

Self-Test Review Sheet - Bonding

- Use the principles of bonding and molecular structure to explain the following statements.
 - The boiling point of argon is -186°C , whereas the boiling point of neon is -246°C .
 - Solid sodium melts at 98°C , but solid potassium melts at 64°C .
 - More energy is required to break up a CaO(s) crystal into ions than to break up a KF(s) crystal into ions.
 - Molten KF conducts electricity, but solid KF does not.
- The carbonate ion, CO_3^{2-} , is formed when carbon dioxide, CO_2 reacts with slightly basic cold water.
 - Draw the Lewis electron dot structure for the carbonate ion. Include resonance forms if they are appropriate.
 - Describe the hybridization of carbon in the carbonate ion.
 - Describe the relative lengths of the three C-O bonds in the carbonate ion.
 - Compare the average length of the C-O bonds in the carbonate ion to the average length of the C-O bonds in carbon dioxide.
- | Substance | Boiling Point ($^{\circ}\text{C}$) | Bond length ($\text{\AA}$) | Bond strength (kcal/mol) |
|---------------|--------------------------------------|------------------------------|--------------------------|
| H_2 | -253 | 0.75 | 104.2 |
| N_2 | -196 | 1.10 | 226.8 |
| O_2 | -182 | 1.21 | 118.9 |
| Cl_2 | -34 | 1.99 | 58.0 |

 - Explain the differences in the properties given in the table above for each of the following pairs.
 - The bond strengths of N_2 and O_2 .
 - The bond lengths of H_2 and Cl_2 .
 - The boiling points of O_2 and Cl_2 .
 - Use the principles of molecular bonding to explain why H_2 and O_2 are gases at room temperature, while H_2O is a liquid at room temperature.
- H_2S , SO_4^{2-} , XeF_4 , ICl_4^-
 - Draw a Lewis electron dot diagram for each of the molecules listed above.
 - Use the valence shell electron-pair repulsion (VSEPR) model to predict the geometry of each of the molecules.
- Use the principles of bonding and molecular structure to explain the following statements.
 - The angle between the N-F bonds in NF_3 is smaller than the angle between the B-F bonds in BF_3 .
 - $\text{I}_2(\text{s})$ is insoluble in water, but it is soluble in carbon tetrachloride.
 - Diamond is one of the hardest substances on Earth.
 - HCl has a lower boiling point than either HF or HBr .

Answers for Self-Test Review Sheet – Bonding

1.

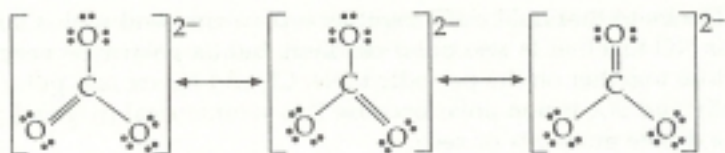
- a) Molecules of noble gases in the liquid phase are held together by London dispersion forces, which are weak interactions brought about by instantaneous polarities in non-polar atoms and molecules. Atoms with more electrons experience stronger London dispersion forces. Argon has more electrons than neon, so it experiences stronger London dispersion forces and boils at a higher temperature.
- b) Sodium and potassium are held together by metallic bonds, and positively charged ions in a delocalized sea of electrons. Potassium is larger than sodium, so the electrostatic attractions that hold the atoms together act at a greater distance, reducing the attractive force and resulting in its lower melting point.
- c) Both CaO(s) and KF(s) are held together by ionic bonds in crystal lattices. Ionic bonds are held together by an electrostatic force which can be determined by using Coulomb's law.

$$F = k \frac{Q_1 Q_2}{r^2}$$

CaO is more highly charged, with Ca^{2+} bonded to O^{2-} . So for CaO, Q_1 and Q_2 are +2 and -2. KF is not as highly charged, with K^+ bonded to F^- . So for KF, Q_1 and Q_2 are +1 and -1. CaO is held together by stronger forces and is more difficult to break apart.

- d) KF is composed of K^+ and F^- ions. In the liquid (molten) state, these ions are free to move and can thus conduct electricity. In the solid state, the K^+ and F^- ions are fixed in a crystal lattice and their electrons are localized around them, so there is no charge that is free to move and thus no conduction of electricity.

