Recitation Worksheet Thirteen: Exam Four Review

Name: Key UGA ID:

Textbook:
Chemistry & Chemical Reactivity
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Instructions:

- This recitation worksheet is a review for Exam Four.
- Exam coverage: Ch. 8.3-8.10, 9.1-9.2.
- You **do not** need to submit it to Gradescope.
- The answer key has been posted with this worksheet to eLC.
- The **recitation session during the exam week (November 18-21) is still mandatory**. Your attendance will be recorded.
- A periodic table and formula sheet are attached to the end of this worksheet.

1. Which statement about drawing Lewis structures is **false**?

B

A. Double and triple bonds can be used to fulfill the octet rule and/or minimize formal charges
B. Expanded octets for second period elements can only be drawn when the substance is a free radical (not permitted for 2nd period elements)
C. Formal charges should be as close to zero as possible
D. Negative formal charges should be assigned to more electronegative atoms
E. The atom with the lowest electronegativity is typically the central atom
F. None of the above are false

2. A compound contains the atoms C, H, N, and O. Which atom is most likely to be the central atom?

A

A. C
B. H
C. N
D. O

3. Draw the best Lewis structure of HCN. How many single bonds, double bonds, triple bonds, and lone pairs are present? Answer by using integers (e.g. 0, 1, etc.).

10 valence e⁻s

I. Single bonds: 1

II. Double bonds: 0

III. Triple bonds: 1

IV. Lone pairs: 1

4. Draw the best Lewis structure of SiH_2O. How many single bonds, double bonds, triple bonds, and lone pairs are present? Answer by using integers (e.g. 0, 1, etc.).

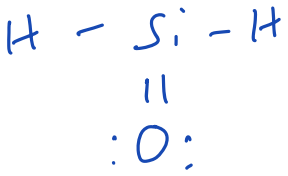
12 valence e⁻s

I. Single bonds: 2

II. Double bonds: 1

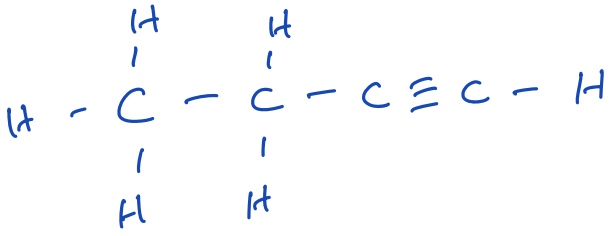
III. Triple bonds: 0

IV. Lone pairs: 2



5. Draw the best Lewis structure of CH_3CH_2CCH. How many single bonds, double bonds, triple bonds, and lone pairs are present? Answer by using integers (e.g. 0, 1, etc.).

I. Single bonds: 8



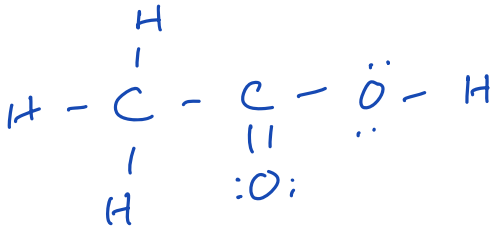
II. Double bonds: 0

III. Triple bonds: 1

IV. Lone pairs: 0

6. Draw the best Lewis structure of CH_3COOH. How many single bonds, double bonds, triple bonds, and lone pairs are present? Answer by using integers (e.g. 0, 1, etc.).

I. Single bonds: 6



II. Double bonds: 1

III. Triple bonds: 0

IV. Lone pairs: 4

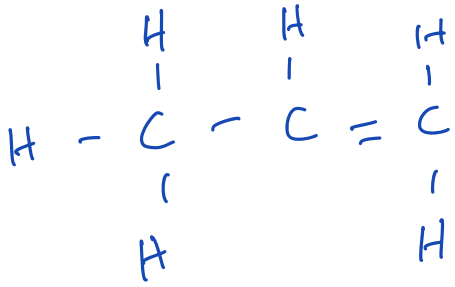
7. Draw the best Lewis structure of CH_3CHCH_2. How many single bonds, double bonds, triple bonds, and lone pairs are present? Answer by using integers (e.g. 0, 1, etc.).

I. Single bonds: 7

II. Double bonds: 1

III. Triple bonds: 0

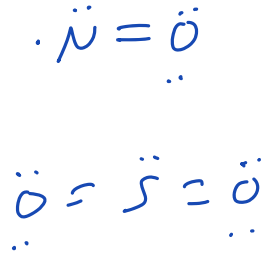
IV. Lone pairs: 0

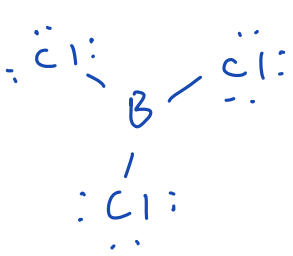


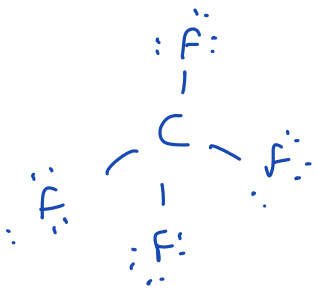
8. Which of the following Lewis structures would violate the octet rule (in their best structure)? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

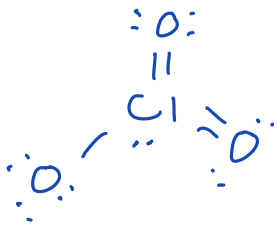
ABCEF

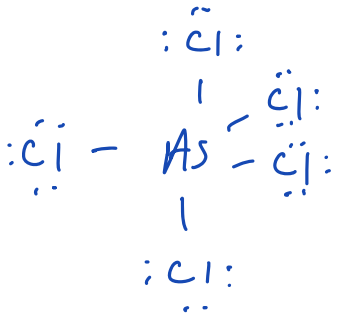
A. NO
B. SO_2
C. BCl_3
D. CF_4
E. ClO_3^-
F. $AsCl_5$







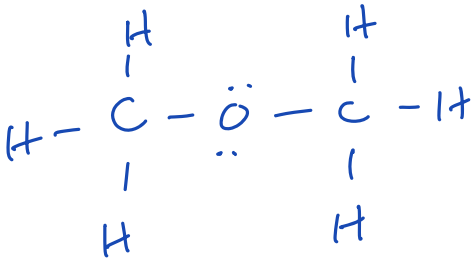




9. Write the Lewis structure for the organic compound CH_3OCH_3. How many total bonding pairs are in the compound? How many total lone pairs are in the compound? Answer by using integers (e.g. 0, 1, etc.).

I. Bonding pairs: 8

II. Lone pairs: 2

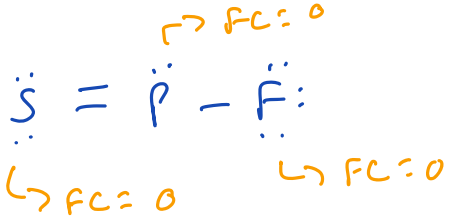


10. In SPF, how many lone pairs are on the central atom in the best Lewis structure? Answer by using an integer (e.g. 0, 1, etc.).

1

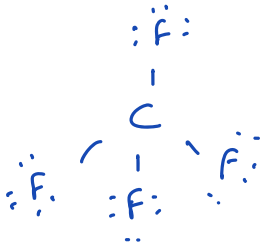
18 valence e's

FC: formal charge

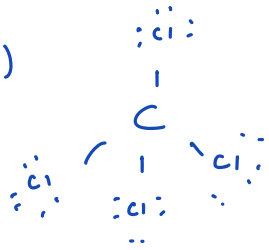


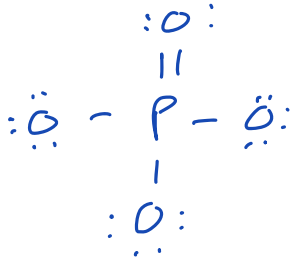
11. Which of the following Lewis structures would violate the octet rule (in their best structure)?

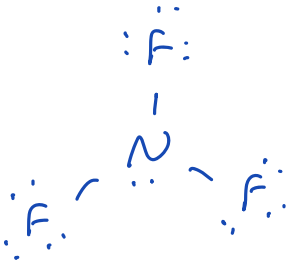
D



A. SiF_4
B. CF_4
C. CCl_4
D. PO_4^{3-} (expanded octet)
E. NF_3
F. None of the above



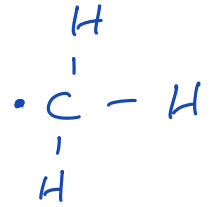


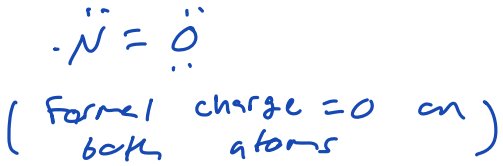


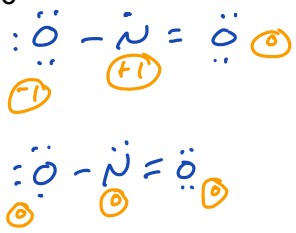
12. Which of the following statements are **true**? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

C D

A. The reactivity of a hydroxide ion (OH^-) is expected to be the same as a hydroxyl radical (•OH) because their chemical formulas are identical → free radicals very reactive
B. The Lewis structure of the nitrogen monoxide free radical is expected to have an unpaired electron on the oxygen atom
C. The formal charge on nitrogen in the nitrogen dioxide free radical is +1 or 0 depending on the placement of the unpaired electron
D. The methyl radical (•CH_3) has a total number of 7 valence electrons







13. Consider a set of hypothetical elements in the table below and the number of valence electrons each has.

Element Symbol	# of valence electrons
X	4
Z	5

Which of the hypothetical compounds formed from the elements above would you expect to be free radicals? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

A D

A. XZ 9 e⁻s → odd e⁻s
B. X_2Z_2 18 e⁻s
C. XZ_2 14 e⁻s
D. X_3Z 17 e⁻s → odd e⁻s
E. There is not enough information to determine this

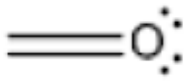
14. Which of the following compounds would be the most reactive?

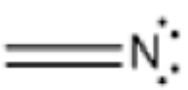
B

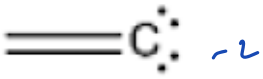
A. BF_3 → 24 valence e's
B. OF_3 → 27 valence e's (odd number) → Free radical
C. PF_3 → 26 valence e's
D. IF_3 → 28 valence e's
E. All compounds listed would be equally reactive
F. Reactivity cannot be determined from Lewis structures

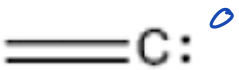
15. Which of these atoms has a formal charge of -1 in the given electronic configuration?

