

12.E: The Chemical Bond (Exercises)

12.1: Lewis Structures

Q12.1

Which of the following molecules has the shortest bond length?

- O_2
- Cl_2
- Br_2
- I_2

Q12.2

Draw a plausible Lewis structure for 1,3-Bisphosphoglycerate (1,3-BPG), ($C_3H_8O_{10}P_2$).

Q12.3

Draw resonance structures for NO_3^- and ClO_3^- , please show formal charges in drawings.

Q12.4

Calculate the dipole moment (μ) of a two ions of $+2e$ and $-2e$ that are separated by 100 pm. Express dipole moment in both units of Cm and D .

S12.4

$$\mu = Q \times r = 2(1.602 \times 10^{-19})(8 \times 10^{-10}) = 2.56 \times 10^{-28} Cm \quad (12.E.1)$$

$$(2.56 \times 10^{-28} \cancel{Cm}) \left(\frac{1 D}{3.336 \times 10^{-30} \cancel{Cm}} \right) = 76.8 D \quad (12.E.2)$$

12.2: Valence Bond Theory

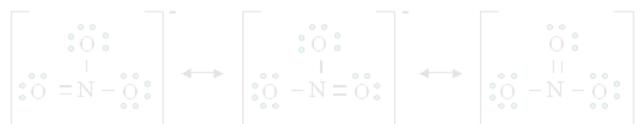
Q12.5

What are the resonance of NO_3^- ?



S12.5

Resonance structure in basic means that there are multiple way to draw a Lewis structure. For example:



*Source from Michael Blaber

Q12.6

Draw resonance structures for the carbonate ion (CO_3^{2-}).

S12.6



Q12.7a

How is it that this structure, PF_5 , have P have 5 bonds to it?

S12.7a

The d orbitals are available to make extra bonds allowing the P to bond to 5 Fluorines instead of just Four.

Q12.7b

Draw the Lewis structure for nitric acid (HNO_3). This may or may not include resonance structures.

S12.7b



12.3: Hybridization of Atomic Orbitals

Q12.8a

What is the hybridization of carbon in CH_4 ?

S12.8a

Carbon has the electron configuration $1s^2 2s^2 2p^2$. In the excited state, because the 2s and 2p orbitals are so close one of the s electrons is able to fill the empty 2p orbital. All the carbon bonds are identical so the four unpaired electrons will be in a sp^3 hybridization. The sp^3 hybridization is the only hybridization that accounts for four identical orbitals.

Q12.8b

Describe the pattern of valence electrons across the periodic table (left to right and top to bottom), excluding the transition metals.

S12.8b

The number of valence electrons increases going left to right along the same row and stays constant going from top to bottom along the same column.

Q12.9a

What is the difference between covalent bond and ionic bond wave functions?

S12.9a

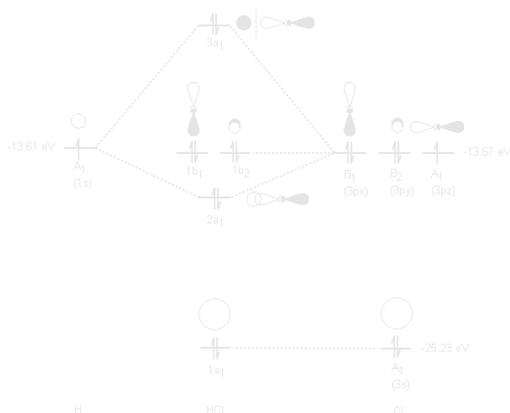
An ionic bond wave function takes into account the probability that the electrons of a multiatomic molecule might exist on the same atom; the covalent bond wave function assumes they exist on separate atoms.

Q12.9b

What is the hybridization of HCl?

S12.9b

There is no orbital hybridization in HCl. The $3p_z$ of Cl can overlap with the 1s of H just fine; they are only 0.06 eV apart in energy. However, the 3s of Cl and the 1s of H are too far away in energy to interact, so there is no reason why the 3p of Cl can interact with the 3s of Cl anyway.



Q13.7

Calculate the potential energy of interaction between an electron situated 5.5 Å away from an HF molecule with a dipole moment of 2.5 D.

S13.7

$$\mu = 2.5D \times \frac{3.3356 \times 10^{30} Cm}{D} = 8.39 \times 10^{-30} Cm \quad (12.E.3)$$

$$r = 5.5 \text{ angstroms} = 5.5 \times 10^{-10} m \quad (12.E.4)$$

$$V = \frac{q\mu}{4\pi\epsilon_0 r^2} = \frac{(+1.602 \times 10^{-19} C)(8.39 \times 10^{-30} Cm)}{4\pi(8.851 \times 10^{-12} C^{-2} N^{-1} m^{-2})(5.5 \times 10^{-10})} = 2.196 \times 10^{-11} J \quad (12.E.5)$$

Q12.10

Give two types of bonding that present in the molecule CH₂. how do you do this?

