Name ______________________ Section ________ Date ________

Chapter 14: Basic Review Worksheet

1. Explain how the densities and compressibilities of solids and liquids contrast with those properties of gaseous substances.

2. Describe some of the physical properties of water.

3. Define the normal boiling point of water and the normal freezing point of water. Sketch a representation of a heating/cooling curve for water, marking clearly the normal freezing and boiling points.

4. Define the term *changes in state.*

5. What type of forces must be overcome to melt or vaporize a substance (are these forces *intra*molecular or *inter*molecular)?

6. Define *molar heat of fusion* and *molar heat of vaporization.*

7. The heat of fusion of aluminum is 3.95 kJ/g. What is the molar heat of fusion of aluminum?

8. What is a *dipole-dipole attraction*? What is *hydrogen bonding*?

9. Define *London dispersion forces.* Although London forces exist among all molecules, for what type of molecule are they the *only* major intermolecular force?

10. What is *vaporization*? What is *condensation*?

11. Define the *equilibrium vapor pressure* of a liquid. How is the magnitude of a liquid's vapor pressure related to the intermolecular forces?

12. What is the vapor pressure of water at 100.0°C? How do you know this?

13. Define *crystalline solid.*

14. What are metal *alloys*?

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Chapter 14: Review Worksheet

1. How do we know that the properties of the solid and liquid states of a substance are more similar than to the properties of the substance in the gaseous state?

2. Why is water one of the most important substances on earth?

3. Why does a sample of boiling water remain at the same temperature until all the water has been boiled away?

4. Are changes in state physical or chemical changes? Explain. Why is the molar heat of vaporization of water so much larger than its molar heat of fusion?

5. Why does the boiling point of a liquid vary with altitude?

6. How do the strengths of dipole-dipole forces compare with the strengths of typical covalent bonds?

7. What conditions are necessary for hydrogen bonding to exist in a substance or mixture? Provide a molecular level sketch and label the hydrogen bonding.

8. Explain how London forces arise. Are London forces relatively strong or relatively weak? Explain.

9. Why does the process of *vaporization* require an input of energy?

10. Calculate the total energy required to melt 55.1 g of ice at 0°C, to warm the resulting liquid water from 0°C to 100°C , and to boil the water completely to vapor at 100°C.

11. Explain how the process of vaporization and condensation represent an *equilibrium* in a closed container.

12. Why is the magnitude of a liquid's vapor pressure related to its intermolecular forces?

13. Explain in your own words why the boiling point of a liquid is related to the atmospheric pressure.

14. Describe in detail some important types of crystalline solids and name a substance that is an example of each type of solid. Explain how the particles are held together in each type of solid (the interparticle forces that exist).

15. Describe the bonding that exists in metals and how this model explains some of the unique physical properties of metals.

16. Identify the two main types of alloys, and describe how their structures differ. Give two examples of each type of alloy.

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Chapter 14: Challenge Review Worksheet

1. What experimental evidence do we have for hydrogen bonding?

2. Why is it so important that water has a large heat of vaporization?

3 Describe an experiment that demonstrates vapor pressure.

4. How do the interparticle forces in a solid influence the bulk physical properties of the solid?

5. Which is the more ideal gas, CO or N_2? Explain.

Chapter 14: Basic Review Worksheet

1. Solids and liquids have much greater densities than do gases, and are much less compressible, because there is so little room between the particles in the solid and liquid states (solids and liquids have definite volumes of their own, and their volumes are not affected much by the temperature or pressure).

2. Water is a colorless, odorless, tasteless liquid that freezes at 0°C and boils at 100°C at 1 atm pressure.

3. The normal boiling point of water, that is, water's boiling point at a pressure of exactly 760 mm Hg, is 100°C (the boiling point of water was used to set one of the reference temperatures of the Celsius temperature scale). The normal (760 mm Hg) freezing point of water is exactly 0°C (again, this property of water was used as one of the reference points for the Celsius temperature scale). A cooling curve for water is given as Figure 14.7: notice how the curve shows that the amount of heat needed to boil the sample is much larger than the amount needed to melt the sample.