C

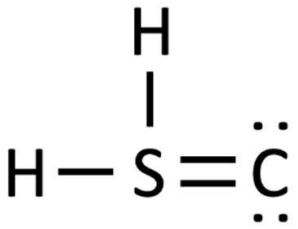
A.  0

C.  -1

B.  -2

D.  0

16. The complete Lewis structure of a molecule is provided below. What is the formal charge of the sulfur atom? What is the formal charge of the carbon atom? Answer with an integer and sign (e.g. +4, -2) or with a zero if no charge is present.



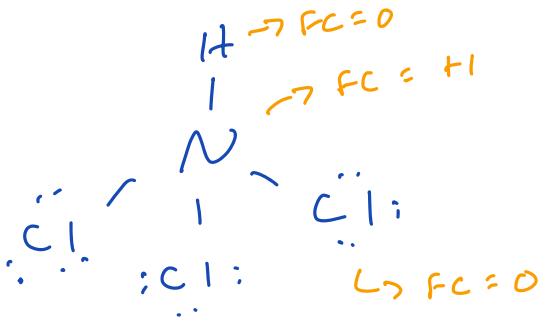
I. Sulfur: +2

II. Carbon: -2

26 valence e⁻s

17. What is the formal charge on nitrogen in $NHCl_3^+$? Answer with an integer and sign (e.g. +4, -2) or with a zero if no charge is present.

+1

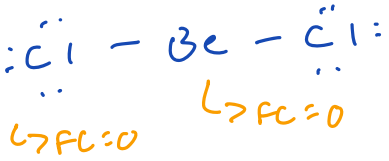


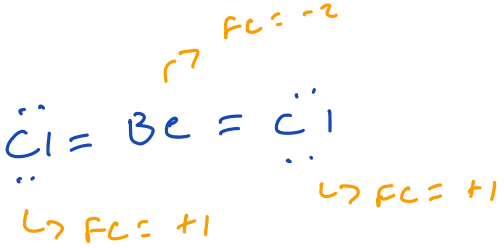
18. Why don't we draw double bonds between the Be atom and the Cl atoms in the best Lewis structure of $BeCl_2$?

A

A. That would give positive formal charges to the chlorine atoms and a negative formal charge to the beryllium atom.
B. There aren't enough electrons.
C. That would result in more than eight electrons around beryllium.
D. That would result in more than eight electrons around each chlorine atom.
E. That would result in the formal charges not adding up to zero.

16 valence e⁻s





19. Which statement is **true** about resonance?

C

A. Any molecule can be drawn with at least two valid Lewis structures.
B. There is always a major and minor contributor when two valid Lewis structures can be drawn.
C. Atom connectivity can never change in a resonance structure for a molecule.
D. Any molecule with a double bond has at least one other valid resonance form.
E. None of the above are true.

20. What is **true** of resonance structures? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

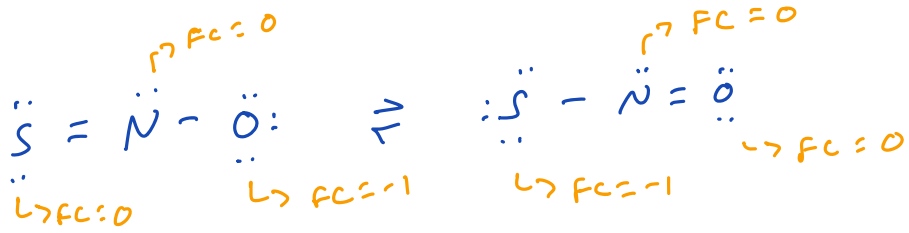
ADE

A. Different resonance contributing structures differ by placement of electrons only.
B. Molecules that exhibit resonance rapidly switch between different resonance contributing structures.
C. Different resonance contributing structures differ by placement of electrons and atoms
D. The resonance hybrid structure of a molecule is an average of its different resonance contributing structures.
E. Resonance hybrid structures contain delocalized electrons.

21. How many resonance structures does SNO^- have? Note: N is the central atom, and the resonance structures do **not** need to be equivalent. Answer by using an integer (e.g. 0, 1, etc.).

18 valence e's

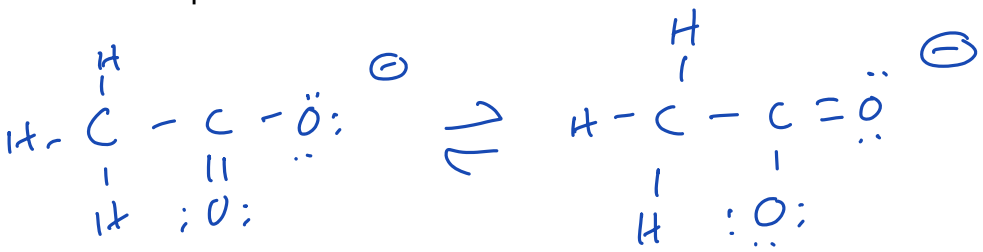
2



22. Draw the Lewis structure for the ion CH_3COO^-. How many total possible octet-satisfied (i.e. best) resonance structures can be drawn for this ion?

B

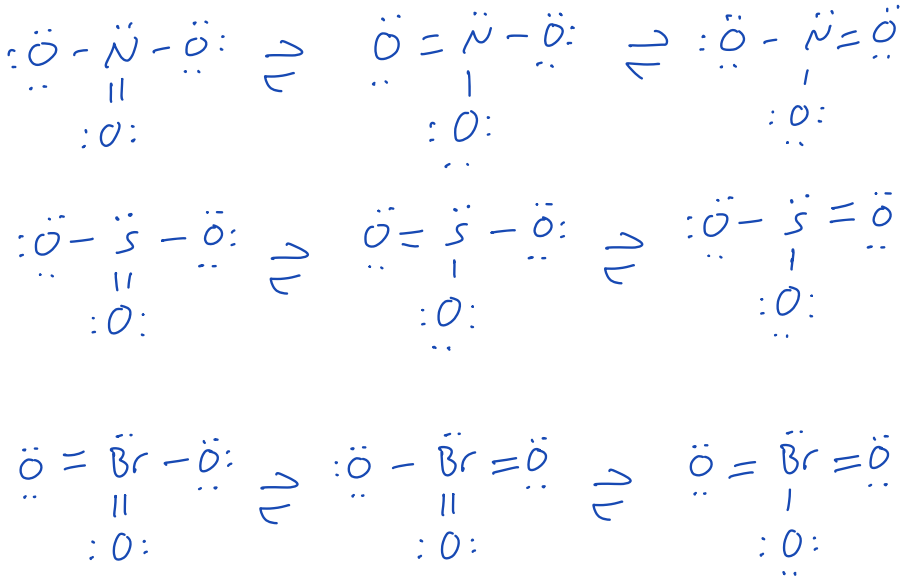
A. There are no resonance structures for this ion (i.e. there is only one way to draw this Lewis structure)
B. Two equivalent resonance structures
C. Two non-equivalent resonance structures
D. Three equivalent resonance structures
E. Three non-equivalent resonance structures



23. There can be three equivalent, best resonance structures of _____. Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

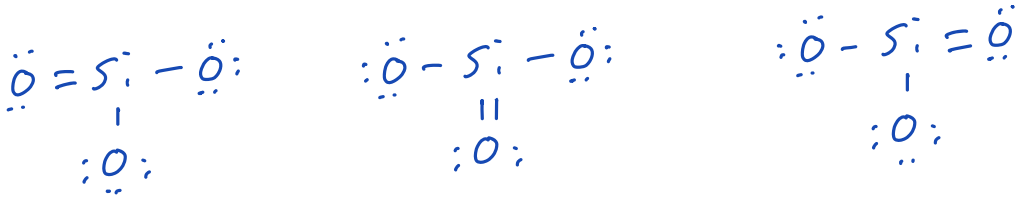
BCE

A. NO_2^-
B. NO_3^-
C. SO_3^{2-}
D. SO_4^{2-}
E. BrO_3^-



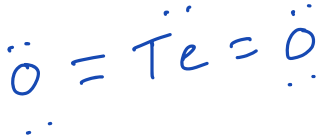
24. How many equivalent, best resonance structures can be drawn for SiO_3^{2-}? Answer by using an integer (e.g. 0, 1, etc.).

3



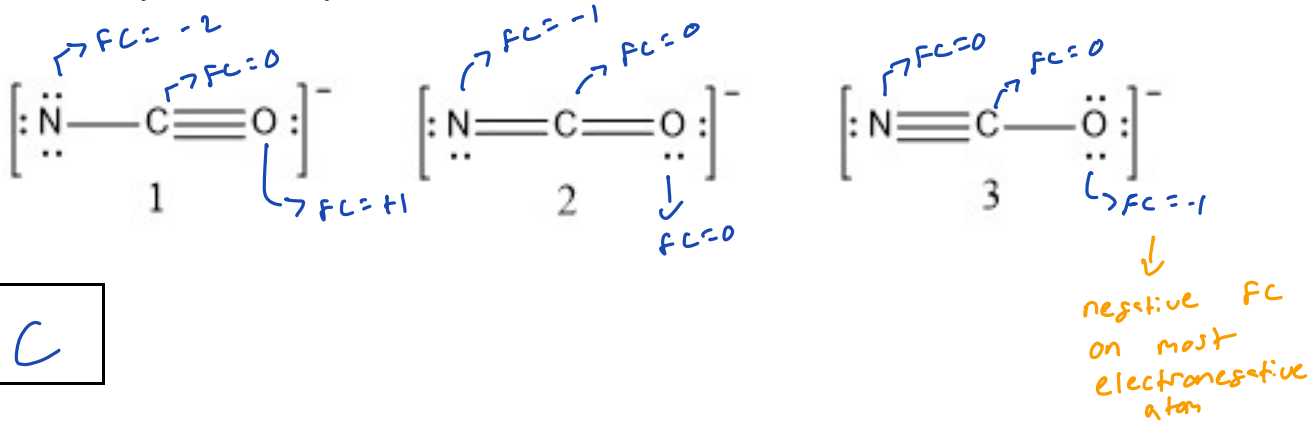
25. How many equivalent, best resonance structures can be drawn for TeO_2?

