Chapter 8

Lota_2 Dæmi A3_ Sameindir og efni

8.8 What is the difference between an amorphous solid and a crystalline solid?

ANS A crystalline solid has a repeating geometric arrangement of order whereas an amorphous solid lacks this characteristic.

8.10 Using circles, draw regular two-dimensional arrangements that demonstrate low packing efficiency and high packing efficiency.

ANS See Figure 8.3

8.12 Using circles, show that a cubic structure (squares in 2-D) has a lower coordination number than a hexagonal structure.

ANS See Figure 8.3.

8.14 Explain why hcp and ccp structures have the same coordination number.

ANS See Figure 8.4.

8.16 Explain why graphite is described as having a layered structure.

ANS The distance between C atoms within a single plane is relatively short compared to the distances between C atoms in different planes.

8.18 Iridium forms a face-centered cubic lattice, and an iridium atom is 271.4 pm in diameter. Calculate the density of iridium.

ANS 22.58 g/cm^3

8.20 Manganese has a body-centered cubic unit cell and has a density of 7.88 g/cm^3. From this information, determine the length of the edge of the cubic cell.

ANS 2.850×10^{-8} cm

Metals and Metallic Bonding

8.22 How many electrons per atom are delocalized in the sea of electrons model for the following metals? (a) iron; (b) vanadium; and (c) silver.

ANS a) iron = 8, b) vanadium = 5, c) silver = 11

8.24 The sea of electrons model is not generally used for quantitative predictions of properties. What factors are left out of this model that might prevent quantitative precision?

ANS Factors related to band theory are not part of the model.

8.26 What is the key difference between metallic bonding (in the sea of electrons model) and ionic bonding (as described in Chapter 7) that explains why metals conduct electricity and ionic solids do not?

ANS Unlike metallic bonding, ionic bonding does not produce "free" electrons in the solid phase. Those "free" electrons in metallic bonding can conduct current, but without the "free" electrons, ionic solid will not conduct electricity.

8.28 Describe how the combination of atomic orbitals gives rise to bands in the limit of large numbers of atoms.

ANS Electrons in bulk materials will occupy the lowest bands. The Fermi level is the electron-occupied level with the highest energy. The next level up from the Fermi level is the conduction band. The energy gap between the valence band (Fermi level) and the conduction band determines how readily the material can conduct electricity.

8.30 In terms of band theory, what is the difference between a conductor and an insulator? Between a conductor and a semiconductor?

ANS Conductors have excited electrons in the upper energy conductance band. These electrons can flow. The band gap between the valence and conductance bands overlaps in conductors but not semiconductors.

8.32 Use the web to find out what a "III-V" semiconductor is. How is this type of semiconductor related to silicon?

ANS A "III-V" semiconductor is a compound semiconductor consisting, in the intrinsic form, of atoms of one element belonging to group three of the periodic table and of one element belonging to group five.

8.34 What type of atom is needed as a dopant in an n-type semiconductor? Why is it called n-type?

ANS An n-type semiconductor is doped with a small amount of substance having an extra electron (ie. P) compared to the Group IV material of the semiconductor. These are called n-type because they add an electron (n for negative) to the matrix but do not impart a full negative charge because of the extra proton that comes along with the dopant.

8.36 Is an n-type semiconductor actually negatively charged?

ANS No, the dopant provides an extra electron, but the dopant also has an extra proton.

8.38 Suppose that a device is using a 15.0-mg sample of silicon that is doped with 1×10^{-5}% (by mass) phosphorous. How many phosphorous atoms are in the sample?

ANS 3×10^{13}

Intermolecular Forces

8.40 Why are dispersion forces attractive?

ANS Dispersion or London forces are the result of instantaneous dipoles. While their lifetimes are very short, these dipoles will attract one another just as opposite charges or "permanent" dipoles would.

8.42 What is the relationship between polarizability and dispersion forces?

ANS Dispersion forces are related to the naturally occurring probabilities of having the electron distribution momentarily askew in two atoms. Polarizability refers to the susceptibility of a molecule to having its electron distribution altered by an external field.