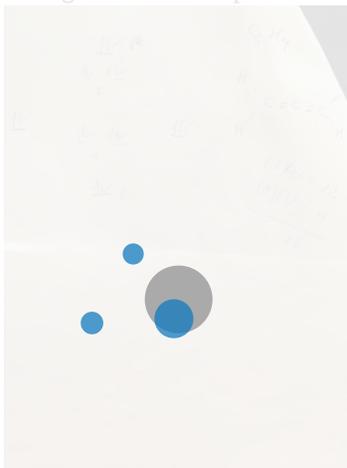
S12.10

1 is C atom to be not hybrid, no paired electrons and the molecule will be diamagnetic.

2 is C atom is sp³ hybridized with 2 of the hybrid orbitals used for bonding to H's, unpaired electron. this is paramagnetic.

Q12.11

Describe bonding CO₂ and C₃H₄ as hybridization. Draw diagram of forming of sigma and pi bond of C₃H₄ there is a double bond CO₂ and its hybridization is sp and C₃H₄ is sp² belong to CH₂ and 1 sp of C=C=C.



Q12.12

Give the bonding scheme in term of molecular orbital H₂⁺, H₂, He₂⁺, He. Besides, give the species in the following decreasing stability.



Q12.13

Between F_2 and F_2^+ which one has longer bond?

S12.13

F_2^+ has bond order 1.5, F_2 has bond order 1.0. The bond lengths are inverse to the bond order, so the order is $F_2^+ < F_2$. There is 1 unpaired electron in F_2^+ , 0 unpaired electrons in F_2 .

Q12.14

Which of the following molecules have the shortest bond: F_2 , N_2 , O_2 ? Why?

S12.14

N_2 has the shortest bond because the bond order is 3 while O_2 is 2 and F_2 is 1.

12.5: Molecular Orbital Theory

Q12.15

Draw the molecular orbital diagram for F_2 with the atomic orbitals labeled and find the bond order.

Q12.16

Comparing benzene and cyclopentadiene, which one has a lesser degree of π -electron delocalization?

Q12.19

Draw the molecular orbital energy diagram for the F_2 . Then compare the relative stability of the molecule to F_2^+ .

Answer

$$\text{BOND ORDER OF } F_2 = (8-6)/2 = 1$$

$$\text{BOND ORDER OF } F_2^+ = (8-5)/2 = 1.5$$

Based on bond order F_2^+ is stable than F_2

Q12.21

Diatomic carbon (C_2) exists at very high temperatures. What type or types of bonds do you expect a molecule of diatomic carbon to have?

S12.21

1. Draw a molecular orbital diagram.

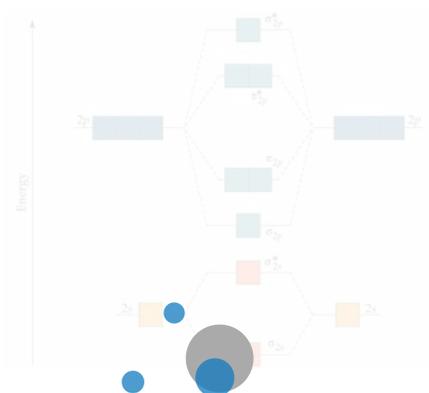
[View molecular orbital diagram for diatomic carbon](#)

Answer: The molecular orbital diagram predicts that there will be a double bond consisting of two π bonds.

Q12.21

Determine the second period for molecule O_2 by using molecular orbital?

S12.21



Based on general diagram for molecular orbital of second row of O_2 molecule, the $2p$ MO is below the $2p$ molecular orbitals.

Q12.30

Though there are some exceptions, the double bond rule states that atoms of period 3 and greater do not form double or triple bonds. Explain why this is generally true. *Hint: What properties of elements change with increasing period?*

S12.30

Pi bonds are usually weaker than sigma bonds because there is less orbital overlap. The larger atomic radius of period 3 and greater elements means that there is even less overlap between the orbitals that would form pi bonds. There is not enough overlap to form the pi bonds that would make for double or triple bonds.

Q12.30

Explain why the Si=Si double bond is not stable than the C=C. Given the covalent radius of carbon is 77 pm and Silicon is 111pm?