A



A. There is only one best structure for TeO_2
B. There are two equivalent, best resonance structures for TeO_2
C. There are three equivalent, best resonance structures for TeO_2
D. There are four equivalent, best resonance structures for TeO_2

26. Based on formal charges, which of the three structures contributes most to the resonance hybrid of the cyanate ion?



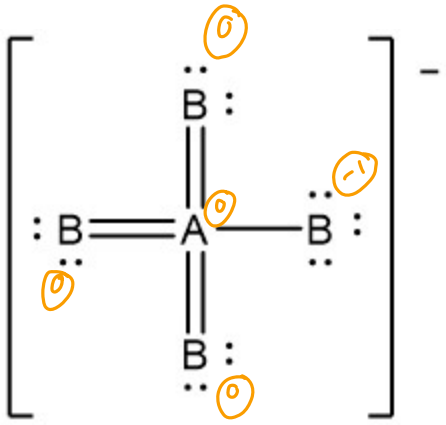
C

A. Structure 1
B. Structure 2
C. Structure 3
D. All of these structures contribute equally

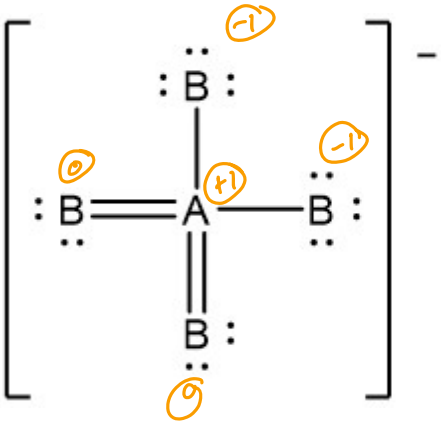
27. The central atom in the generic polyatomic ion AB_4^- is in group 17. The terminal atoms are in group 16. Which resonance structure is the major contributor to the overall structure of the molecule? You may assume that all of these atoms can expand their octet, and that the central atom is the least electronegative.

A

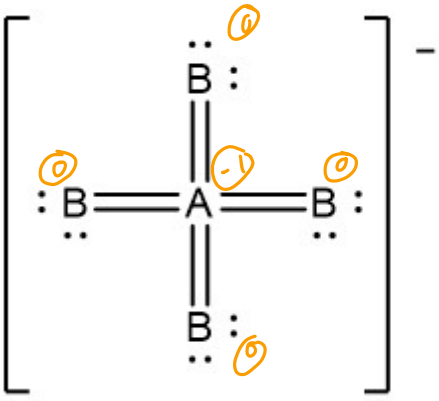
A.



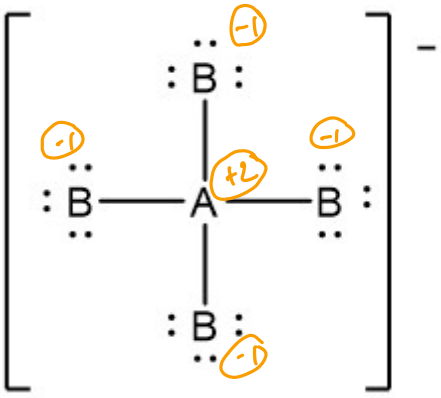
C.



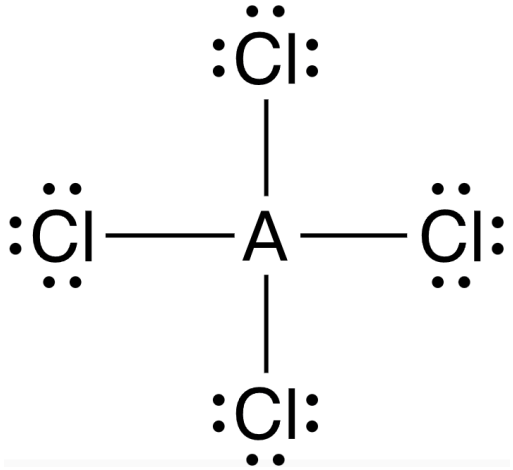
B.



D.



28. In the Lewis structure below, A represents an unknown element. Which of the following is the most reasonable identity of element A?

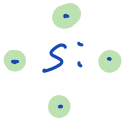


D

total valence e⁻s = 32
valence e⁻s from four Cl atoms = 28
valence e⁻s from "A" = 4

A. P
B. S
C. Cl
D. Si
E. Not enough information to tell

→ also most likely to form four bonds from Lewis symbol



29. In an alternate universe, atoms follow the septet rule, which means they need seven valence electrons to be stable instead of eight. Draw the Lewis structure for nitrogen dioxide in the alternate universe. What is **true** about this structure? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

AF

A. The nitrogen is connected to both oxygens by a single bond
B. The nitrogen is connected to both oxygens by a double bond
C. The nitrogen is connected to both oxygens by a triple bond
D. The nitrogen is connected to one oxygen by a single bond and one oxygen by a double bond
E. More total electrons must be drawn than using our universe's rules.
F. Each atom contains an unpaired electron.
G. Only the central atom contains an unpaired electron.
H. The Lewis structure for nitrogen dioxide can't be drawn without violating the septet rule.
I. Nitrogen dioxide exhibits resonance in this universe

$NO_2 = 17$ valence e^-s

30. What is **false** regarding the compound PCl_4^- ?

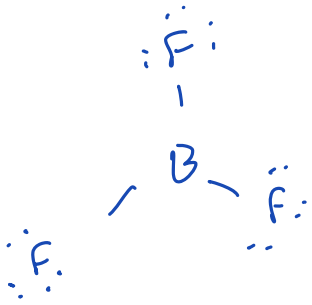
D

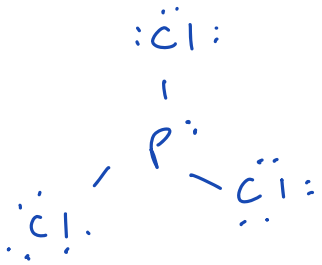
A. It has a trigonal bipyramidal electron geometry
B. It has a seesaw molecular geometry
C. The lone pair occupies an equatorial position
D. The lone pair occupies an ~~axial position~~ must be equatorial
E. The lone pair is more repulsive than the bonding pairs

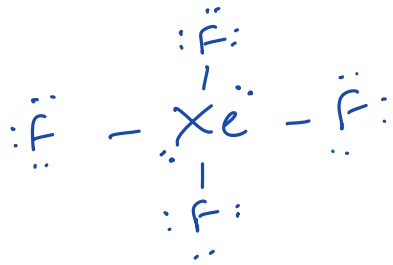
31. For which of these molecules do the electron and molecular geometry differ? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

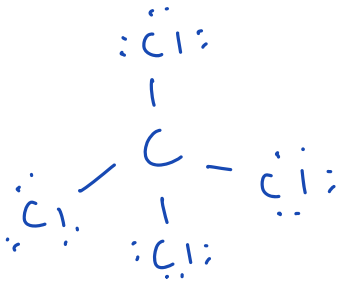
BF

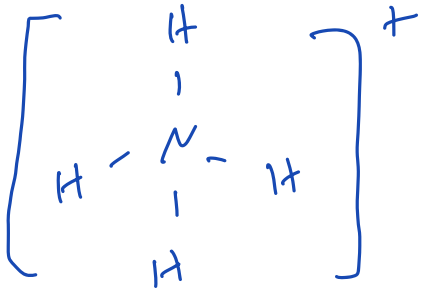
A. BF_3
B. PCl_3
C. CCl_4
D. NH_4^+
E. CO_3^{2-}
F. XeF_4

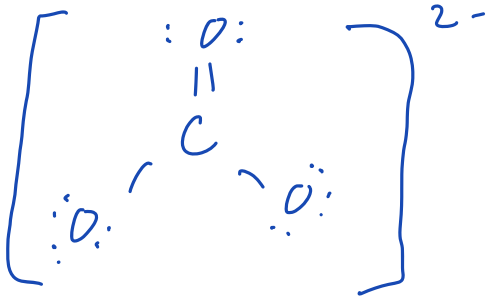








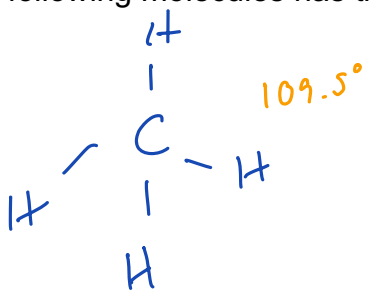


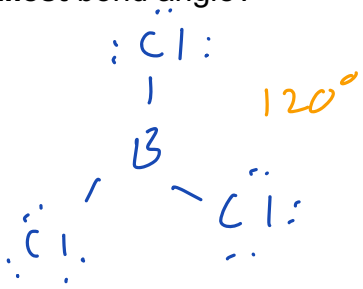


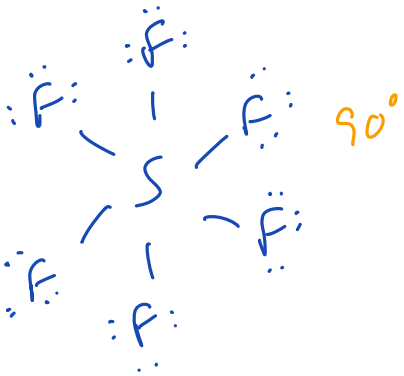
32. Which of the following molecules has the **smallest** bond angle?

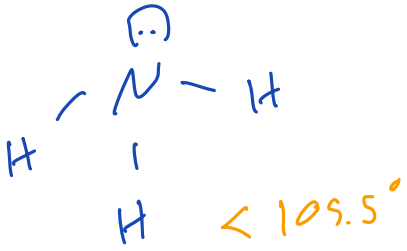
C

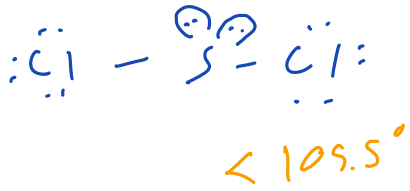
A. CH_4
B. BCl_3
C. SF_6
D. NH_3
E. SCl_2



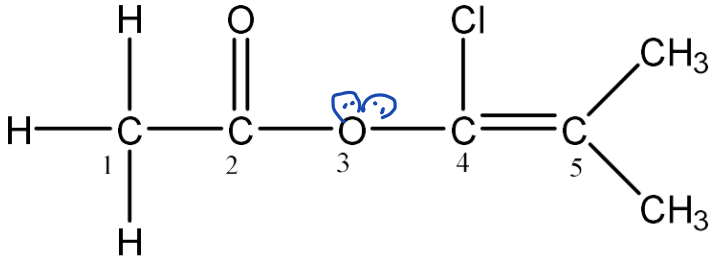








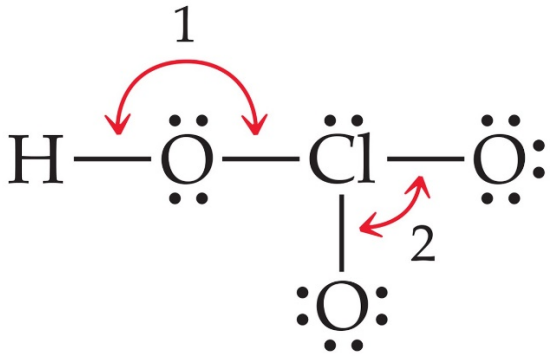
33. Which bond angle would be the smallest in the following structure? Note: lone pairs are not shown in the included Lewis structure.