8.44 Why are dipole-dipole forces typically stronger than dispersion forces?

ANS Dipole-dipole interactions are based upon "permanent" dipoles as an artifact of the electron distribution within the molecule. London forces are based on instantaneous dipoles. The short lifetimes of these dipoles lead to a lesser magnitude of attraction than the dipole-dipole force.

8.46 Which of the following compounds would be expected to form intermolecular hydrogen bonds in the liquid state? (a) CH_3OCH_3 (dimethyl ether), (b) CH_4, (c) HF, (d) CH_3CO_2H (acetic acid), (e) Br_2, (f) CH_3OH (methanol)

ANS (c) HF, (d) acetic acid, and (f) methanol

8.48 What type of intermolecular forces must be overcome in converting each of the following from a liquid to a gas? (a) CO_2, (b) NH_3, (c) $CHCl_3$, (d) CCl_4

ANS (a) Van der Waals (b) hydrogen bonding (c) dipole-dipole (d) Van der Waals

8.50 Rank the following in order of increasing strength of intermolecular forces in the pure substances. Which exists as a gas at 25 °C and 1 atm? (a) $CH_3CH_2CH_2CH_3$ (butane), (b) CH_3OH (methanol), (c) He

ANS He < butane < methanol; helium and butane are gases at the given conditions.

8.52 Explain from a molecular perspective why graphite has properties that are useful for lubrication.

ANS Within a plane the distance between C atoms is roughly the same as the actual bond distance of the C-C bonds. The distance to the next C atom out of the plane though is about twice that far. This provides a series or planes (or sheets). The sheets will “slip” across one another with little external energy. This means that graphite is an excellent lubrication in certain applications.

Condensed Phases – Liquids

8.54 What makes a chemical compound volatile?

ANS A high vapor pressure due to weak attractive forces.

8.56 Why must the vapor pressure of a substance be measured only after dynamic equilibrium is established?

ANS With a dynamic equilibrium the pressure of the molecules in the gas phase will remain constant and can be measured rather easily.

8.58 Predict the order of increasing vapor pressure at a given temperature for the following compounds: (a) FCH_2CH_2F, (b) $HOCH_2CH_2OH$, (c) FCH_2CH_2OH.

ANS $HOCH_2CH_2OH < FCH_2CH_2OH < FCH_2CH_2F$

8.60 Suppose you have three unknown pure substances that are liquids at room temperature. You make vapor pressure measurements and find that substance Q has a pressure of 110 torr, substance R has a pressure of 42 torr, and substance S has a pressure of 330 torr. If you slowly increase the temperature, which substance will boil first and which will boil last?

ANS The highest vapor pressure should be the first to boil. That being the case, “S” should boil first. It will be followed by “Q” and then “R”.

8.62 Rank the following hydrocarbons in order of increasing vapor pressure: C_2H_6, $C_{10}H_{22}$, CH_4, C_7H_{16}, $C_{22}H_{46}$.

ANS $C_{22}H_{46} < C_{10}H_{22} < C_7H_{16} < C_2H_6 < CH_4$

8.64 When water is in a tube such as a buret, in which direction does the meniscus curve? What does this observation say about the relative magnitude of adhesion and cohesion in that system?

ANS The meniscus of water in a tube will curve downward. This says that the adhesive forces are much stronger than the cohesive forces.

Polymers

8.66 Why is temperature increased to start most addition polymerization reactions?

ANS The heating in an addition polymerization takes place to assist with the generation of the free radical necessary for the reaction.

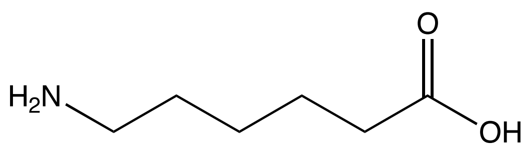
8.68 The monomer of polyvinylchloride is $H_2C{=}CHCl$. Draw an example of an isotactic PVC polymer.

