MATERIALS SCIENCE & SOLID STATE CHEMISTRY

HOMEWORK 2

SCI 1410

SELF-DIRECTED LEARNING SELF-RATING SURVEY

As you may already realize, a big part of the materials science is your development of skills and attitudes that help you attain success in unstructured learning experiences. I hope that your experiences in materials science will contribute in a positive way toward your becoming a lifelong learner.

Olin's current definition of life-long learning (LLL) competency is: *Student is able to identify and to address his/her own educational needs in a changing world*. Developing your capacity as a self-directed, life-long learner is a critical component of this course. The course format provides many opportunities for you to identify project goals, manage your time and effort, select learning strategies, create and implement work plans, discover and evaluate information resources, self-assess your progress, develop personal attributes (e.g., motivation, self-efficacy) that aid your self-directed learning, and reflect on your learning experiences.

To emphasize the importance of this aspect of the course, ten percent of your grade comes from assessment of your competency in life-long learning skills, as demonstrated through the course's many self-directed learning opportunities. The LLL grade is made up of several assignments that ask you to reflect on your development of relevant LLL skills. The first of these assignments is a survey that asks you to rate your abilities in different areas related to self-directed learning.

The self-directed learning self-rating scale is located at:

http://www.surveymonkey.com/s.aspx?sm=ME6A_2bx7In2uO8Q_2bGI6DnoQ_3d_3d

IMPORTANT NOTE: The ratings you give yourself on the survey do not in any way affect your LLL grade in the course. If you complete the survey, you will receive full credit for the assignment. Please respond as honestly and accurately as you can to the survey items.

READINGS

Atomic structure and bonding. This chapter will be a lot of chemistry review for most of you, but it may include some interesting materials angles that you haven't seen in the past.

- Callister Chapter 2, or
- Askeland Chapter 2

Thermal properties. These readings cover the basic thermal behavior of materials. While you are reading about thermal properties, consider how the thermal behavior connects to interatomic bond type and bond strength.

- Callister 6th edition: Chapter 19
- Callister 7th edition: Chapter 19 (I believe this chapter is on the web site: http://bcs.wiley.com/he-bcs/Books?action=resource&bcsId=2971&itemId=0471736961&resourceId=7554. Check the instructions that came with your book)
- Askeland 4th edition: Chapter 21
- Askeland 5th edition: Chapter 22

The key concepts in these sections are:

- Some basic definitions: atom, atomic number, mole, atomic weight, ions, ionization energy (be familiar with these, but don't spend your time memorizing definitions)

- Electrons can move from one energy state to another within atoms through absorption and emission of energy
- Electronegativity – know what it is and how it affects the type of bonding (covalent and ionic)
- Bohr and wave mechanical atomic models for the atom – basic description, differences
- Force and energy vs. interatomic separation plot, relationship between bonding force and bonding energy
- Interpretation of force and energy vs. interatomic separation charts with respect to material properties (thermal expansion, melting temperature, modulus of elasticity)
- Various types of interatomic bonds
  - Ionic, covalent, metallic, secondary – basic description of each type
  - Equation for percent ionic character
  - Expected bonding type(s) in different solids
- Thermal expansion as it relates to interatomic bonding, and the coefficient of thermal expansion
- Heat capacity and specific heat

Please note the concepts that seem to be particularly unclear or difficult.

P R O B L E M S

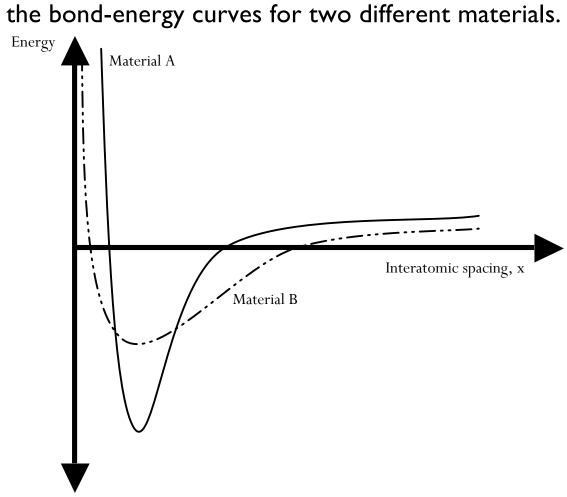
When you work through the problems, consider how the concepts may apply to your project work.

1. Askeland Problem 2-23. Materials such as silicon carbide (SiC) and silicon nitride (Si_3N_4) are used for grinding and polishing applications. Rationalize the choice of these materials for this application (discuss structure-property connections).

2. Askeland Problem 2-32. Would you expect Al_2O_3 or aluminum to have a higher coefficient of thermal expansion? Explain.

3. What type(s) of bonding would be expected for each of the following materials:
   a. Bronze (a copper-tin alloy)
   b. Nylon
   c. Polypropylene
   d. Aluminum Silicate (Al_2SiO_5)
   e. Liquid Helium
   f. Graphite
   g. Barium Sulfide (BaS)

4. Consider the following graph of the bond-energy curves for two different materials.



   a. Which of the two materials will have the lowest coefficient of thermal expansion over a given change in temperature? Justify your answer.
   b. Which of the two materials will have a higher melting temperature? Justify your answer
   c. Which of the two materials will have a higher stiffness? Justify your answer
   d. If Material B is a metal, do you think that Material A is a metal, ceramic, or polymer? Justify your answer.

5. Calculate the percent ionic character in SiC and CaF_2. Which one would you expect to have a higher melting temperature?

6. OPEN-ENDED PROBLEM. Askeland Problems 2-38 and 21-31. *NOTE: Only one answer is required, as they are very similar problems.*
(2-38) Turbine blades used in jet engines can be made from such materials as nickel-based superalloys. We can, in principle, even use ceramic materials such as zirconia or other alloys based on steels. In some cases, the blades also may have to be coated with a thermal barrier coating (TBC) to minimize exposure of the blade material to high temperatures. What design parameters would you consider in selecting a material for the turbine blade and for the coating that would work successfully in a turbine engine? Note that different parts of the engine are exposed to different temperatures, and not all blades are exposed to relatively high temperatures. What problems might occur? Consider the factors such as temperature and humidity in the environment that the turbine blades must function.
(21-31) What design constraints exist in selecting materials for a turbine blade for a jet engine that is capable of operating at high temperatures?

7. The net potential energy between two adjacent ions, E_N, may be represented by the sum of the attractive energy (E_A) and the repulsive energy (E_R).

$$E_A = -\frac{A}{r} \qquad E_R = \frac{B}{r^n}$$

Where *A*, *B*, and *n* are constants specific to the ionic system and *r* is the distance separating the ions.

Calculate the bonding energy E_0 in terms of the parameters *A*, *B*, and *n* using the following procedure:
   a. Differentiate E_N with respect to *r*, and then set the resulting expression equal to zero, since the curve of E_N versus *r* has a minimum value at E_0.
   b. Solve for *r* in terms of *A*, *B*, and *n*, which yields r_0, the equilibrium interionic spacing.
   c. Determine the expression for E_0 by substitution of r_0 into the net potential energy equation.

8. OPEN-ENDED PROBLEM. Below is a graph of Heat Flow vs. Temperature for High Density Polyethylene (HDPE) through its melting point. On top of this graph, sketch the expected graph for Low Density Polyethylene, and explain why your curve looks the way it does. Be sure to consider the relative position of the graph as well as the slope of the curve at the melting point onset.