SOLUTIONS

Name________________________ SID______________

1) An electron in a hydrogen atom undergoes a transition from an unknown initial state n_i to a final state n_f=3, emitting a photon with wavelength = 1290 nm.
Identify the initial state and the region of the electromagnetic spectrum in which the emitted light is observed.

- ● n_i=5, infrared
- ○ n_i=4, infrared
- ○ n_i=6, infrared
- ○ n_i=4, radio
- ○ n_i=5, radio
- ○ n_i=6, radio

$$\frac{91 \text{ nm}}{1290 \text{ nm}} = \frac{1}{3^2} - \frac{1}{n_i^2}$$

2) For a hydrogen atom or one-electron ion, how many atomic orbitals share the same principle quantum number *n*?

- ○ $n - 1$
- ○ $n + 1$
- ○ $2n$
- ● n^2

How many radial and angular nodes does a 4d orbital possess?

- ○ radial = 0, angular = 3
- ● radial = 1, angular = 2
- ○ radial = 2, angular = 1
- ○ radial = 3, angular = 0

'l' angular, '$n-l-1$' radial

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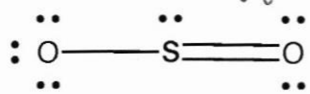
3) Select the best Lewis structure for sulfur dioxide, SO_2.

● all octets full, least amount of formal charge



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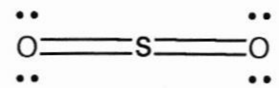

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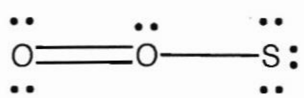

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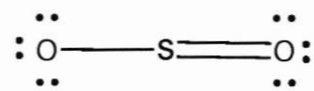


Does the structure you selected have a **non-zero** dipole moment?

● Yes

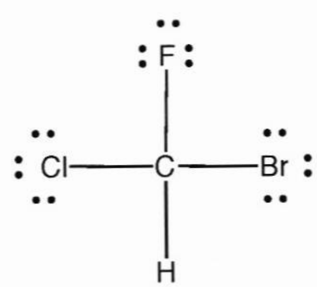
○ No

bent geometry

4) Lewis structures are shown below for four different molecules. Which of these molecules is chiral? Mark all that apply.

●

tetrahedral + four different groups



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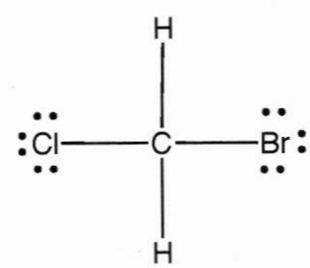

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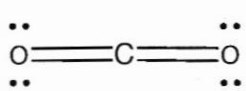

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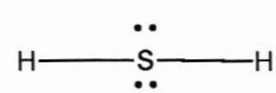

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5) Ionization is the process of removing an electron from an atom. For an atom X, the first and second ionizations are given by the following equations.

First ionization: $X\ (g) \rightarrow X^{+}\ (g) + e^{-}$

Second ionization: $X^{+}\ (g) \rightarrow X^{2+}\ (g) + e^{-}$

Which element in the second period has the **highest second ionization energy**?

- ● Li
- ○ Be
- ○ B
- ○ C
- ○ N
- ○ O
- ○ F
- ○ Ne

(Li^{+}) $1s^2 2s^0$ configuration
→ difficult to lose another electron

Which element in the second period has the **lowest second ionization energy**?

- ○ Li
- ● Be
- ○ B
- ○ C
- ○ N
- ○ O
- ○ F
- ○ Ne

(Be^{+}) $1s^2 2s^1$ configuration
→ easy to lose an electron & go to closed shell

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6) This question concerns elements in the fourth row of the periodic table, such as vanadium (V) and chromium (Cr).

i. What is the full electronic configuration for vanadium? (Do not worry about possible exceptions to the standard Aufbau rules.)

$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,4s^2\,3d^3$

ii. How many valence electrons does a vanadium atom have? Consider all electrons in the 4s, 3d, and 4p orbitals to be part of the valence shell.

[2 in 4s + 3 in 3d]

$\cdot\ddot{V}:$

Final Answer

5 electrons

iii. Now consider a diatomic molecule V_2 composed of two covalently bonded vanadium atoms. Draw a Lewis structure for this molecule, assuming that the octet rule applies to its valence electrons. What bond order is suggested by your structure?

5 valence electrons ⇒ similar to nitrogen

$:V \equiv V:$

→ triple bond

3 Bond Order

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Some of the molecular orbitals for bonding in V_2 involve d orbitals.

The picture below shows a d orbital centered on one vanadium atom, together with a d orbital centered on the other vanadium atom. The two V nuclei are located on the *z* axis, as indicated by the black spheres (or dashed outlines where they are obscured by other surfaces).

