1. A Student's View of Liquids and Solids

Introduction

A student of general chemistry is usually asked to carry out experiments for which the methods and procedures have been prescribed in detail. Very little latitude is granted. It is a rare occasion when the student is asked to plan the experiment as well as do it. This experiment, which focuses on certain properties of liquids and solids (Ebbing/Gammon, Chapter 11), provides that opportunity.

Purpose

There are two principal tasks in this experiment. First, you will measure the densities of one or more solids whose crystalline lattices belong to the cubic system. Second, you will determine the heat (enthalpy) of fusion for ice.

Intermolecular forces

Most, if not all, of the differences among the properties of the three states of matter are due to differences in their intermolecular forces. These forces are largest for solids, somewhat diminished for liquids, and smallest for gases. As you might expect, the densities of solids, liquids, and gases and the enthalpies that accompany phase changes reflect these forces and their differences.

Concept of the experiment

This experiment gives you a unique chance to plan and execute procedures that will enable you to accomplish two tasks. No unusual glassware or equipment is required.

Your first task is to measure the densities of two or more metals. These metals may be powders, irregularly shaped pieces, or pieces with well-defined shapes. You will need to devise a general method that will not be affected by the form of the metal.

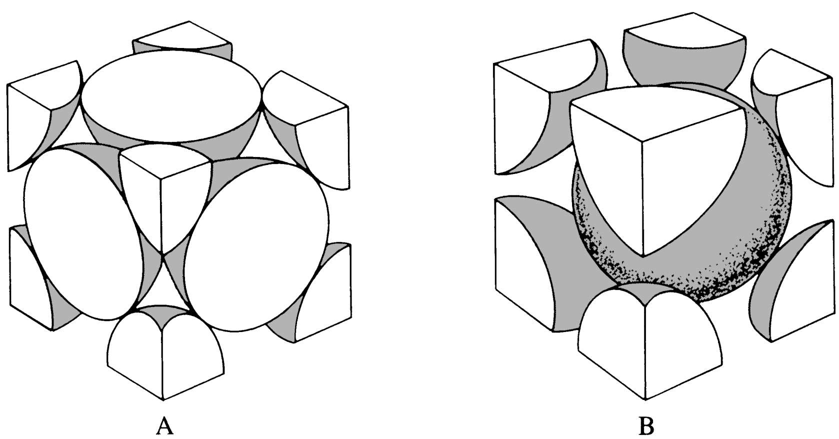

FIGURE 1.1
(A) Face-centered and (B) body-centered unit cells. Note that the radii of four spheres comprise a body diagonal of the body-centered unit cell and a face diagonal of the face-centered unit cell.

These metals will have either a face-centered cubic unit cell or a body-centered cubic unit cell. Both unit cells are shown in Figure 1.1. When coupled with the edge length of the unit cells, this information will allow you to calculate the densities of these metals. You will then be able to compare the densities you have measured with the ones you have calculated. You will also calculate the empty space in each lattice and show that it is independent of the edge length of the unit cell.

Your second task is to determine the heat (enthalpy) of fusion (Ebbing/Gammon, Section 11.2) for ice. The calorimeter will consist of two nested Styrofoam (polystyrene) coffee cups. This calorimeter will already be familiar to you if you did the Thermochemistry and Hess's Law experiment. To become more familiar with it, read Appendix: Using a Coffee-Cup Calorimeter carefully. It may give you some ideas about approaching this part of the experiment. Ice and, of course, distilled water will be available.

In addition to devising the procedures for this task, you will also be required to devise a mathematical equation that will allow you to calculate the desired enthalpy. Use common sense when you construct this equation. Remember that heat will flow from warm water and a warm calorimeter to ice and cold water.

Procedure

Getting started

1. You may be asked to work with a group of students. If so, your laboratory instructor will designate the size of the group and its members.
2. Determine the temperature of the laboratory.
3. Obtain samples of two or more metals and the required structural information. Record that information below.

Metal	**Structure***	**Edge Length (Å)**
....	....	....
....	....	....
....	....	....

*FCC = face-centered cubic; BCC = body-centered cubic.

Doing the experiment

1. To do the experiment, follow the procedures that you devise in the Prelaboratory Assignment.

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Date: ....

Course: ....

Section: ....

Instructor: ....

Student name: ....

Team members: ....

....

....

Prelaboratory assignment

1. Give the step-by-step procedures that you will use for the following tasks:

   a. Measuring the density of the metals

   b. Measuring the heat of fusion of ice

2. What equation will you use to calculate the heat of fusion of ice? The specific heat of water is 4.184 J/(g • °C), and the heat capacity of your calorimeter is 1.0×10^1 J/°C. Explain the reasoning behind your equation.

3. What special safety precautions, if any, will be necessary in following your procedures?

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Date:	....	Student name:	....
Course:	....	Team members:	....
Section:	....		....
Instructor:	....		....

Results

Student name: .... Course/Section: .... Date: ....

Questions

1. Calculate the percentage of empty space in 1 mole of water at 25°C. Obtain the density from the experiment "Some Measurements of Mass and Volume." The volume of a molecule of water can be taken as the sum of the volumes of the two hydrogen atoms and the oxygen atom. Use the single-bond covalent radii of 37 pm for hydrogen and 66 pm for oxygen and $V = 4\pi r^3/3$ to calculate the volume of each atom.

2. a. Calculate the density of each metal from its structure, edge length, and atomic weight.

b. Compare the calculated and experimental densities, and comment on the comparison.

3. a. Calculate the percentage of empty space in a face-centered cubic lattice, and show that it does not depend on the edge length of the unit cell or on the size of the atoms in the unit cell. For this calculation, you must find the edge length in terms of the radii of the atoms in the unit cell, the total volume of the unit cell in terms of the edge length, and the filled volume from the total volume of the atoms in the unit cell.

b. Calculate the percentage of empty space in a body-centered cubic lattice, and show that it does not depend on the edge length or the size of the atoms in the unit cell.

c. Provide a general comparison of the empty space in a solid with that in a liquid. If you did the experiment “Boyle’s Law and the Empty Space in Air,” include the empty space in a gas in your comparison.

4. Compare your experimental value for the heat of fusion of ice with the accepted value, 6.01 kJ/mol. Comment on the comparison and try to explain your error (if it exists).