

Chemical Bonding Practice Items

- Covalent bonds
 - are a kind of Van der Waals force.
 - involve the sharing of electrons between atoms.
 - consist of the electrostatic attraction between ions.
 - concentrate the greatest electron density outside the internuclear axis.
- Ionic bonding occurs in the following pair of elements:
 - C and Cl
 - Cu and I
 - Mg and Cl
 - C and S
- Isoelectric species have the same electron configuration. Which of the following does not belong in the same group of isoelectric species with the others?
 - O^{2-}
 - F^-
 - Na^+
 - Ar
- Sulfur can form a transargononic compound with fluorine, SF_6 , in which the atomic orbitals of sulfur hybridize to form six sp^3d^2 orbitals. What is the shape of the molecule?
 - trigonal bipyramidal
 - tetrahedral
 - octahedral
 - planar
- Two Lewis structures may be drawn for SO_2 that obey the octet rule. Bond lengths and bond energies in SO_2
 - correspond to a sulfur-oxygen single bond and a sulfur-oxygen double bond.
 - lie between those expected for sulfur-oxygen double and triple bonds.
 - demonstrate periodic fluctuation between single and double bonds.
 - are identical for the two sulfur-oxygen bonds.
- The H–O–H bond angle in water equals
 - 104.5°
 - 109.5°
 - 120°
 - 180°
- Which of the following molecules is linear?
 - H_2O
 - NO_2
 - SO_2
 - CO_2
- Bonding in ozone (O_3) can be expressed as a resonance hybrid.

The diagram shows two resonance structures of ozone (O_3) separated by a double-headed arrow. In the first structure, the central oxygen atom has a positive charge (+) and is bonded to two oxygen atoms. One bond is a double bond to an oxygen atom with two lone pairs, and the other is a single bond to an oxygen atom with three lone pairs and a negative charge (-). In the second structure, the central oxygen atom also has a positive charge (+) and is bonded to two oxygen atoms. One bond is a double bond to an oxygen atom with two lone pairs, and the other is a single bond to an oxygen atom with three lone pairs and a negative charge (-).

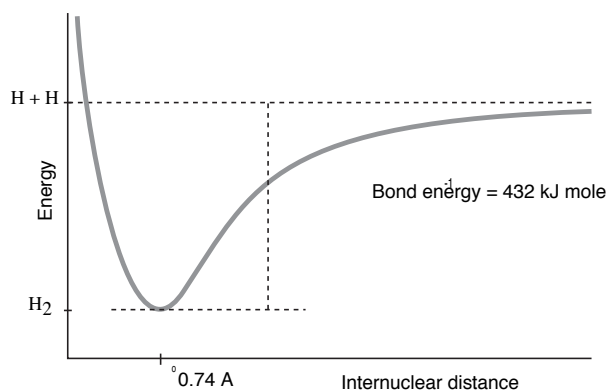
The angle formed by the three oxygens in ozone is nearest to

 - 109°
 - 117°
 - 120°
 - 180°

9. Which of the following reactions at standard temperature and 0.01 atm between atomic species would be most exothermic?

- A. $\text{H}(\text{g}) + \text{F}(\text{g}) \longrightarrow \text{HF}(\text{g})$
 B. $\text{H}(\text{g}) + \text{Cl}(\text{g}) \longrightarrow \text{HCl}(\text{g})$
 C. $\text{H}(\text{g}) + \text{Br}(\text{g}) \longrightarrow \text{HBr}(\text{g})$
 D. $\text{H}(\text{g}) + \text{I}(\text{g}) \longrightarrow \text{HI}(\text{g})$

The energy diagram for the formation of H_2 below pertains to questions 10 and 11.



10. From the diagram we can conclude that

- A. at distances less than 0.74\AA the repulsion between the electrons increases sharply.
 B. breaking the bonds of hydrogen molecules releases 432 kJ/mole of energy.
 C. 0.74\AA is the H_2 bond distance.
 D. when two hydrogens share a pair of electrons, the spins of the electrons become paired.