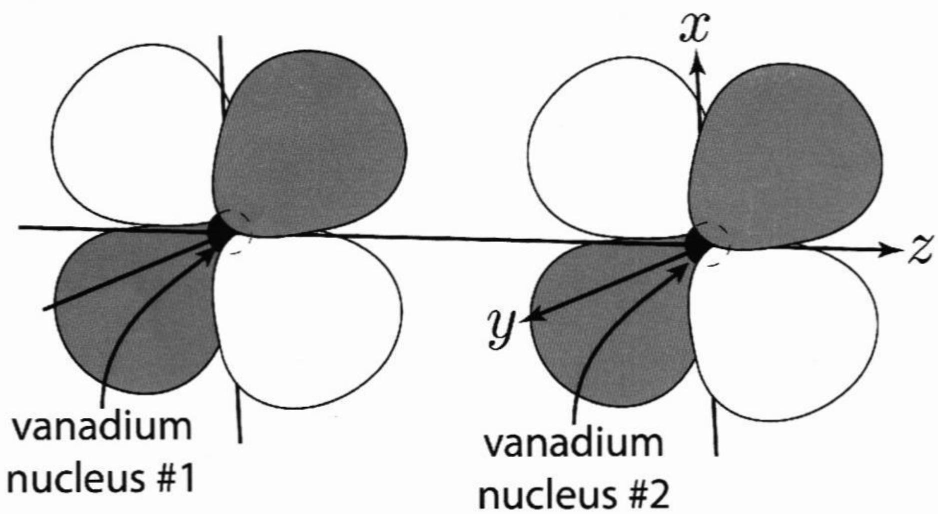
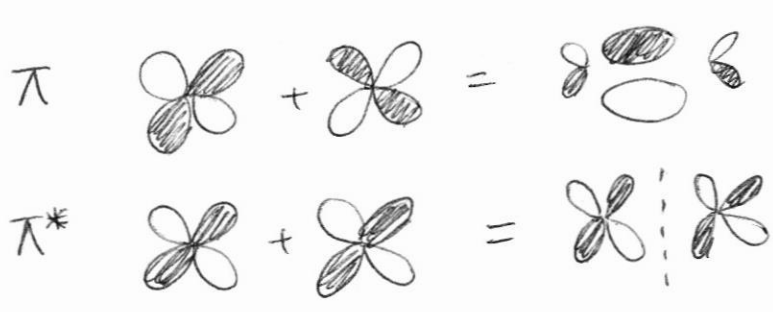


Figure 1

Gray and white lobes in this picture depict isosurfaces of the two d-orbital wavefunctions. White lobes indicate a positive value of the atomic wavefunction, and gray lobes indicate a negative value of the atomic wavefunction. Each of these orbitals therefore has two nodal planes: One is perpendicular to the *z* axis. The other is the *yz*-plane, which runs through both nuclei.

iv. When the two nuclei are brought together along the *z* axis, hybridizing the d orbitals in Figure 1 produces one or more molecular orbitals. Which of the following molecular orbitals can be formed by **adding or subtracting** the atomic orbitals shown in Figure 1? (Check all that apply.) **Note**: the nuclei cannot move off the *z* axis.

- ○ σ bonding orbital
- ○ σ^* antibonding orbital
- ● π bonding orbital
- ● π^* antibonding orbital



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The picture below shows a different pair of d orbitals, one centered on each nucleus. In this case the nuclei are completely obscured by the wavefunction's isosurfaces, so they are shown as dashed outlines. The nodal surfaces for these two orbitals do not include the z axis.

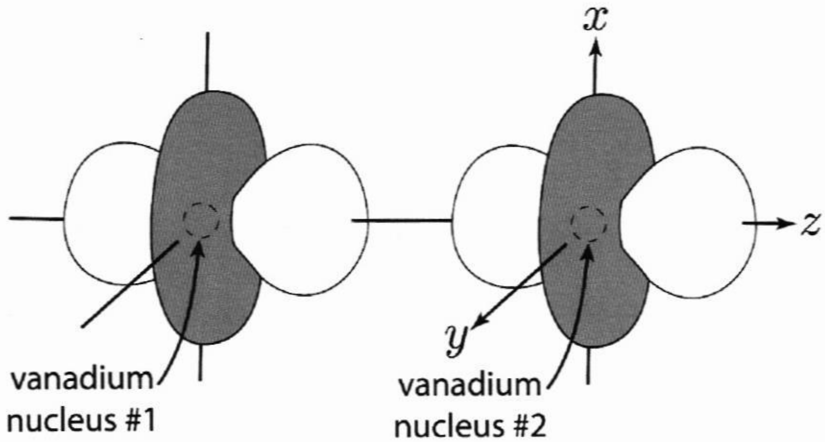

Figure 2

v. When the two nuclei are brought together along the z axis, hybridizing the d orbitals in Figure 2 produces one or more molecular orbitals. Which of the following molecular orbitals can be formed by **adding or subtracting** the atomic orbitals shown in Figure 2? (Check all that apply.) **Note**: the nuclei cannot move off the z axis.

- ● σ bonding orbital
- ● σ^* antibonding orbital
- ○ π bonding orbital
- ○ π^* antibonding orbital