts at –272 °C while tantalum hafnium carbide melts at 4215 °C. Some are conductive, others are not. Some readily dissolve in water, others do not. In this activity, you'll look at four types of solids, the types of substances that are typically in each category, and some of the properties typical for each.

Model 1 – Arrangements of Atoms in Solids

Ionic Solids	 Iron(II) Sulfide (FeS)	 Calcium Bromide ($CaBr_2$)	 Sodium Chloride (NaCl)
Molecular Solids	 Nitrogen (N_2)	 Ice (H_2O)	 Dry Ice (CO_2)
Network Covalent Solids	 Diamond (Carbon)	 Silica (SiO_2)	 Silicon (Si)
Metallic Solids	 Platinum (Pt)	 Brass (Cu and Zn)	 Nickel (Ni)

1. List the four types of solids illustrated in Model 1.

2. Complete columns A–C in the table below by referring to the examples in Model 1. Place a check in the box that appropriately describes the types of atoms that are usually seen in each type of solid.

	A	B	C	D	E	F
	All atoms are nonmetals	**All atoms are metals**	**Atoms are metals and nonmetals**	**Molecular structure**	**Formula units**	**Attractive forces**
Ionic Solids						
Molecular Solids						
Network Covalent Solids						
Metallic Solids						

3. Complete columns D and E in the table above by referring to the examples in Model 1. Place an X in the box that appropriately describes the arrangement of atoms or molecules in the solid (either **molecular**—distinct molecules, or **formula units**—repeating units in three dimensions with no distinct molecules).

4. There are four possible forces of attraction that hold atoms or molecules together in a solid: covalent bonds, ionic bonds, metallic bonds and intermolecular forces. These depend on the type of atoms in the solid and whether the connections are between ions, atoms or molecules. Within your group, discuss the type of attractive forces that are most likely holding the atoms or molecules together in each type of solid. List your answers in column F in the table above.

STOP

Read This!

When a solid substance is heated, the weakest attractive forces in the solid structure are overcome, and the solid melts. In some cases, this results in individual atoms or ions, and in other cases, this results in individual molecules. Regardless, melting is a physical change and does not alter the chemical formula of the substance.

5. For each type of solid in Model 1, indicate the type of attractive forces that are broken upon melting, and describe the individual particles that make up the resulting liquid.

	Bonds/forces broken upon melting	**Individual particles in the liquid**
Ionic		
Molecular		
Network covalent		
Metallic		

6. Match the following descriptions with one of the four types of solids.

____________________ Metallic atoms with very loose electrons for a lattice of nuclei held together by a sea of electrons, or metallic bonds.

____________________ Nonmetal atoms form molecules with covalent bonds. The molecules are held together in a solid by intermolecular forces of attraction.

____________________ Metal and nonmetal atoms form a lattice of alternating positive and negative ions held together by ionic bonds.

____________________ Nonmetal atoms form a lattice structure held together with covalent bonds.

7. If a particular solid had very strong attractive forces, would you expect the melting point of that solid to be relatively high or relatively low? Explain your reasoning.

Model 2 – Melting Points and Enthalpies of Fusion

Type of Solid	Substance	Chemical Formula	Melting Point (°C)	Enthalpy of Fusion (kJ/mole)
Ionic	Iron(II) sulfide	FeS	1195	51.0
	Calcium bromide	$CaBr_2$	730	17.5
	Sodium chloride	NaCl	804	30.3
Molecular	Nitrogen	N_2	–210	0.72
	Water	H_2O	0.0	6.02
	Carbon dioxide	CO_2	–78	8.10
Network covalent	Diamond	C	3550	117.0
	Silica	SiO_2	1650	12.5
	Silicon	Si	1687	50.0
Metallic	Platinum	Pt	1770	24.0
	Brass	Cu and Zn	~930	Varies
	Nickel	Ni	1453	71.0

8. Notice that the substances listed in Model 2 are the same as those in Model 1.

   a. Which type of solid has the lowest melting points?

   b. Is your answer in part *a* consistent with your answer to Question 7?

9. The **enthalpy of fusion** given in Model 2 for each substance is a measure of the energy (in kJ) needed to melt a mole of that substance.

   a. Which type of solid has the lowest enthalpies of fusion?

   b. Is your answer in part *a* consistent with what you know to be the relative strength of the four types of attractive forces? Explain why or why not.

10. Using both melting point data and enthalpy of fusion data, rank the remaining three types of solids from weakest attractive forces to strongest attractive forces. Make sure there is consensus in your group before moving on.

STOP

Read This!

As you may have found in answering the previous question, there is a lot of overlap in properties among the four types of solids. For example, platinum (a metallic solid) has a higher melting point than several of the network covalent solids, but the majority of metallic solids have a much lower melting point than network covalent solids. The categories for solids are not as clear cut as we would like them to be; nevertheless, they are useful for predicting relative properties.

11. Use the concepts you have learned in this activity to predict the type of solid for each of the following substances. Anyone in your group should be able to justify your group's answers.

Substance	Chemical Formula	Melting Point (°C)	Enthalpy of Fusion (kJ/mole)	Type of Solid
Chlorine	Cl_2	–102	6.41	
Hydrogen bromide	HBr	–87	2.41	
Titanium	Ti	1668	20.9	
Sodium bromide	NaBr	747	26.1	
Boron	B	2076	50.2	
Mercury	Hg	–38.3	2.29	

Read This!

Properties other than melting point and enthalpy of fusion can be helpful when categorizing a substance as one of the four types of solids. For example, conductivity and solubility can give great insight into the structure of a solid. For a substance to be soluble in water it must be charged or polar. (Remember the rule "like dissolves like.") For a substance to be conductive, in any state, there must be charged particles in a mobile state so that they can complete a circuit.

Model 3 – Solubility and Conductivity of Solids

Substance	Chemical Formula	Solubility in Water	Conductive as a Solid	Conductive as a Liquid	Conductive in Aqueous Solution
Iron(II) sulfide	FeS	Insoluble	No	Yes	N/A
Calcium bromide	$CaBr_2$	Very soluble	No	Yes	Yes
Sodium chloride	NaCl	Very soluble	No	Yes	Yes
Nitrogen	N_2	Slightly soluble	No	No	No
Water	H_2O	N/A	No	Slightly	N/A
Carbon dioxide	CO_2	Slightly soluble	No	No	No
Diamond	C	Insoluble	No	No	N/A
Silica	SiO_2	Insoluble	No	No	N/A
Platinum	Pt	Insoluble	Yes	Yes	N/A
Brass	Cu and Zn	Insoluble	Yes	Yes	N/A
Nickel	Ni	Insoluble	Yes	Yes	N/A

N/A = not applicable

12. Refer to Model 3.

    a. Which type(s) of solid is generally very soluble in water?

    b. Which type(s) of solid is least soluble in water?

13. Refer to Model 3.

    a. Which type of solid is most conductive in the solid state?

    b. Use the concepts you have learned about the type of solid in part *a* to explain why it is conductive in the solid state.

14. Explain why ionic substances would be conductive after they are melted, even though they are not conductive as solids.

Extension Questions

15. The last column in Model 3 (Conductive in Aqueous Solutions) has several N/A entries. Give two reasons why conductivity data for those substances would not exist.

16. Engineers use materials to perform different functions based on the properties of the materials. For centuries we have used metals for tools and more recently for electrical circuits. What properties of metallic solids make them well suited for this purpose?