11. Suppose that instead of H_2 formation the diagram showed formation of N_2 .

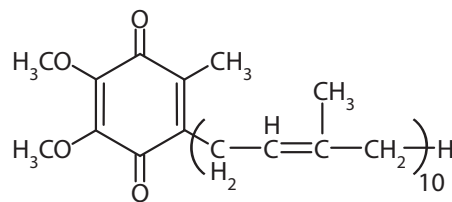
- A. The internuclear distance at the curve minimum would be lower.
 B. The depth of the energy well would be greater.
 C. There would be three minima.
 D. The energy would be greatest for large values of internuclear distance.

12. Determine the kind of hybrid orbitals used by sulfur in SF_4

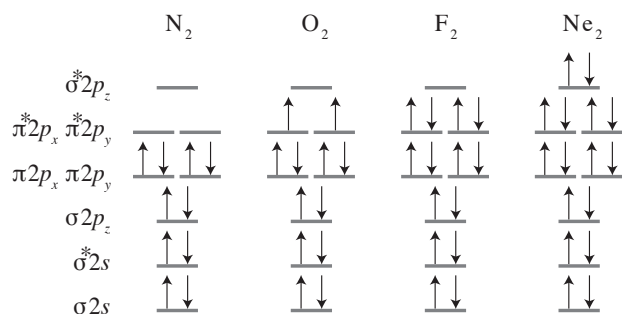
- A. sp^2
 B. sp^3
 C. sp^3d
 D. sp^3d^2

13. How many carbons in ubiquinone, pictured below, are sp^2 hybridized?

- A. 6
 B. 8
 C. 26
 D. 28



The following molecular orbital electron configurations pertain to questions 14 - 16:



14. Which molecule is shown by its molecular orbital electron configuration to have a bond order of 1?

- A. N_2
- B. O_2
- C. F_2
- D. Ne_2

15. Which molecule is shown by its molecular orbital electron to be unstable?

- A. N_2
- B. O_2
- C. F_2
- D. Ne_2

16. Which molecule is shown by its molecular orbital electron configuration to be paramagnetic?

- A. N_2
- B. O_2
- C. F_2
- D. Ne_2



Chemical Bonding

Answers and Explanations

1. B

A covalent bond involves the sharing of electron pairs between atoms leading to a stable balance of attractive and repulsive forces between atoms. In many cases, the sharing of electrons allows each atom to attain the equivalent of a full outer shell, which is a stable electronic configuration.

2. C

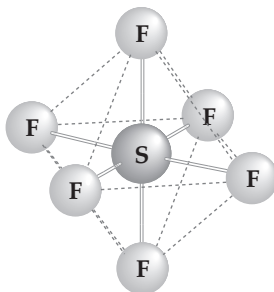
As with Mg (electronegativity 1.3) and Cl (electronegativity 3.1), a bond will be ionic (> 50% ionic character) when the electronegativity difference between bonded atoms is 1.7 or greater. Ionic bonding occurs when elements from the far left of the periodic table (alkali and alkaline earth metals) form compounds with the more electronegative nonmetals from the right side of the periodic table.

3. D

O^{2-} , F^- and Na^+ possess the same configuration as neon, not argon.

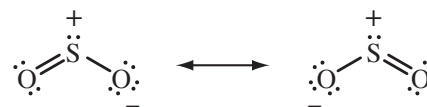
4. C

The premise of valence shell electron pair repulsion theory (VSEPR) is that the valence electron pairs surrounding an atom tend to repel each other and adopt an arrangement that minimizes this repulsion. In SF_6 there are six electron pairs in the covalent bonds between sulfur and fluorine. The geometry that results is octahedral.



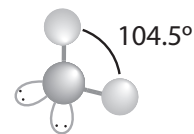
5. D

Sulfur dioxide has two resonance structures which contribute equally to the overall hybrid structure of the molecule.