4. Changes in state refer to changes from solid to liquid (or vice-versa), liquid to gas (or vice-versa), or solid to gas (or vice-versa).

5. In order to melt or vaporize a substance, intermolecular forces must be overcome. Intramolecular forces are also known as chemical bonds.

6. The quantities of energy required to melt and to boil 1 mol of a substance are called the molar heat of fusion and molar heat of vaporization, respectively.

7. (3.95 kJ/g) x (26.98 g/mol) = 107 kJ/mol

8. Dipole-dipole forces are a type of intermolecular force that can exist between molecules with permanent dipole moments. Molecules with permanent dipole moments try to orient themselves so that the positive end of one polar molecule can attract the negative end of another polar molecule. Hydrogen bonding is an especially strong sort of dipole-dipole attractive force that can exist when hydrogen atoms are directly bonded to the most electronegative atoms (N, O, and F).

9. London dispersion forces are the relatively weak forces that must exist to explain the fact that substances consisting of single atoms or of nonpolar molecules can be liquefied and solidified. They arise from instantaneous dipole moments. Although an instantaneous dipole can arise in any molecule, in most cases other, much stronger intermolecular forces predominate. However, for substances which exist as single atoms (e.g., the noble gases), or which exist as nonpolar molecules (e.g., H_2, O_2), London forces are the only intermolecular forces.

10. Vaporization refers to the process by which molecules in the liquid state form a vapor. Condensation is the opposite process to vaporization: condensation refers to the process by which molecules in the vapor state form a liquid.

11. The pressure of the vapor over the liquid in a closed container at equilibrium is characteristic for the liquid at each particular temperature. Typically, liquids with strong intermolecular forces have small vapor pressures (they have more difficulty in evaporating) than do liquids with very weak intermolecular forces. For example, the components of gasoline (weak forces) have much higher vapor pressures than water (strong forces) and evaporate more easily.

12. The vapor pressure of water at 100.0°C is 1 atm. Recall the normal boiling point of water is 100.0°C, and the boiling point of a liquid is the point at which the vapor pressure of the liquid is equal to the atmoshpheric pressure.

13. Cyrstalline solids consist of a regular lattice array, which extends in three dimensions, of the components of the solid (atoms, molecules, or ions).

14. An alloy is a material (which has metallic properties) that contains a mixture of elements.

Chapter 14: Review Worksheet

1. Solids and liquids are much more condensed states of matter than are gases: the molecules are much closer together in solids and liquids and interact with each other to a much greater extent. Although solids are more rigid than liquids, the solid and liquid state have much more in common with each other than either of these states has with the gaseous state. We know this is true since it typically only takes a few kilojoules of energy to melt 1 mol of solid (since not much change has to take place in the intermolecular forces), whereas it may take 10 times more energy to vaporize a liquid (since there is such a great change in the intermolecular forces in going from the liquid to the gaseous state).

2. Water is one of the most important substances on earth. Water forms the solvent for all of the biochemical processes necessary for plant and animal life. Water in the oceans moderates the temperature of the earth. Because of its relatively large specific heat capacity, and its great abundance, water is used as the primary coolant for industrial machinery. Water provides a medium for transportation across vast distances on the earth. Water provides a medium for the smallest plants and animals in many food chains.

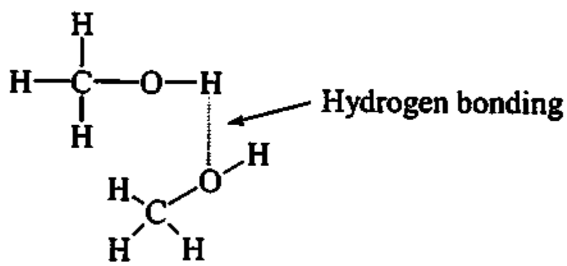
3. Water remains at 100°C while boiling, until all the water has boiled away, because the additional heat energy being added to the sample is used to overcome attractive forces among the water molecules as they go from the condensed, liquid state to the gaseous state.