C

A. H – C1 – C2 → 109.5°
B. C1 – C2 – O3 → 120°
C. C2 – O3 – C4 → < 109.5°
D. O3 – C4 – C5 → 120°
E. C4 – C5 – CH_3 → 120°

34. Consider the Lewis structure of the molecule below. What is the H-O-Cl bond angle represented by arrow 1? What is the O-Cl-O bond angle represented by arrow 2?



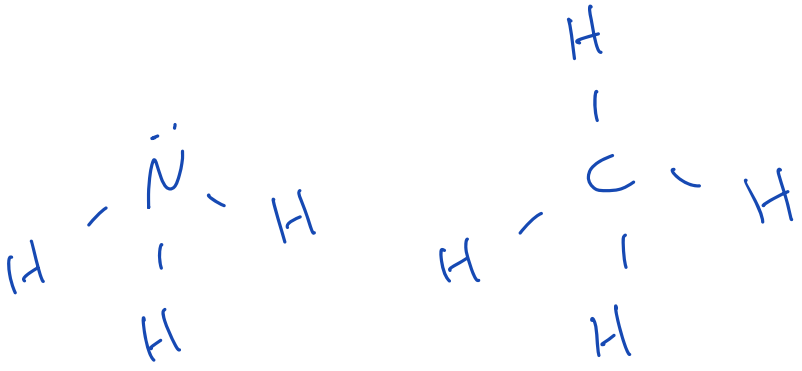
A

A. <109.5°, <109.5°
B. 180°, <109.5°
C. 120°, 120°
D. <120°, <120°
E. <109.5°, 180°
F. <180°, 120°

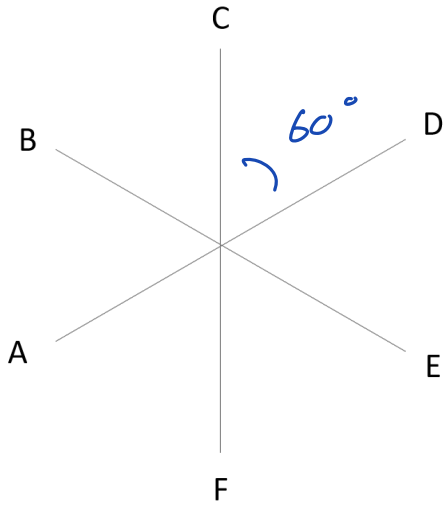
35. According to the VSEPR model, the arrangement of electron domains around NH_3 and CH_4 is:

D

A. different, because in each case there are a different number of atoms around the central atom
B. different, because in each case there are a different number of electron domains around the central atom
C. the same, because both nitrogen and carbon are both in the second period
D. the same, because in each case there are the same number of electron domains around the central atom (4 e⁻ domains)
E. different or the same, depending on the conditions leading to maximum repulsion



36. In the alternate universe of Flatland, there are only two dimensions. An atom with six electron groups has a hexagonal planar structure (see the diagram below).



I. What are the bond angles in the hexagonal planar structure?

60	degrees

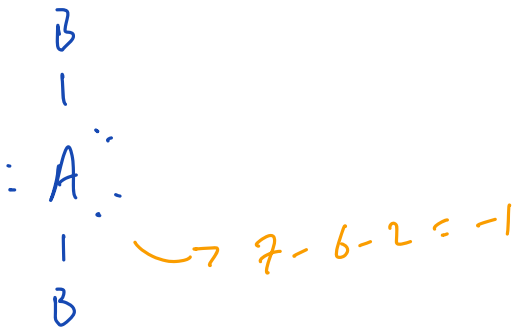
II. Which pair of spaces would two lone pairs likely occupy?

C

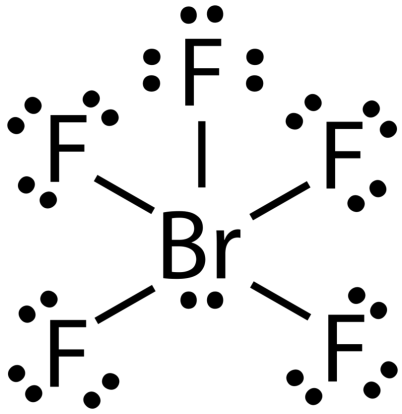
A. A and B
B. F and D
C. B and E e⁻ repulsions minimized
D. D and B
E. More than one of the above

37. The generic polyatomic ion AB_2^- has a trigonal bipyramidal electron group geometry. The central atom, A, belongs to group 17 and is connected to the terminal atoms with single bonds. What is the formal charge on the central atom? Answer with an integer and sign (e.g. +4, -2) or with a zero if no charge is present.

-1



38. Consider the Lewis structure for BrF_5 below. Which of the following statement(s) is/are **true**? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

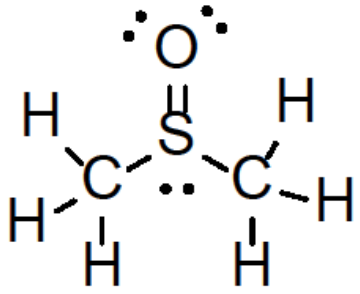


CD

FC = 0 (all atoms)

A. The formal charge on all of the elements above are ~~-1 because they are all halogens~~
B. The molecular geometry for this molecule is octahedral
C. The electron geometry for this molecule is octahedral
D. The molecular geometry for this molecule is square pyramidal
E. The electron geometry for this molecule is square pyramidal

39. The Lewis structure of dimethylsulfoxide is given below. Answer the following questions with the geometries, bond angles, or hybridization in dimethylsulfoxide. Non-standard bond angles should be written as inequalities (e.g. <120).



I. What is the H-C-H bond angle? 109.5 degrees (tetrahedral)

II. What is the hybridization state of the carbon atom? sp^3

III. What is the molecular shape around the sulfur atom?

trigonal Pyramidal

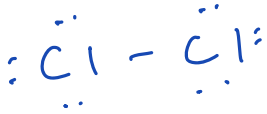
IV. What is the O-S-C bond angle? $\angle$ 109.5 degrees

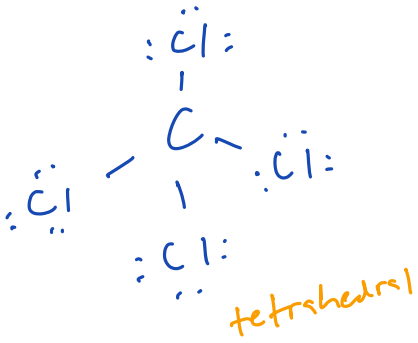
V. What is the hybridization state of the sulfur atom? sp^3

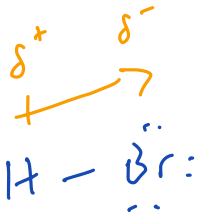
40. Which of these molecules have an overall dipole moment? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

ADE

A. H_2O
B. Cl_2
C. CCl_4
D. PCl_3
E. HBr



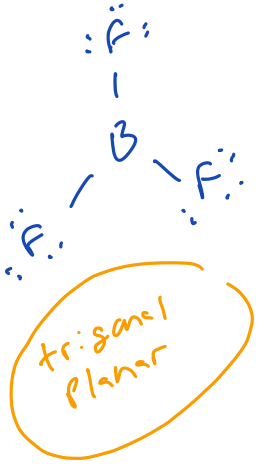


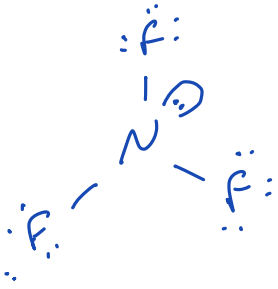


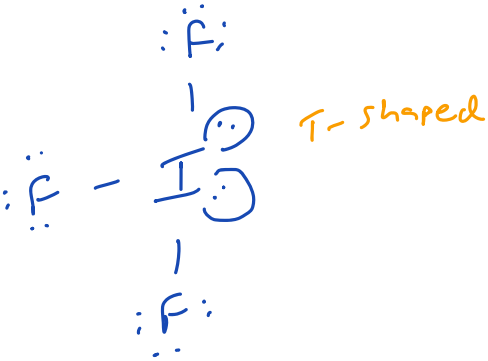
41. Of the molecules below, only _____ is nonpolar.

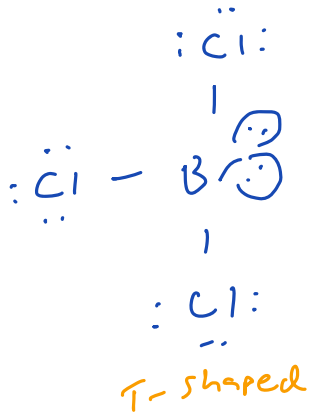
A

A. BF_3
B. NF_3
C. IF_3
D. PBr_3
E. $BrCl_3$



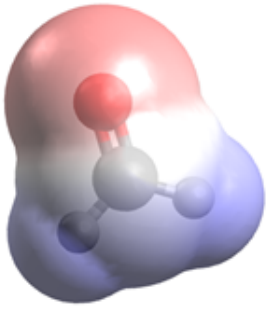






42. The following electrostatic potential map below has a significant difference in color. It shows a _____ molecule.

A



A. Polar
B. Nonpolar
C. Ionic
D. Stoichiometric

43. Which of the following compounds has the greatest ionic character?

A

A. BaO
B. BaS
C. BaSe
D. BaTe

44. In which of the molecules below is the carbon-carbon distance the **shortest**?

B

A. $H_2C=CH_2$
B. $HC\equiv CH$ → triple bond shortest
C. H_3C-CH_3
D. $H_2C=C=CH_2$
E. $H_3C-CH_2-CH_3$

45. Of the bonds C-N, C=N, and C≡N...the C-N bond is _____.

↳ single bond

D

A. strongest/shortest
B. strongest/longest
C. weakest/shortest
D. weakest/longest
E. intermediate in both strength and length