2. a)



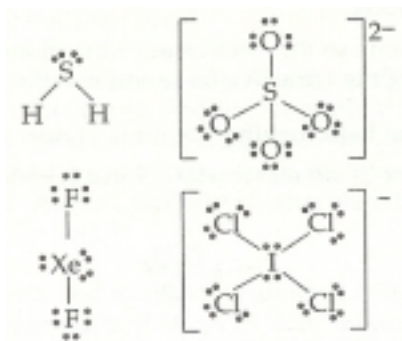
- b) The central carbon atom forms three bonds with oxygen atoms and has no free electron pairs, so its hybridization must be sp^2 .
- c) All three bonds will be the same length because no particular resonance form is preferred over the others.
- d) The C-O bonds in the carbonate ion have resonance forms between single and double bonds while the C-O bonds in carbon dioxide are both double bonds. The bonds in the carbonate ion will be shorter than single bonds and longer than double bonds, so the carbonate bonds will be longer than the carbon dioxide bonds.

3. a)

- i. The bond strength of N_2 is larger than the bond strength of O_2 because N_2 molecules have triple bonds and O_2 molecules have double bonds. Triple bonds are stronger and shorter than double bonds.
 - ii. The bond length of H_2 is smaller than the bond length of Cl_2 because hydrogen is a smaller atom than chlorine.
 - iii. Liquid oxygen and liquid chlorine are both non-polar substances that experience only London dispersion forces of attraction. These forces are greater for Cl_2 because it has more electrons, so Cl_2 has a higher boiling point than O_2 .
- b) H_2 and O_2 are both non-polar molecules that experience only London dispersion forces, which are

too weak to form the bonds required in order for a substance to be liquid at room temperature. H_2O is a polar substance whose molecules form hydrogen bonds with each other. Hydrogen bonds are strong enough to form the bonds required in a liquid at room temperature.

4. a)



- (b) H_2S has two bonds and two free electron pairs on the central S atom. The greatest distance between the electron pairs is achieved by tetrahedral arrangement. The electron pairs at two of the four corners will cause the molecule to have a bent shape, like water.

SO_4^{2-} has four bonds around the central S atom and no free electron pairs. The four bonded pairs will be farthest apart when they are arranged in a tetrahedral shape, so the molecule is tetrahedral.

XeF_2 has two bonds and three free electron pairs on the central Xe atom. The greatest distance between the electron pairs can be achieved by a trigonal bipyramidal arrangement. The three free electron pairs will occupy the equatorial positions, which are 120° apart, to minimize repulsion. The two F atoms are at the poles, so the molecule is linear.

ICl_4^- has four bonds and two free electron pairs on the central I atom. The greatest distance between the electron pairs can be achieved by an octahedral arrangement. The two free electron pairs will be opposite each other to minimize repulsion. The four Cl atoms are in the equatorial positions, so the molecule is square planar.

5.

- a) BF_3 has three bonds on the central B atom and no free electron pairs, so the structure of BF_3 is trigonal planar, with each of the bonds 120° apart. NF_3 has three bonds and one free electron pair on the central N atom. The four electron pairs are pointed towards the corners of a tetrahedron, 109.5° apart. The added repulsion from the free electron pair causes the N-F bonds to be even closer together, and the angle between them is more like 107° .
- b) Polar solvents are best at dissolving polar solutes. Non-polar solvents are best at dissolving non-polar solutes. $\text{I}_2(\text{s})$ is non-polar, so it dissolves better in carbon tetrachloride, CCl_4 , which is non-polar, than in water, H_2O , which is polar.
- c) The carbon atoms in diamond are bonded together in a tetrahedral network, with each carbon atom bonded to three other carbon atoms. The tetrahedral structure of the network bonds does not leave any planes along which the diamond can be broken, so a diamond behaves as one big molecule with no weaknesses.
- d) HBr and HCl are polar molecules. In liquid form, both substances are held together by dipole-dipole interactions. These interactions are stronger for molecules with more electrons, so HBr has stronger intermolecular bonds and a higher boiling point. HF has a higher boiling point than HCl because HF undergoes hydrogen bonding, while HCl does not; this causes HF to remain a liquid at higher temperatures than HCl , even though HF is a polar molecule with fewer electrons than HCl .