ANS See Figure 8.23 (a)

8.70 Why are isotactic or syndiotactic polymers often more attractive for materials development?

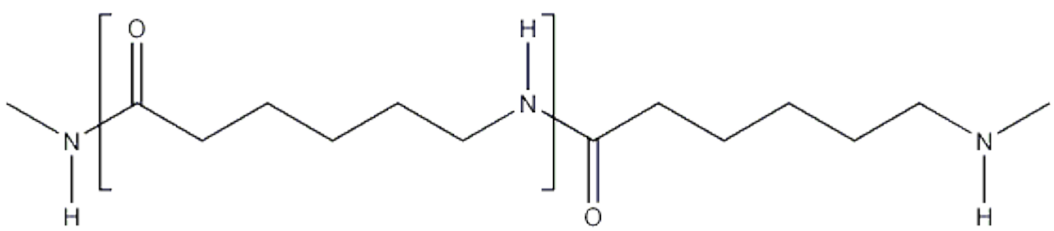
ANS The structure of these polymers is much better defined than that of an atactic polymer. This means that the physical properties of the isotactic and syndiotactic polymers are better known and these provide reactions that are more predictable and controllable.

8.72 Nylon-6 is made from a single monomer:



Sketch a section of the polymer chain in Nylon-6.

ANS



8.74 Use the web to look up the polymers used for six synthetic fibers. Classify the polymers as: (a) addition or condensation polymers and (b) as alternating, block or graft copolymers if they are copolymers.

ANS Given the wide array of polymers, answers may vary. Use a web search engine to acquire the reference.

8.76 What conditions would prohibit the use of a thermoplastic polymer?

ANS Thermoplastic polymers are not suited for use in high temperature applications.

8.78 What structural characteristics are needed for additives such as plasticizers?

ANS The plasticizer must be easily incorporated into the solid polymer and should be non-volatile. Loss of the plasticizer will most likely result in a loss of elasticity and could produce off-odors.

8.80 Use the web to find an application where the presence of isotactic, syndiotactic, or atactic polymers affects the physical properties important for an application of a polymer.

ANS Once again, there is a wide variety of answers for this question.

Insight into the Invention of New Materials

8.82 What was the observation that caused Smalley and coworkers to investigate further and ultimately discover C_{60}?

ANS Spectroscopy experiments produced results that coincided with 60 and 70 C-atom entities.

8.84 Many experts feel that applications of OLED technology will soon become common. Do a web search to identify emerging uses for OLEDs. Can you find any available commercial products using OLED displays?

ANS Organic Light Emitting Diodes (OLED) consume much less power than conventional LEDs. As such there is a wide variety of applications including displays for digital cameras and cell phones along with applications in "heads-up" displays for automotive and aircraft manufacturers. Kodak's LS633 digital camera is one example of this technology.

8.86 Which of the following monomers might you expect would lead to a conducting polymer? (a) $H{-}C{\equiv}C{-}CH_3$, (b) $H_2C{=}CH{-}CH_3$

ANS (a) $H{-}C{\equiv}C{-}CH_3$

Additional Problems

8.88 Cylinders of compressed gas are equipped with pressure gauges that allow the user to monitor the amount of gas remaining. But such gauges are not useful for substances like propane or carbon dioxide, which are stored as liquids. So tanks of propane or carbon dioxide are sometimes mounted on scales to allow the user to see the rate of consumption. Use ideas from this chapter to explain why this is so.

ANS The gas above the liquid is in equilibrium with the liquid. As gas is released from the tank, liquid molecules will pass into the gas phase to re-establish the equilibrium in the tank. This means that the reading on the gauge, a measure of the molecules in the gas phase, would not be directly proportional to the total amount of the substance remaining in the tank.

8.90 Geckos are known for their ability to climb smooth vertical walls or windows. Recent research has shown that this unusual trait results from van der Waals forces between the surface and the tips of tiny hairlike setae in the Gecko's feet. Many materials science and engineering groups are working to develop tapes and other adhesives designed to mimic this behavior. Do a web search to find information about such efforts and write a short summary explaining how one resulting adhesive is related to ideas we explored in this chapter.

ANS Please use an appropriate search engine to find this information.

8.92 An environmental engineering team is brought in to investigate a small oil spill caused by a leak in a crude oil pipeline. They find that the average molar mass of a sample collected from the spilled oil is notably higher than that of the oil in the pipeline. Nonetheless, they are able to verify that the oil in the spill originated in the pipeline. Use ideas related to intermolecular forces to explain the difference between the spill oil and the pipeline oil.