S12.30

Silicon is significantly bigger than carbon. Thus the Si-Si bond is longer than C-C bond. However, the longer bond result in lowering the effective overlap of 3p orbital to form a π bonds. In contrast, C atoms can form the π bond from 2p orbital. Thus the Si=Si is less stable despite its larger size.

Q12.33

Myohemerythrin is an iron-containing protein that binds oxygen in marine invertebrates. The protein is monomeric (has one subunit) and contains 0.8107% iron by mass. Estimate the molar mass of myohemerythrin. Is your answer the same as the known molar mass of myohemerythrin, 13,780 grams per mole? If it is not, account for the difference between your estimate and the known value.



Myohemerythrin ribbon schematic, a 4-helix bundle protein structure with a bound iron. Hand drawn by Jane Richardson in 1980, from PDB file 2MHR.

S12.33

1. Find the mass of the protein if there is one atom of iron per protein.

$$55.85 \text{ g Fe/mol} \times \frac{100.0 \text{ g protein}}{0.8107 \text{ g Fe}} \quad (12.E.6)$$

$$6889 \text{ g/mol} \quad (12.E.7)$$

2. This is much less than the known molar mass. In fact, it is half.

$$\frac{13780 \text{ g/mol}}{6889 \text{ g/mol}} = 2.000 \quad (12.E.8)$$

We know the protein is monomeric, so there must be two atoms of iron in each protein.

Q12.19

Neon is a noble gas. Draw the molecular orbital diagram of Ne_2 and Ne_2^+ . From that, describe the bonding scheme of those two molecules based on molecular orbital theory.



S12.19

Based on the molecular orbital diagram, there are more anti-bonding than bonding state. The bonding order of Ne_2 is:

$$BO = 1/2 (8-8) = 0$$

Therefore, Ne_2 does not exist in nature.

Q12.21

What is the difference between the last three group, including O_2 , F_2 and the other diatomic molecules in the second row of Periodic table in term of Molecular orbital theory?

S12.21

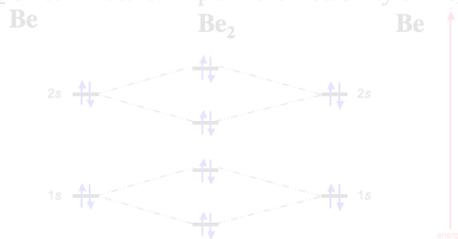
For O_2 and F_2 , the pi bonds(2p) have higher energy than the sigma bonds (2p). Whereas, a group of B_2 , C_2 , and N_2 , the sigma bonds(2p) have higher energy than the pi bonds(2p)



Copyright by Sidra®

Q12.30

Be is in the second period, and very rare Be_2 exist in nature. Explain the instability of Be_2 , and calculate the bond order.



S12.30

Be_2 molecule has 2 valence electrons. The bonding order, $\text{BO} = 1/2 (2-2) = 0$ Therefore, diatomic Be_2 is not stable! Not exist in nature

12.4: Electronegativity and Dipole Moment

Q12.36

Will the dipole moment of a cis-dichloroethylene molecule increase or decrease upon heating? Why?

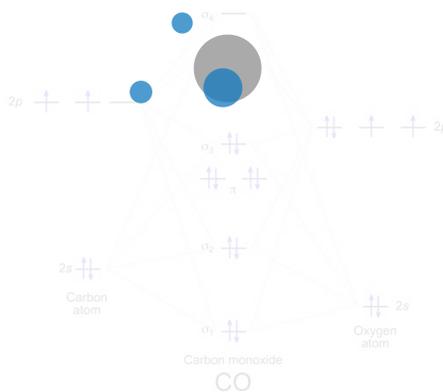
S12.36

The dipole moment will decrease because cis-trans isomerization will occur when heated. This is because the trans isomer of the molecule does not have a dipole moment present.

Q12.37

Draw the σ and σ^* molecular orbital of CO . Draw the MO energy level diagram and write the electron coefficient. Calculate the Bond order.

S12.37



Electron Configuration:

$$(\sigma 1s)^2(\sigma^* 1s)^2(\sigma 2s)^2(\sigma^* 2s)^2(\pi x)^2(\pi y)^2(\sigma 2sp)^2$$

Bond Order: $1/2(\text{Bonding Electrons}-\text{Antibonding Electrons})$

$$=1/2(8-2) = 3$$

12.6: Diatomic Molecules

12.7: Resonance and Electron Delocalization

12.8: Coordination Compounds

12.9: Coordination Compounds in Biological Systems

12.E: The Chemical Bond (Exercises) is shared under a [CC BY-NC-SA 4.0](https://creativecommons.org/licenses/by-nc-sa/4.0/) license and was authored, remixed, and/or curated by LibreTexts.