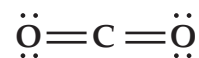
6. A

The H–O–H bond angle in water equals 104.5° . With four regions of electron density, ie. the two electron pairs in the covalent bonds plus the two nonbonded pairs, the geometry is based on the tetrahedron, but the angle is not the tetrahedral angle of 109.5° because the nonbonded pair repulsions are stronger.



7. D

With all of its electrons participating in the double bonds to the two oxygens, the carbon of CO_2 has two regions of electron density. A double bond is considered a single region of electron density in VSEPR. This produces a linear geometry. In other words, the O–C–O bond angle is 180° .



8. B

Molecules with three regions of electron density have a geometry that is trigonal planar, so one might expect the O–O–O bond angle to be 120° . However, lone pairs of electrons are slightly more repulsive than bonding pairs of electrons. Therefore the O–O–O angle is a few degrees less than 120° .

9. A

The energy released when the bond is formed is the bond dissociation energy. The respective bond dissociation energies for the respective hydrogen-halogen bonds is as follows:

Bond dissociation energy – kJ mol⁻¹

HF	570
HCl	432
HBr	366
HI	298

As a general rule, bonds with greater electronegativity difference will involve greater bond dissociation energy. As the bond forms there is not only the decrease in energy as the atoms fall into the well of binding energy associated with electrons in a molecular orbital between the nuclei pulling them together. There is also the additional decrease in energy associated with the electronegative element pulling the bonding electrons in towards its nucleus.

10. A

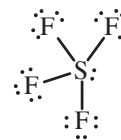
Bond length or bond distance is defined as the average distance between nuclei of two bonded atoms in a molecule. In the energy diagram, there is an energy minimum at 0.74 Å. It would energy to pull the two atoms apart from this distance due to the attractive force exerted on nuclei by the electrons within the sigma bonding orbital between them. It would also take energy to push the two atoms any nearer to each other due to the repulsive force of the two nuclei. Due to the thermal energy they possess being at some temperature, the two atoms will be vibrating much like a mass-spring oscillator with the bond distance analogous to the the equilibrium position of the oscillator.

11. B

Because it is a triple bond, the bond dissociation energy of N₂ (945 kJ/mol) is greater than the bond dissociation energy of H₂. In forming the bond, the nitrogen atoms fall together into a deeper well of electrostatic potential energy.

12. C

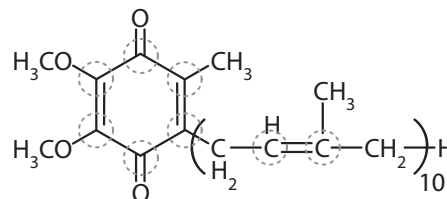
Sulfur has six valence electrons. Fluorine has seven. Constructing the Lewis dot structure of SF₄, after completing the octets of the fluorine atoms in the molecule, sulfur has one pair of electrons remaining.



Along with phosphorus, having access to *d* subshell orbitals, sulfur is a prominent example of an element that can form an 'expanded octet.' Here, to accommodate five pairs of electrons, sulfur undergoes *sp*³*d* hybridization. This is the only choice available with five orbitals.

13. C

There are 26 *sp*² hybridized carbons depicted – 6 in the benzoquinone ring and 20 in the isoprenoid tail.



14. C

In F₂ there is one more pair of electrons in bonding orbitals than in antibonding orbitals, corresponding to a bond order of 1.

15. D

In the Ne₂ molecular orbital diagram there are equal numbers of electrons in bonding and antibonding orbitals. The bond order is zero. Any covalent bonding interaction would be transitory and unstable.

16. B

The O₂ molecular orbital diagram provides the explanation for why the O₂ molecule is paramagnetic. There are two singlet electrons in antibonding orbitals. With O₂ you have a triple bond with two additional singlet electrons in antibonding orbitals. The bond order is 2.