46. Which of the following would have the **shortest** bond length?

D

A. C-O
B. C-C
C. C-N
D. C-F
E. C-Cl

F → smallest atomic size

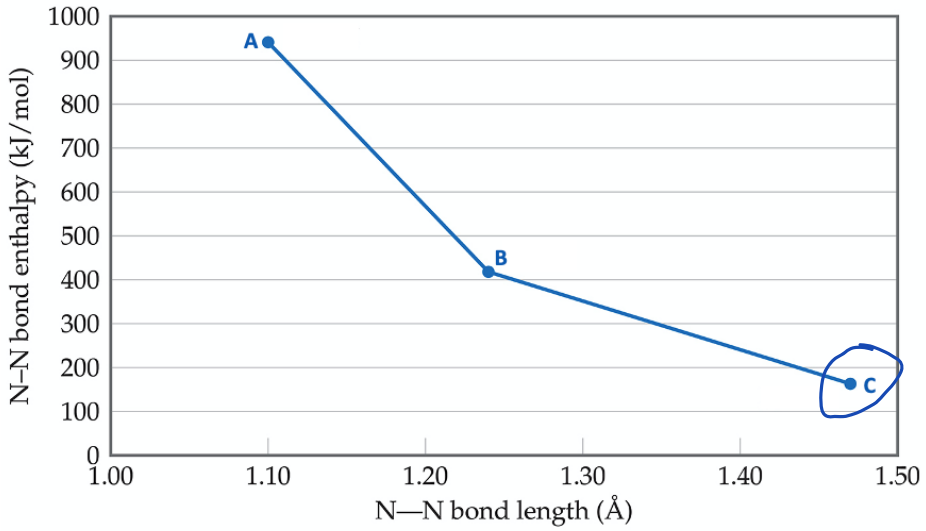
47. A series of bonds W—H, X—H, Y—H, and Z—H were formed where H is hydrogen, and W, X, Y, and Z are generic atoms. The generic atoms' atomic radii, from smallest to largest, are W < X < Y < Z. Which bond is the **strongest**, assuming they are all single bonds?

↓ smallest, forms shorter bond

A

A. W—H → shorter → stronger
B. X—H
C. Y—H
D. Z—H
E. There is not enough information available to make a conclusion.

48. Three different nitrogen-nitrogen bonds are illustrated in the graph below (labeled A, B, and C). Which of the following options below likely corresponds to the point labeled C?



A

weakest and largest

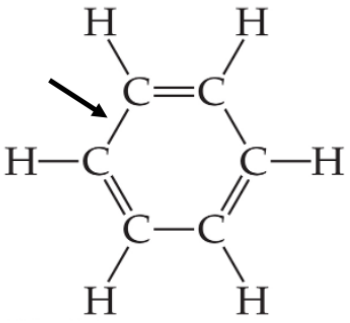
A. N-N
B. N=N
C. N≡N
D. More information is needed to make a conclusion

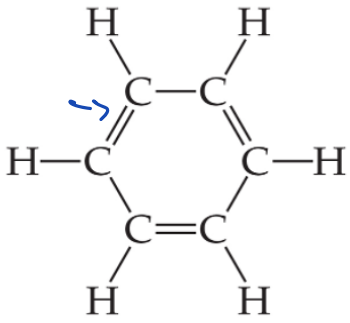
49. Which of the following are **true**? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

ADE

A. Double bonds are shorter than single bonds because the electron clouds of the two atoms overlap more.
B. Triple bonds are longer than single bonds because the bonding electrons repel each other, pushing the two atoms farther apart.
C. Single bonds are stronger than double bonds because it takes less energy to form a single bond.
D. Triple bonds are stronger than double bonds because it takes more energy to break a triple bond.
E. An increase in bond order results in a decrease in bond length and an increase in bond strength.

50. Consider the resonance structures of benzene given below. What is the bond order of the carbon-carbon bond pointed out by the arrow below?





equivalent resonance structures

BO = 1

BO = 2

B

resonance... so take the average

$\frac{1+2}{2} = 3/2$

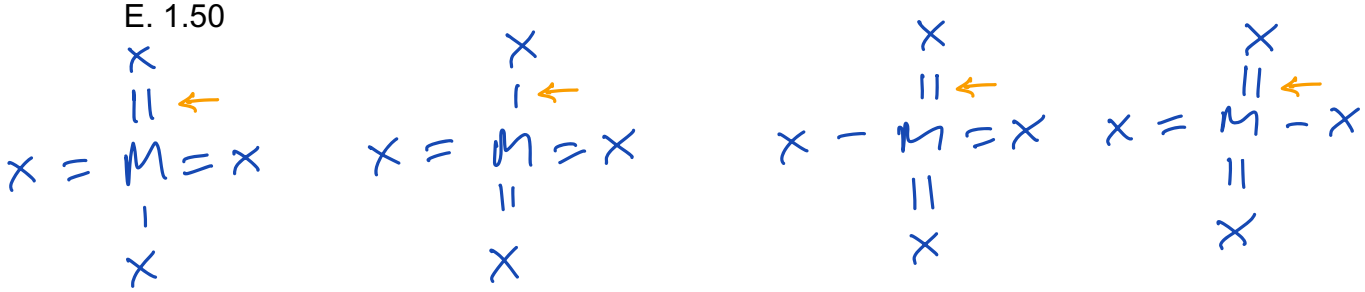
A. 1
B. Between 1 and 2
C. 2
D. Between 2 and 3
E. 3
F. Between 3 and 4
G. 4

"MX4"

51. A hypothetical polyatomic ion has four equivalent resonance structures. Each structure contains one single bond and three double bonds. What is the bond order for any one of the bonds in this molecule?

D

A. 5
B. 1.25
C. There are two bond orders: 1 and 2
D. 1.75
E. 1.50



resonance... so take the average → $\frac{2+1+2+2}{4} = 1.75$

52. Bond formation _____ energy; it is an _____ process.

D

A. requires, endothermic
B. requires, exothermic
C. releases, endothermic
D. releases, exothermic

53. An exothermic reaction should have I. _____ chemical bonds in the reactants and form compounds with II._____ bonds. (Answer using A. weak or B. strong for the blanks. Use only the letters.).

I. A

II. B

54. Consider the following reaction:

$$A_2 + B_2 \rightarrow 2\ AB \qquad \Delta H = -285\ kJ$$

The bond energy for A-A is one-half the amount of the A-B bond energy. The bond energy of B-B is 432 kJ/mol. What is the bond energy of A-A?

C

A. 478 kJ/mol
B. −478 kJ/mol
C. 239 kJ/mol
D. −239 kJ/mol

1st part

$-285\ kJ = [(1\ mol\ A_2 \times \frac{1}{2} AB) + (1\ mol\ B_2 \times 432\ kJ/mol)] - [(2\ mol\ AB \times AB)]$

$-285\ kJ = \frac{1}{2} \frac{AB}{mol} + 432\ kJ - 2 \frac{AB}{mol}$

$-717\ kJ = -1.5\ AB\ mol \rightarrow AB = 478\ kJ/mol$

2nd part

$AA = \frac{1}{2} AB = \frac{1}{2}(478\ kJ/mol)$

$= 239\ kJ/mol$

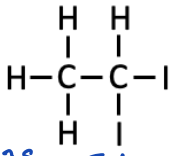
55. Using the table of average bond energies below, the ΔH for the reaction is _____ kJ/mol.

H – C≡C – H H–I:

$$C_2H_2\ (g) + 2\ HI\ (g) \rightarrow C_2H_4I_2$$

Bonds	C-C	C=C	C≡C	C-H	C-I	H-I
Energies (kJ/mol)	348	614	839	413	240	299

Hint: the Lewis structure for $C_2H_4I_2$ (lone pairs omitted) is given here:



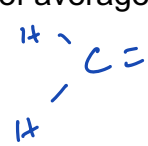
C

A. +160
B. −160
C. −217
D. −63
E. +63

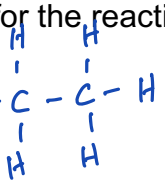
[1 mol (2 × 413 kJ/mol) + 1 mol (1 × 839 kJ/mol) + 2 mol (1 × 299 kJ/mol)] −

[1 mol (4 × 413 kJ/mol) + 1 mol (2 × 240 kJ/mol) + 1 mol (1 × 348 kJ/mol)]

56. Using the table of average bond energies below, the ΔH for the reaction is _____ kJ/mol.



H-H



$$C_2H_4\ (g) + H_2\ (g) \rightarrow C_2H_6$$

Bonds	C-C	C=C	C≡C	C-H	C-I	H-H
Energies (kJ/mol)	348	614	839	413	240	436

A

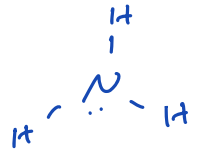
A. −124
B. +98
C. +700
D. −102
E. −166

[1 mol (4 × 413 kJ/mol) + 1 mol (1 × 614 kJ/mol) + 1 mol (1 × 436 kJ/mol)]

− [1 mol (6 × 413 kJ/mol) + 1 mol (1 × 348 kJ/mol)]

57. Using the table of average bond energies below, the ΔH for the reaction is _____ kJ/mol.

$$N_2\,(g) + 3\,H_2\,(g) \rightarrow 2\,NH_3\,(g)$$



Bonds	N-N	N=N	N≡N	N-H	H-H
Energies (kJ/mol)	163	418	945	391	432

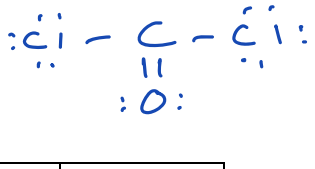
C

A. −969
B. −204
C. −105
D. 204
E. 595

$$\left[1\ \text{mol} \times (1 \times 945\ \text{kJ/mol}) + 3\ \text{mol} \times (1 \times 932\ \text{kJ/mol})\right] - \left[2\ \text{mol} \times (3 \times 391\ \text{kJ/mol})\right]$$

58. Using the table of average bond energies below, the ΔH for the reaction is _____ kJ/mol.

$$CO\,(g) + Cl_2\,(g) \rightarrow COCl_2\,(g)$$



Bonds	C-O	C=O	C≡O	C-Cl	Cl-Cl
Energies (kJ/mol)	358	745	1072	339	239

B

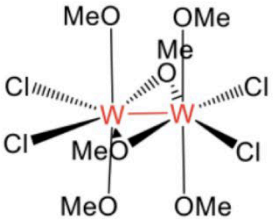
A. −51
B. −112
C. −244
D. −412
E. −733

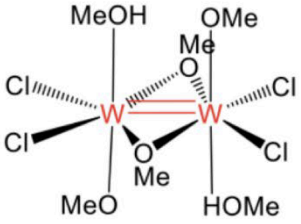
$$\left[1\ \text{mol} \times (1 \times 1072\ \text{kJ/mol}) + 1\ \text{mol} \times (1 \times 239\ \text{kJ/mol})\right] - \left[1\ \text{mol} \times (1 \times 745\ \text{kJ/mol}) + 1\ \text{mol} \times (2 \times 339\ \text{kJ/mol})\right]$$

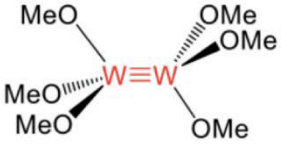
59. Inorganic chemists have long been interested in the bonding environments of organometallic compounds (i.e. compounds that contain a metal center and organic groups, like those shown below). In the compounds below, two tungsten (W) metal centers are in the center of each molecule, and the bonding between the metal's varies from a single bond (Compound A), to a double bond (Compound B), to a triple bond (Compound C), to a quadruple bond (Compound D).