4. Changes in state are only physical changes: no chemical bonds are broken during the change and no new substances result (no changes in the intramolecular forces take place). The molar heat of vaporization of water (or any substance) is much larger than the molar heat of fusion because in order to form a vapor, the molecules have to be moved much farther apart, and virtually all the intermolecular forces must be overcome (when a solid melts, the intermolecular forces remaining in the liquid are still relatively strong).

5. The boiling point of a liquid decreases with altitude because the atmospheric pressure (against which the vapor must be expanded during boiling) decreases with altitude (the atmosphere is "thinner").

6. Dipole-dipole forces are not nearly as strong as ionic or covalent bonding forces (typically only about 1% strong as covalent bonding forces) since electrostatic attraction is related to the magnitude of the charges of the attracting species. Since polar molecules have only a "partial" charge at each end of the dipole, the magnitude of the attractive force is not as large. The strength of such forces also drops rapidly as molecules move farther apart and is important only in the solid and liquid states (such forces are negligible in the gaseous state since the molecules are too far apart).

7. Hydrogen bonding is an especially strong sort of dipole-dipole attractive force that can exist when hydrogen atoms are directly bonded to the most strongly electronegative atoms (N, O, and F). Because the hydrogen atom is so small, dipoles involving N-H, O-H, and F-H bonds can approach each other much more closely than can dipoles involving other atoms. Since the magnitude of dipole-dipole forces is dependent on distance, unusually strong attractive forces can exist in such molecules. Molecular level sketches will vary, but an example is provided below. The students should understand that hydrogen-bonding interactions are intermolecular forces, not intramolecular bonds.



8. London forces are instantaneous dipole forces, which come about as the electrons of an atom move around the nucleus. Although we usually consider that the electrons are uniformly distributed in space around the nucleus, at any given instant there may be more electronic charge on one side of the nucleus than on the other, which results in an instantaneous separation of charge and a small dipole moment. Such an instantaneous dipole can induce a similar instantaneous dipole in a neighboring atom, which then results in an attractive force between the dipoles.

9. Vaporization of a liquid requires an input of energy because the intermolecular forces that hold the molecules together in the liquid state must be overcome.

10. total energy = energy to melt ice + energy to heat water + energy to boil water

$$\text{energy to melt ice} = 55.1\text{g} \times \frac{1\text{ mol}}{18.016\text{g}} \times \frac{6.02\text{ kJ}}{1\text{ mol}} = 18.4\text{ kJ}$$

$$\text{energy to heat water} = 55.1\text{g} \times (4.184\text{ J/g°C}) \times 100°\text{C} = 23{,}100\text{ J} = 23.1\text{ kJ}$$

$$\text{energy to boil water} = 55.1\text{g} \times \frac{1\text{ mol}}{18.016\text{g}} \times \frac{40.6\text{ kJ}}{1\text{ mol}} = 124\text{ kJ}$$

total energy = 166 kJ

11. In a closed container containing a liquid and some empty space above the liquid, an equilibrium is set up between vaporization and condensation. The liquid in such a sealed container never completely evaporates. When the liquid is first placed in the container, the liquid phase begins to evaporate into the empty space. As the number of molecules in this space accumulate, some re-enter the liquid phase. Eventually, every time a molecule of liquid somewhere in the container enters the vapor phase, somewhere else in the container a molecule of vapor re-enters the liquid. There is no further net change in the amount of liquid or vapor phases (although molecules are continually moving between the liquid and vapor phases).

12. As the strength of the intermolecular forces increases, the vapor pressure decreases. The more particles in a liquid are attracted to one another, the less likely the particles are to escape into the vapor; that is, and the less likely they are to evaporate. Therefore, the vapor pressure will be smaller.

13. A liquid boils when its vapor pressure is equal to atmospheric pressure. As the temperature of the liquid is increased, the particles of the liquid are more likely to have enough energy to escape the liquid. However, this amount of energy is dependent on the pressure around the liquid. Thus, as the atmospheric pressure decreases less energy is required and the boiling point of the liquid is decreased.

