Name _____**Chem 162, Section**: _____**Group Number:** _____

ALE 20. Crystalline Solids, Unit Cells, Liquids and the Uniqueness of Water

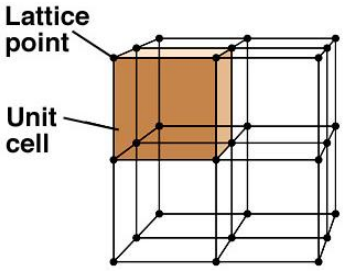
(Reference: pp. 463 – 473 of Sec. 12.6 *Silberberg 5th edition*)

How are the particles within a crystalline solid arranged?

The Model: Unit Cells—the Simplest Repeating Unit in a Crystal

Solids can be classified into two broad categories crystalline solids and amorphic solids (or non-crystalline) solids. The particles (atoms, molecules or ions) in a **crystalline solid** are arranged in a regular repeating geometrical pattern in 3-Dimensional space. The particles in an **amorphic solid** are arranged in a somewhat random hap hazard manner. The discussion below concerns crystalline solids.

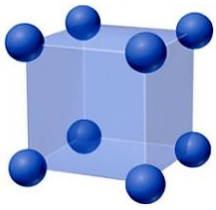
The structure of solids can be described as if they were 3-dimensional analogs of a piece of wallpaper. Wallpaper has a regular repeating design that extends from one edge to the other. Crystals have a similar repeating design, but in this case the design extends in 3-dimensions from one edge of the solid to the other. A **unit cell** is the simplest regular repeating pattern of particles (ions, atoms, or molecules) that pervades the crystalline **lattice**. Each unit cell is defined in terms of **lattice points—**the points in space about which the particles are free to vibrate in a crystal. Unit cells may be used to determine the empirical formula of an ionic compound, a substance's molar mass and its density.



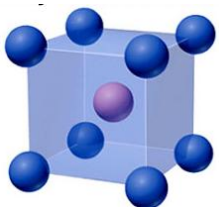
A Portion of a 3-D Lattice

In 1850, Auguste Bravais showed that crystals could be divided into 14 different unit cells—in this class we will only focus on the **simple cubic**, **body-centered cubic** and **face-centered cubic** unit cells:

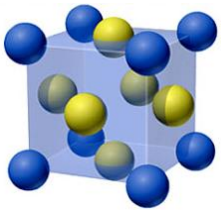
Expanded View of Cubic Unit Cells



Simple cubic

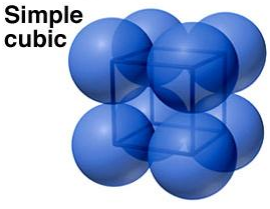


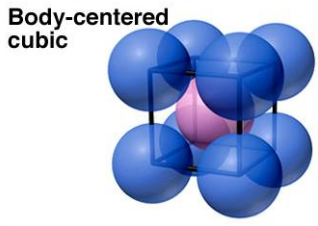
Body-centered cubic

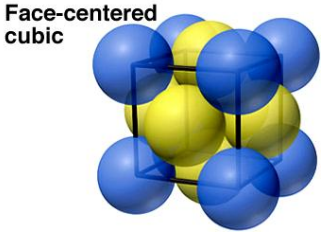


Face-centered cubic

Space-filling View of Cubic Unit Cells







Key Questions

1. What is the difference between an amorphous solid and a crystalline solid on the molecular and macroscopic levels? Give an example of each type of solid.

2. How are a solid's unit cell and crystal structure related?

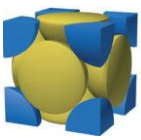
3. Both solid Kr and solid Cu consist of individual atoms at their lattice points. Why do their physical properties differ so much? (e.g. Cu conducts electricity, Kr doesn't; Cu melts at 1084.62 °C, Kr at -157 °C)

4. Enter the appropriate number in each of the blanks below
   a.) An atom at one of the corners of a cubic unit cell is shared by total of ____ unit cells. Hence, a cubic unit cell contains a total of _____ atom(s) at the corners.
   b.) A cube has _____ faces. An atom on one of the faces of a face-centered cubic unit cell is shared by total of _____ unit cells. Hence, a face-centered cubic unit cell has a total of _____ atom(s) at on the faces.

5. Name each unit cell and determine the number of atoms per unit cell for each metal illustrated below. Show your work/explain how you arrived at your answer.
   a.) Polonium, Po

   b.) Iron, Fe

   c.) Silver, Ag



6. Identify the kind of particles that would be found at the lattice points (*be very specific*) and the major intermolecular force of attraction in the following crystalline solids:

Substance	Particle(s) found at lattice points	Major IMF present
Diamond		
Gold		
Ice crystals		
Sodium phosphate		

7. A compound between elements "A" and "Z" forms a crystal with a ***face-centered cubic unit cell***. If each unit cell has atoms of element "A" at each corner and atoms of element "Z" on each face, what is the empirical formula of the compound? *Explain/show how you arrived at your answer*. Hint: See question 5 since one of the unit cells is face-centered-cubic.

8. An element crystallizes with a ***face-centered cubic*** lattice and has a density of 1.45 g/cm^3. The edge of its unit cell is 4.52 x 10^{-8} cm. *Explain/show how you arrived at of your answers below*. Hint: See question 5 since one of the unit cells is face-centered-cubic.

   a.) How many atoms are in each unit cell?

   b.) Calculate the volume of the unit cell.

   c.) Calculate the mass of the unit cell. (Hint: D = mass / volume)

   d.) Calculate the approximate molar mass in amu (atomic mass unit: 1 amu = 1.67 x 10^{-24} g) of the element and then identify the element. (Hint: don't forget to take into account then number of atoms per unit cell.)

Properties of the Liquid State

Read Section 12.4, Properties of the Liquid State, and then answer the questions below.

10. a.) Does the *strength* of the intermolecular forces in a liquid change as the liquid is heated? Explain.

    b.) Why does liquid viscosity decrease with rising temperature?

11. n-Pentanol ($C_5H_{11}OH$; MW = 88.15 g/mol) has nearly the same molar mass as n-hexane (C_6H_{14}; MW = 86.17 g/mol), but is more than 12 times as viscous at room temperature. Explain why in terms of the relevant intermolecular forces.

12. Rank the following in order of *decreasing* surface tension at a given temperature. Briefly explain your reasoning in terms of the relevant intermolecular forces.

    Methanol (CH_3CH_2OH), ethane (CH_3CH_3), formaldehyde ($H_2C{=}O$)

13. Rank the compounds in the previous question in order of *decreasing* viscosity at a given temperature. Briefly explain your reasoning in terms of the relevant intermolecular forces.

14. Why does an aqueous solution of ethanol (CH_3CH_2OH) have a lower surface tension than water?

The Uniqueness of Water

Read Section 12.5, The Uniqueness of Water, and then answer the questions below.

15. For what types of substances is water a good solvent? For what types is it a poor solvent? Explain in terms of the relevant intermolecular forces.

16. Water is quite unusual in that in the solid state it floats on the surface of liquid water, rather than sink like other substances do as they make the phase change from the liquid to solid. Describe the molecular basis of the property of water responsible for the presence of ice on the surface of a frozen lake.