Based on this information, which of the following statements are **true**? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

Compound A | Compound B | Compound C | Compound D



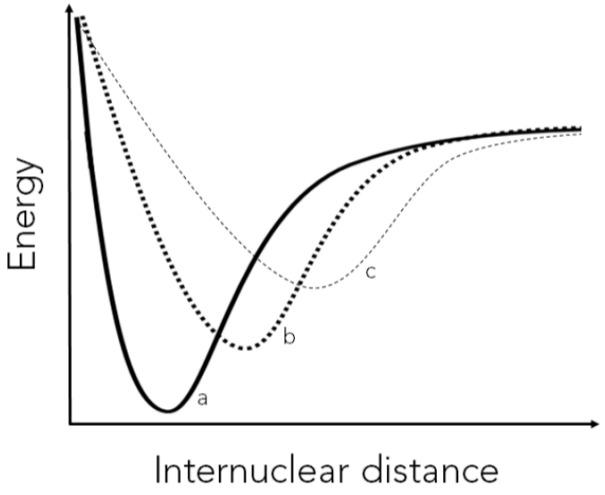




ACF

A. Compound D has the strongest tungsten-tungsten bond compared to the other 3 compounds
B. If Compound A has a tungsten-tungsten bond length of 272 pm, then it is reasonable for Compound D to have a bond length of 312 pm because of its increased strength
C. The tungsten-tungsten bond length for Compound B is likely somewhere between Compound A and Compound C
D. The bond energy associated with the tungsten-tungsten bond in Compound C is smallest due to this compound being the simplest compared to the other compounds
E. The bond energy associated with the tungsten-tungsten bond in Compound A is greatest due to the presence of the tungsten-tungsten single bond
F. If Compound B has a tungsten-tungsten bond enthalpy of 321 kJ/mol, then it is reasonable for Compound C to have a tungsten-tungsten bond enthalpy of 406 kJ/mol because of its increased bond order

60. The bond energy diagrams below represent three carbon-carbon bonds with various orders.



I. Which bond energy diagram is likely to correspond to a double bond?

B

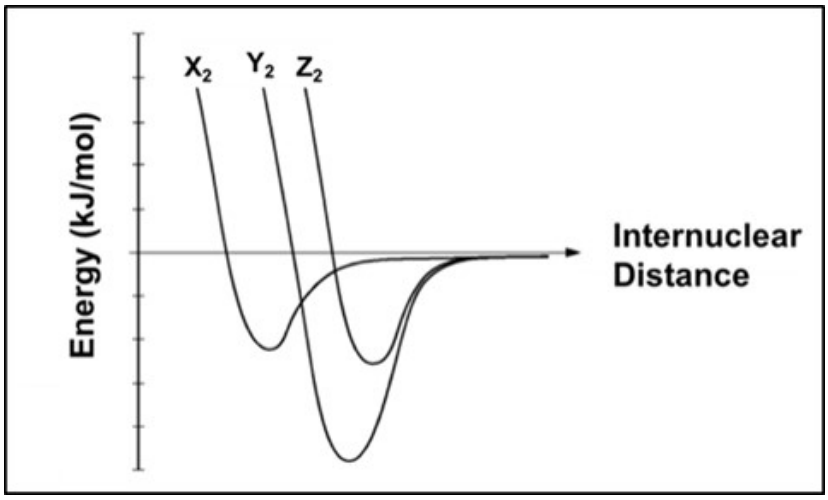
A. a → likely triple bond
B. b
C. c → likely single bond
D. All carbon-carbon bonds will have the same length

II. What does the lowest point on each of the bond energy diagrams represent?

A

A. The lowest overall potential energy and the bond length
B. The largest amount of electron-electron repulsion
C. The largest amount of nuclei-nuclei repulsion
D. The largest amount of nuclei-nuclei attraction
E. The largest amount of electron-electron attraction

61. Consider the potential energy diagram below showing three diatomic molecules. Based on **both** bond length and strength, which molecule most likely has a single bond?



C

A. X_2
B. Y_2
C. Z_2
D. It is not possible to draw a conclusion.

X_2 and Z_2 have similar potential energy, but Z_2 is much longer

62. What is true of hybrid orbitals?

C

A. They can only form from s and p orbitals
B. They only appear in organic compounds
C. They are both an average of the shapes and energy levels of the orbitals that form them
D. They result in the same bond angles as unhybridized orbitals
E. They are involved in pi bonds

63. Select the **correct** statement about pi bonds in Valence Bond Theory.

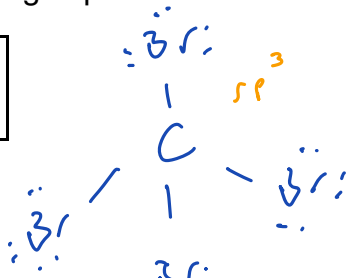
E

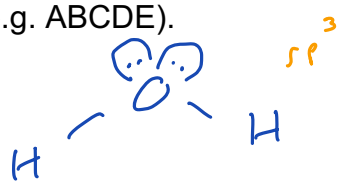
A. A pi bond is stronger than a sigma bond.
B. A pi bond can hold 4 electrons, two above and two below the sigma bond axis.
C. A carbon-carbon double bond consists of two pi bonds.
D. A pi bond is the same strength as a sigma bond.
E. A pi bond between two carbon atoms restricts rotation about the C–C axis because it has electron density above and below the bond axis.

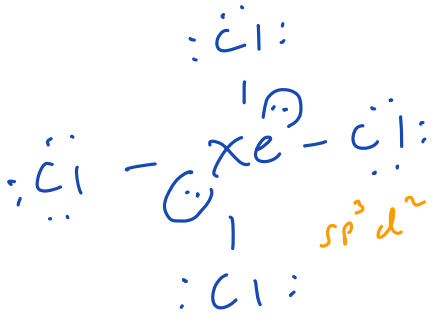
64. Which of the following molecules have sp^3 hybridization on the central atom? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

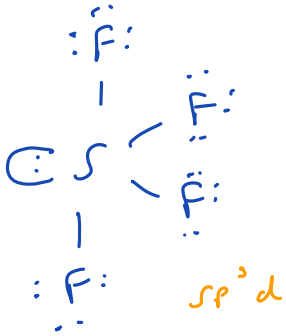
BD

A. C_2H_2
B. CBr_4
C. $XeCl_4$
D. H_2O
E. SF_4







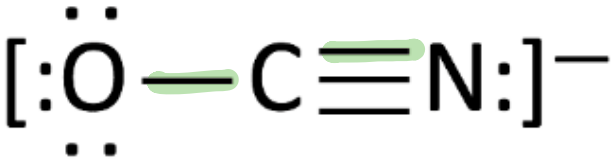


65. According to hybrid orbital theory, a triple bond consists of:

C

A. 1 sigma bond and 1 pi bond
B. 2 sigma bonds and 1 pi bond
C. 1 sigma bond and 2 pi bonds
D. 2 sigma bonds and 2 pi bonds
E. 3 pi bonds

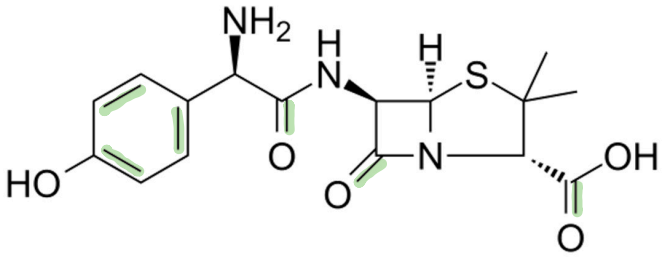
66. How many sigma and pi bonds are shown in the structure below? Answer by using an integer (e.g. 0, 1, etc.).



I. Sigma: 2

II. Pi: 2

67. The Lewis structure for amoxicillin, a commonly prescribed antibiotic, is provided below. How many pi bonds are present in this molecule? Answer by using an integer (e.g. 0, 1, etc.).



6

68. Which of the following depicts a (singular) sp hybrid orbital?

C

A.

B.

C.

D.

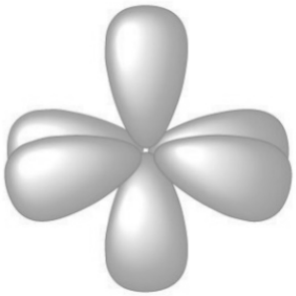
69. Which of the following depicts a set of sp^3 hybrid orbitals?

3

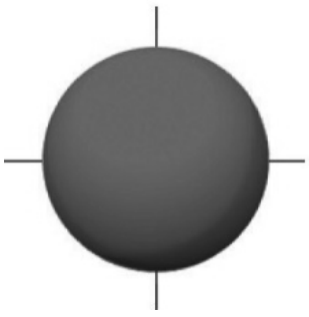
A.

B.

C.



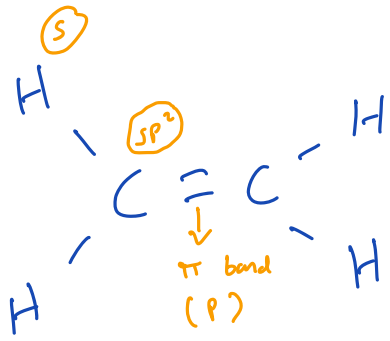
D.