ANS Intermolecular forces can lead to the formation of dimers.

8.94 Hydraulic fluids are liquids moving in a confined space under pressure, and they can serve many purposes in engineering designs. One use of hydraulic fluids is lubrication. Suppose you need to choose a hydrocarbon for use as a lubricant. What size molecules would provide high viscosity for a lubricant in a design?

ANS Higher number hydrocarbons would be the best suited. The longer carbon chain results in a higher intermolecular force and lower boiling point. I would begin searching larger hydrocarbon chains above C_{25} to identify candidates with sufficient viscosity and thermal properties.

8.96 A business manager wants to provide a wider range of p- and n-type semiconductors as a strategy to enhance sales. You are the lead materials engineer assigned to communicate with this manager. How would you explain why there are more ways to build a p-type semiconductor from silicon than there are ways to build an n-type semiconductor from silicon?

ANS The p-type requires a dopant that produces a hole in the silicon crystal (i.e. aluminum); the n-type requires a dopant that adds an electron to the crystal (i.e.

phosphorous). If one were to consider dopants with atomic radii of various sizes in an effort to have a variety of both types, the issue at hand is that the p-type possibilities are all metals relatively easy to use. The options other than P include As and Sb (both metalloids) and the relatively large Bi.

Focus on Problem Solving Exercises

8.98 If you know the density of a material and the length of the edge of its cubic lattice, how would you determine if it is face-centered cubic, body-centered cubic, or simple cubic? Would you have to look up any information?

ANS Trial and error is one approach to solve this problem. We could assume a crystal structure such as face-centered cubic, and from the density calculate the edge length. Comparing this calculation to the given edge length would tell us if the crystal lattice was correct. If they do not match, we would assume a different crystal structure and repeat the calculation, and so on. You would need to look up the atomic mass of the material to solve this problem.

8.100 You go into the laboratory to look for a squirt bottle containing acetone. You find two unlabeled bottles with different colored tops suggesting they are different liquids. Unfortunately, you have a terrible cold and cannot tell by smell which one might be acetone. What simple test could you use to determine which liquid is acetone and which is water? How does this test tell you this information?

ANS Water is very polar; hydrogen bonding is present. Acetone is moderately polar, but cannot hydrogen bond. Since water has much stronger intermolecular forces, we would predict differences in the properties of the two liquids, such as vapor pressure and evaporation rate. Acetone should have much higher vapor pressure and evaporation rate. Spilling a little of the two liquids and observing how fast they evaporate should tell us which is water and which is acetone.

Cumulative Problems

8.102 How is polarizability related to the periodic trends of elements in the periodic table?

ANS Polarizability is the extent to which a molecule or atom responds to an external electric field. The larger the atom, the more polarizable it is, because the electrons are farther from the nucleus and are not experiencing the full nuclear charge due to shielding. Therefore, polarizability increases from top to bottom on the periodic table.

8.104 Use the web to look up the percentage of dopant for a commercially available p-type semiconductor. Imagine that you were setting up a process for doping 1 metric ton of silicon with this dopant. (a) What mass would be required? (b) What would be the mole fraction of the dopant?

ANS Answers will vary according to the website found. Typically, a very small amount of dopant is required, such as 1 dopant atom per 200,000 semiconductor atoms. This ratio would be the same expressed on a molar basis.

To produce a p-type semiconductor, we need to use an atom with 3 valence electrons (one fewer than Si) such as gallium. The necessary dopant for one metric ton (1000 kg) of silicon is:

$$1000 \text{ kg Si} \times \frac{\mathbf{1000\ g\ Si}}{\mathbf{1\ kg\ Si}} \times \frac{\mathbf{1\ mol\ Si}}{\mathbf{28.09\ g\ Si}} \times \frac{\mathbf{1\ mol\ Ga\ atoms}}{\mathbf{200{,}000\ mol\ Si\ atoms}} \times \frac{\mathbf{69.72\ g\ Ga}}{\mathbf{1\ mol\ Ga}} =$$

12.41 g Ga per 1000 kg Si

The mole fraction of dopant is $\frac{\mathbf{1}}{\mathbf{200{,}000}}$.