14. The three important types of crystalline solids are ionic solids, molecular solids, and atomic solids.

    Sodium chloride is a typical ionic solid. It's crystals consist of an alternating array of positive Na^+ ions and negative Cl^- ions. Each positive ion is surrounded by several negative ions, and each negative ion is surrounded by several positive ions. The electrostatic forces that develop in such an arrangement are very large, and the resulting substance is very stable, and has very high melting and boiling points.

    Ice is a molecular solid. The crystals consist of polar water molecules arranged in three dimensions so as to maximize dipole-dipole interactions (hydrogen bonding). Figure 14.18c shows a representation of an ice crystal, showing how the negative end of one water molecule is oriented towards the positive end of another water molecule, and how this arrangement repeats. Since dipole-dipole forces are weaker than ionic bonding forces, substances that exist as molecular solids typically have much lower melting and boiling points.

    Atomic solids vary as to how the atoms are held together in the crystal. Substances such as the noble gases are held together in the solid only by very weak London dispersion forces. Such substances have extremely low melting and boiling points because these forces are so weak. In other atomic solids, such as the diamond form of carbon, adjacent atoms may actually form covalent bonds with each other, causing the entire crystal to be one giant molecule. Such atomic solids have much higher boiling and melting points than those substances held together by only London forces. Finally, the metallic substances are also atomic solids, in which there are strong, but nondirectional, bonding leading to the properties associated with metals. Metals are envisioned in terms of the "electron sea" model in which a regular array of metal atoms exist in a "sea" of freely moving valence electrons.

15. The simple model we use to explain many properties of metallic elements is called the electron sea model. In this model we picture a regular lattice array of metal cations in a "sea" of mobile valence electrons. The electrons can move easily to conduct heat or electricity through the metal, and the lattice of cations can be deformed fairly easily, allowing the metal to be hammered into a sheet or stretched to make a wire.

16. Substitutional alloys consist of a host metal in which some of the atoms in the metal's crystalline structure are replaced by atoms of other metallic elements of comparable size to the atoms of the host metal. For example, sterling silver consists of an alloy in which approximately 7% of the silver atoms have been replaced by copper atoms. Brass and pewter are also substitutional alloys. An interstitial alloy is formed when other smaller atoms enter the interstices (holes) between atoms in the host metal's crystal structure. Steel is an interstitial alloy in which carbon atoms occupy the interstices of a crystal of iron atoms. The presence of the interstitial carbon atoms markedly changes the properties of the iron, making it much harder and tougher. Depending on the amount of carbon introduced into the iron crystal, the properties of the resulting steel can be carefully controlled.

Chapter 14: Challenge Review Worksheet

1. The fact that the boiling point of water is so much higher than that of the other covalent hydrogen compounds of the Group 6 elements is evidence for the special strength of hydrogen bonding (it takes more energy to vaporize water because of the extra strong forces between the molecules in the liquid state).

2. The high heat of vaporization of water is essential to life on earth, since much of the excess energy striking the earth from the sun is dissipated in vaporizing water.

3. A simple experiment to determine vapor pressure is shown in Figure 14.11. Samples of a liquid are injected into a sealed tube containing mercury. Since mercury is so dense, the liquids float to the top of the mercury where they evaporate. As the vapor pressures of the liquids develop to the saturation point, the level of mercury in the tube changes as an index of the magnitude of the vapor pressures.

4. The stronger the interparticle forces in a solid, the higher the melting and boiling points.

5. N_2 is a more ideal gas than CO. The carbon monoxide molecule is polar, whereas N_2 is a nonpolar molecule. Thus, the intermolecular forces for CO are greater than those for N_2. One of the premises of the kinetic molecular theory is that the gas particles exert no forces on each other. This is more true for N_2 than for CO thus, N_2 is a more ideal gas than CO.

Chapter 15: Basic Review Worksheet

1. A solution is a homogeneous mixture, a mixture in which the components are uniformly intermingled.

2. In a crystal of sodium chloride there is a negative chloride ion at one of the corners of the crystal. When this crystal is placed in water, water molecules surround the chloride ion, and orient themselves with the positive end of their dipoles aimed at the negative chloride ion. When