70. What orbitals participate in the bonding of H_2CCH_2? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

ABD

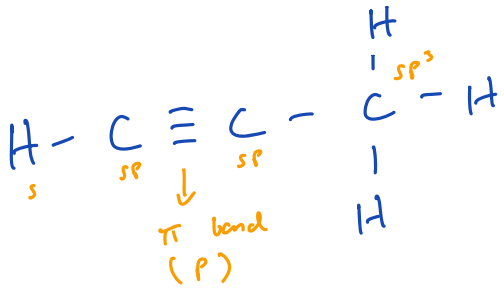
A. s
B. p
C. sp
D. sp^2
E. sp^3
F. sp^3d
G. sp^3d^2



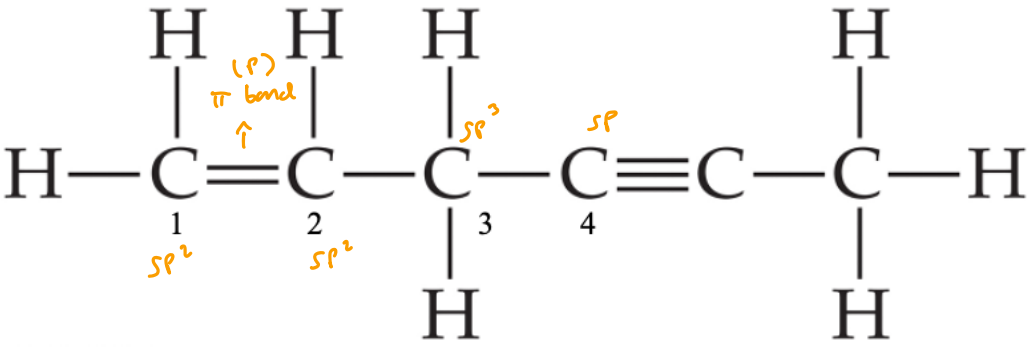
71. What orbital(s) do(es) **not** participate in any of the bonding of $HCCCH_3$?

D

A. s
B. p
C. sp
D. sp^2
E. sp^3
F. More than one of the orbitals above do **not** participate in the bonding of this molecule
G. All of the orbitals above participate in the bonding of this molecule



Answer questions 72-73 using the Lewis structure of the organic molecule below.



72. Which of the following options below best describe the bonding environment between C1 and C2? The specific orbitals for each carbon are written in parentheses below. Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

BD

A. Sigma overlap: C1(p) and C2(p)
B. Sigma overlap: C1(sp^2) and C2(sp^2)
C. Sigma overlap: C1(sp^3) and C2(sp^3)
D. Pi overlap: C1(p) and C2(p)
E. Pi overlap: C1(sp^2) and C2(sp^2)
F. Pi overlap: C1(sp^3) and C2(sp^3)

73. Which of the following options below best describe the bonding environment between C3 and C4? The specific orbitals for each carbon are written in parentheses. Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

C

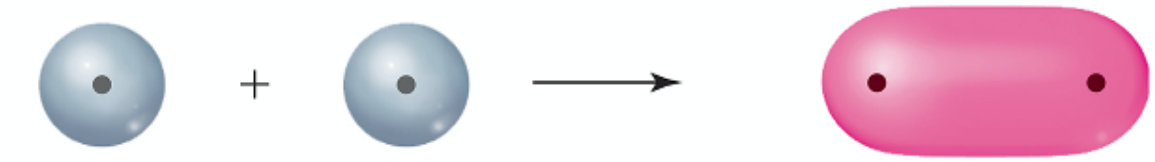
A. Sigma overlap: C3(p) and C4(p)
B. Sigma overlap: C3(sp) and C4(sp^2)
C. Sigma overlap: C3(sp^3) and C4(sp)
D. Pi overlap: C3(p) and C4(p)
E. Pi overlap: C3(sp) and C4(sp^2)
F. Pi overlap: C3(sp^3) and C4(sp)

74. Which of the following statements are **true** regarding molecular orbital (MO) theory? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

H

A. Antibonding orbitals are a result of ~~constructive~~ destructive interference between their corresponding atomic orbitals
B. A bond order of ~~zero~~ or higher indicates a stable bond
C. Placing electrons in either a bonding or ~~antibonding~~ orbital help stabilize an ion or molecule
D. Antibonding orbitals ~~may either be in a lower or~~ higher energy than their corresponding atomic orbitals, depending on the specific ion or molecule given
E. A π^*_{2p} orbital represents a ~~bonding~~ antibonding orbital
F. The total number of atomic orbitals that combine to form molecular orbitals ~~may not necessarily~~ match the total number of molecular orbitals produced, depending on the specific molecule or ion
G. Adding an electron to a ~~nonbonding~~ antibonding orbital decreases the stability of an ion or molecule
H. None of the above are true

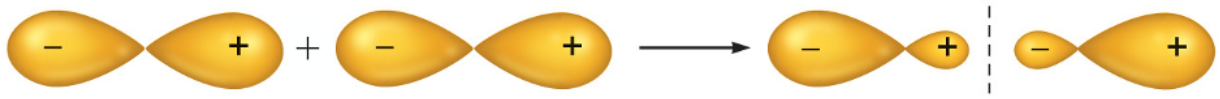
75. Consider the illustration below showing the overlap of two s orbitals resulting in a molecular orbital. Which of the following statements below are **true**?



A

A. The orbital is a σ molecular orbital
B. The orbital is a σ^* molecular orbital
C. The orbital is a π molecular orbital
D. The orbital is a π^* molecular orbital
E. None of the above are true

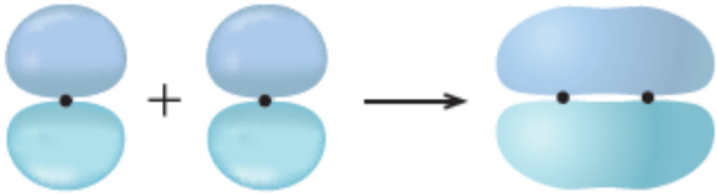
76. Consider the illustration below showing the overlap of two p orbitals resulting in a molecular orbital. Which of the following statements below are **true**?



B

A. The orbital is a σ molecular orbital
B. The orbital is a σ* molecular orbital
C. The orbital is a π molecular orbital
D. The orbital is a π* molecular orbital
E. None of the above are true

77. Consider the illustration below showing the overlap of two p orbitals resulting in a molecular orbital. Which of the following statements below are **true**?



C

A. The orbital is a σ molecular orbital
B. The orbital is a σ* molecular orbital
C. The orbital is a π molecular orbital
D. The orbital is a π* molecular orbital
E. None of the above are true

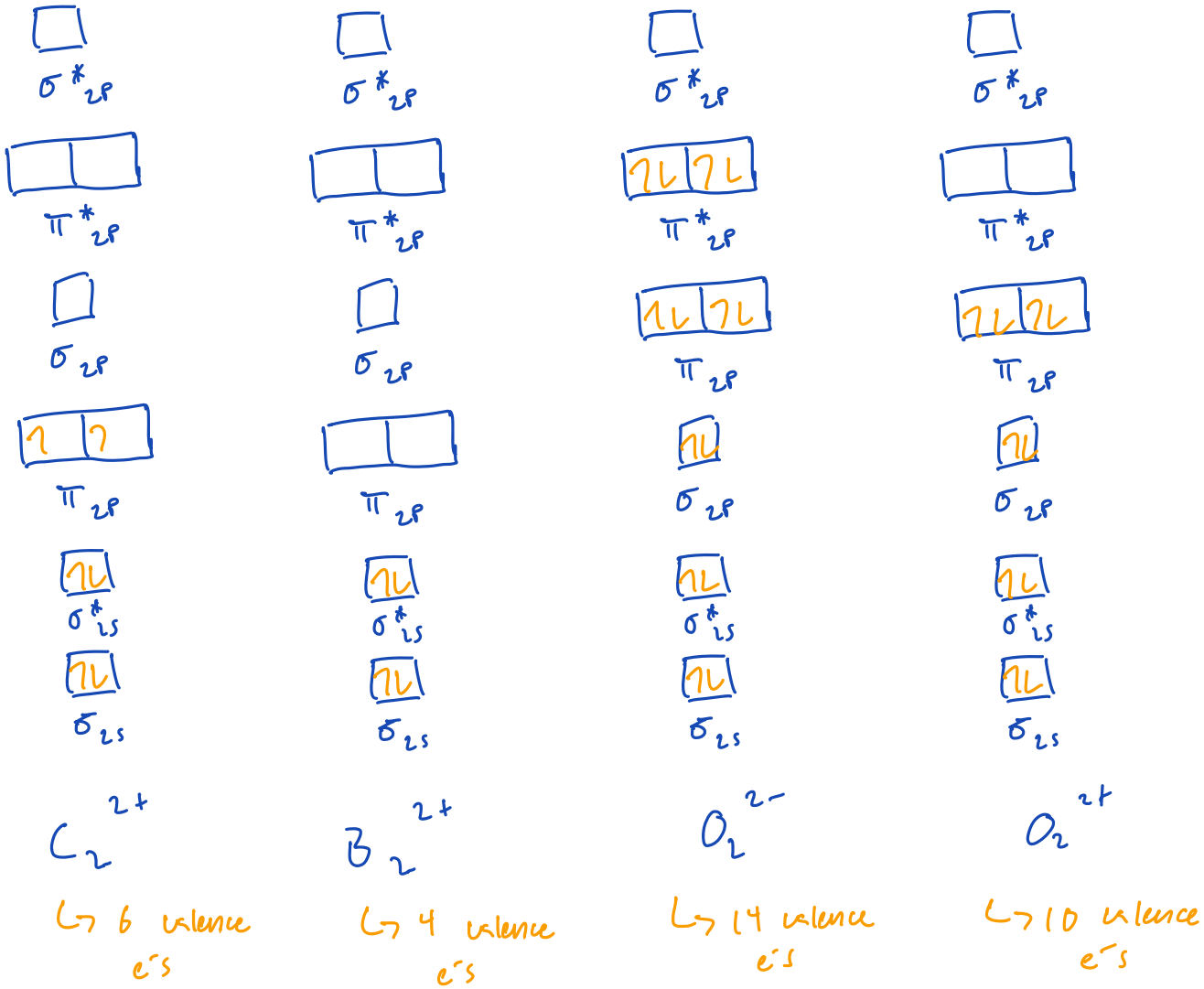
78. The MO diagrams of some homonuclear diatomic molecules vary due to *s-p* mixing, which changes the energy levels of the corresponding molecular orbitals. Which of the following molecules below are significantly affected by *s-p* mixing? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

ABC

A. B_2
B. C_2
C. N_2
D. O_2
E. F_2

s-p mixing

Draw MO diagrams for the ions C_2^{2+}, B_2^{2+}, O_2^{2-}, O_2^{2+} and answer questions 79-86 starting on the next page. The area below has been left blank to draw your diagrams if needed.



79. What is the bond order for each of these ions? Answer with an integer or a decimal to two decimal places (e.g. 2, 0.75).

I. C_2^{2+} [1] $\frac{4-2}{2}$

II. B_2^{2+} [0] $\frac{2-2}{2}$

III. O_2^{2-} [1] $\frac{8-6}{2}$

IV. O_2^{2+} [3] $\frac{8-2}{2}$

80. Which of the following ions is the most stable?

[D]

A. C_2^{2+}
B. B_2^{2+}
C. O_2^{2-}
D. O_2^{2+}

81. Which of the following ions is expected to have the shortest bond?

[D]

A. C_2^{2+}
B. B_2^{2+}
C. O_2^{2-}
D. O_2^{2+}

82. Which of the following ions would become more stable if an electron is removed? Select any that apply and answer using capital letters with no spaces (e.g. ABCDE).

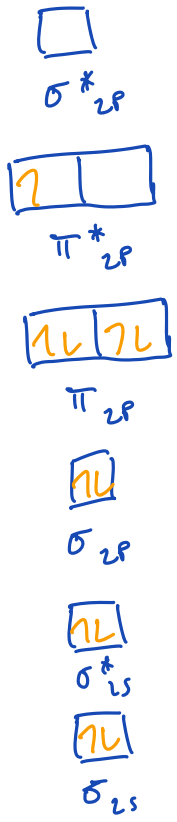
BC

A. C_2^{2+}
B. B_2^{2+}
C. O_2^{2-}
D. O_2^{2+}

83. What is the bond order of the O_2^{2-} ion if three electrons are removed? Answer with an integer or a decimal to two decimal places (e.g. 2, 0.75).

2.50

$\frac{8-3}{2}$



84. Which of the following ions is/are predicted to be paramagnetic?

A

A. C_2^{2+}
B. B_2^{2+}
C. O_2^{2-}
D. O_2^{2+}
E. More than one of the above
F. None of the above

85. What is the highest occupied molecular orbital (HOMO) in the C_2^{2+} ion?

E

A. σ_{2s}
B. σ^*_{2s}
C. σ_{2p}
D. σ^*_{2p}
E. π_{2p}
F. π^*_{2p}

86. What is the lowest unoccupied molecular orbital (LUMO) in the C_2^{2+} ion?

C

A. σ_{2s}
B. σ^*_{2s}
C. σ_{2p}
D. σ^*_{2p}
E. π_{2p}
F. π^*_{2p}

Consider the hypothetical ions and molecule MX^-, MX, and MX^+. The element "M" contains 4 valence electrons and the element "X" has 5 valence electrons. Their best Lewis structures are provided below, in addition to three blank MO diagrams that you may use as a model for each on the next page. Answer questions 87-90 with this information.

87. Based on their Lewis structures, which of the following would you expect to be the most stable?

A

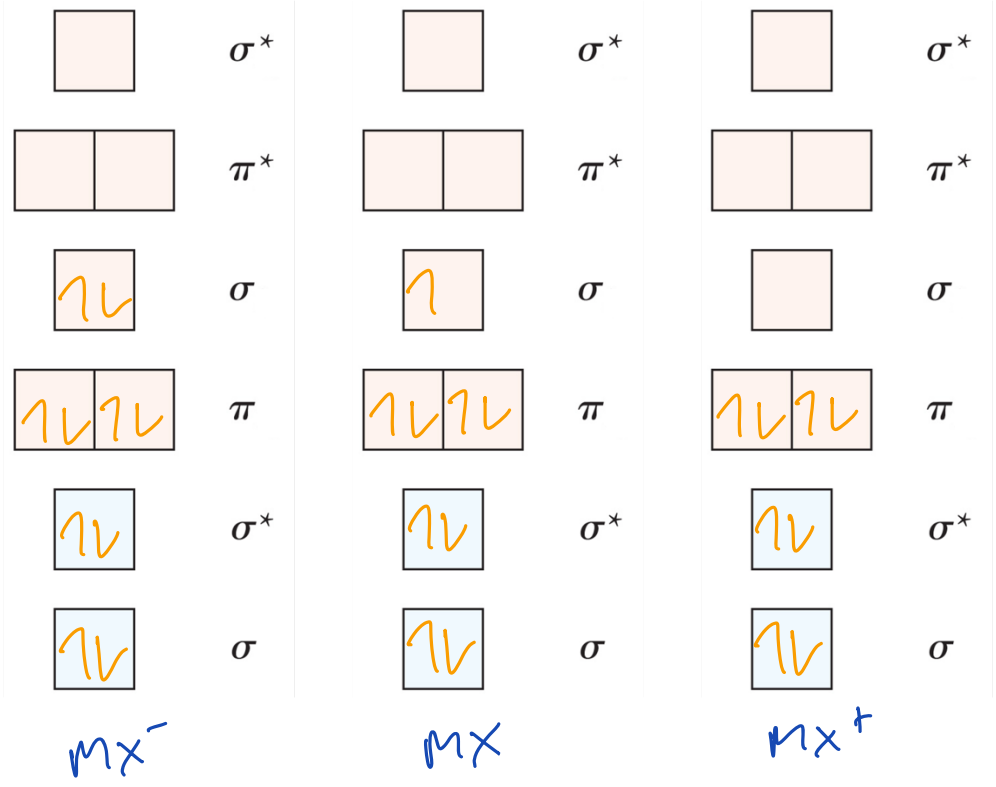
A. MX^- → all atoms fulfill octet rule
B. MX
C. MX^+
D. They are all expected to have the same stability

88. Fill in the MO diagrams below for MX^-, MX, and MX^+. Afterwards, determine the bond order for each. Answer with an integer or a decimal to two decimal places (e.g. 2, 0.75).

I. MX^- | 3 | $\frac{8-2}{2}$

II. MX | 2.50 | $\frac{7-2}{2}$

III. MX^+ | 2 | $\frac{6-2}{2}$



89. Based on the bond order you calculated using MO theory, which of the following would you expect to be the most stable?

A

A. MX^-
B. MX
C. MX^+
D. They are all expected to have the same stability

90. Based on your answers, do the Lewis model and the MO model agree with each other regarding the most stable molecule or ion?

A

A. Yes
B. No
C. A conclusion cannot be drawn

Periodic Table of the Elements

1																	18
1 H 1.01	2											13	14	15	16	17	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31	3	4	5	6	7	8	9	10	11	12	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.63	33 As 74.92	34 Se 78.97	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc [97]	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
37 Cs 132.91	56 Ba 137.33		72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [209]	85 At [210]	86 Rn [222]
87 Fr [223]	88 Ra [226]		104 Rf [267]	105 Db [268]	106 Sg [269]	107 Bh [270]	108 Hs [269]	109 Mt [277]	110 Ds [281]	111 Rg [282]	112 Cn [285]	113 Nh [286]	114 Fl [290]	115 Mc [290]	116 Lv [293]	117 Ts [294]	118 Og [294]

57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm [145]	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97
89 Ac [227]	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np [237]	94 Pu [244]	95 Am [243]	96 Cm [247]	97 Bk [247]	98 Cf [251]	99 Es [252]	100 Fm [257]	101 Md [258]	102 No [259]	103 Lr [262]

Formula Sheet

Length
1 kilometer = 0.62137 mile
1 inch = 2.54 centimeters (exactly)
1 Ångstrom = 1×10^{-10} meter

Energy
1 joule = 1 kg·m^2/s^2
1 calorie = 4.184 joules
1 Calorie = 1 kilocalorie = 1000 calories
1 L·atm = 101.325 joules

Pressure
1 pascal = 1 N/m^3 = 1 kg/m·s^2
1 atmosphere = 101.325 kilopascals = 760 mm Hg = 760 torr = 14.70 lb/in^2
1 bar = 1×10^5 Pa (exactly)

Temperature
0 K = −273.15°C
K = °C + 273.15
°C = (5/9)(°F − 32)

Mass
1 kg = 2.205 lbs

Volume
1 mL = 1 cm^3 = 1 cc

Constants
c = 2.998×10^8 m/sec
h = 6.626×10^{-34} J·sec
R = 0.08206 L·atm/mol·K = 8.314 J/mol·K
Specific heat of water = 4.184 J/g·K
Mass of an electron: 9.109 x 10^{-31} kg
Mass of a proton: 1.673 x 10^{-27} kg
RH = 2.18 x 10^{-18} J
Specific heat of water = 4.184 J/g·K
Avogadro's number: 6.022×10^{23}
F = 96485 J/(V·mol e$^-$)
$K_w = 1.0 \times 10^{-14}$ at 25 °C
$k_b = 1.381 \times 10^{-23}$ J/K

Equations
$(P + a(n^2/V^2))\cdot(V - nb) = nRT$
molar mass (M) = mRT/PV
density (d) = MP/RT

$$KE = \frac{3}{2}RT$$

$$\mu_{rms} = \sqrt{\frac{3RT}{M}}$$

$$\frac{Rate\ of\ effusion\ A}{Rate\ of\ effusion\ B} = \sqrt{\frac{MW_B}{MW_A}}$$

$$\Delta E = -2.18 \times 10^{-18} J(\frac{1}{n_f^2} - \frac{1}{n_i^2})$$

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{\Delta H_{vap}}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$C_g = kP_g$
$P_{solution} = P_{solvent}\ X_{solvent}$
$P_{solution} = \sum P_j = \sum P_j X_j$
$\pi = MRTi$

Thermodynamic and Electrochemistry

$S = k_b \times \ln(W)$
$\Delta S = q_{rev}/T$
$\Delta G = \Delta G° + RT \cdot \ln Q$
$R = 8.314$ J/mol.K
$\Delta G° = -RT \cdot \ln K$
$\Delta G = -nFE_{cell}$
$E°_{cell} = RT/nF \ln K$
$E°_{cell} = (0.0257/n) \ln K = (0.0592/n) \log K$
$E_{cell} = E°_{cell} - (RT/nF) \ln Q$
$E_{cell} = E°_{cell} - (0.0257/n) \ln Q$
Electrolysis: Q (total charge) = I × t = n × F

Integrated Rate Laws & half-life

$$\ln\frac{[A]}{[A]_0} = -kt$$

$$\frac{1}{[A]} = kt + \frac{1}{[A]_0}$$

$$[A] = -kt + [A]_0$$

$$t_{1/2} = \frac{[A]_0}{2k}$$

$$t_{1/2} = \frac{\ln 2}{k} = \frac{0.693}{k}$$

$$t_{1/2} = \frac{1}{k[A]_0}$$

$$ln\frac{k_2}{k_1} = -\frac{E_a}{R}(\frac{1}{T_2} - \frac{1}{T_1})$$

Equilibrium and Acid / Base

$K_P = K_c \times (RT)^{\Delta n}$

$$ln\frac{K_2}{K_1} = \frac{\Delta H^\circ_{rxn}}{R}(\frac{1}{T_1} - \frac{1}{T_2})$$