Correct answer is in RED (numbers 1-8, 2.5 points each)

1. Which of the following bonds should be the most polar? [UNIT 9, exam mat’l]

2. Choose the element that should have the lowest electronegativity. [UNIT 8, exam mat’l]

3. What is the change in energy of a reaction in which 800 kJ of energy is required to break bonds and 980 kJ of heat is generated by bond formation? [UNIT 6 – to be covered later]
   a. +1780 kJ  b. -1780 kJ  c. +180 kJ  d. -180 kJ  e. none of the above

4. Which of the following species has a central atom with sp³ hybridization? [Unit 10, exam mat’l]
   a. SO₂  b. NO₃⁻  c. CH₄  d. CO₃²⁻  e. none of the above

5. Which of the following bonds should be the shortest and strongest? [Unit 10, exam mat’l]

6. Which of the following sets contains the greatest number of linear molecules? [Unit 10, exam mat’l]

7. Which of the following is a trigonal pyramidal molecule? [Unit 10, exam mat’l]
   a. BCl₃  b. SO₂  c. CH₄  d. NH₃  e. I₂

8. Which of the following is a bent molecule? [Unit 10, exam mat’l]
   a. BCl₃  b. SO₂  c. CH₄  d. NH₃  e. I₂

Complete the following as directed (point values as indicated).

(12 points)

9. Calculate the heat of reaction for the hydrogenation of ethylene from the bond energies listed and the reaction as shown.

   \[
   \begin{align*}
   \text{C}_2\text{H}_4 (g) + \text{H}_2 (g) & \rightarrow \text{C}_2\text{H}_6 (g) \\
   \text{C}−\text{C} & \quad \text{H}−\text{H} \quad \text{C}−\text{H} \quad \text{and} \quad \text{C}−\text{C} \\
   \text{BE (kJ/mole)} & \quad 620 \quad 436 \quad 414 \quad 347 \\
   \Delta\text{H}_\text{rxn} & = ??? \text{kJ}
   \end{align*}
   \]

[UNIT 6, will be covered later]
10. Draw the best Lewis structure of the species SF$_5^+$ (yes there is a charge of plus one on this ion), and give the names of the electron pair geometry and of the molecular shape. Calculate the formal charge on the sulfur and on the fluorines. Finally, comment on number of electrons around the central atom and give the hybridization (ex. sp) which this atom must have (and DRAW the hybrid orbital diagram).

$\text{SF}_5^+$ (has 40 electrons)  

Please note each F has three lone pairs around it (you will need to show them on your quiz – I have omitted them because my software refuses to show them . . . ) and the formal charges are:

e pair geometry trigonal bipyrimidal molecular shape trigonal bipyrimidal

bond angles: axial F-S- equit F is 90°, equit F – S – equit F is 120°, and
axial F-S- axial F is 180°

$FC (S) = 6 - 5 - 0 = +1$ and $FC (F) = 7 - 1 - 6 = 0$, same for all five fluorines

The S has ten electrons (an expanded octet) in five bonding pairs around it. This is permitted because S is in period three and has access to d orbitals in its valence shell.

11. (a) Draw Lewis structures for the nitrogen molecule, N$_2$, and for the azide ion N$_3^-$ (yes it has a minus one charge). Label all atoms with their formal charges.

$\text{:N≡N:}$

In $N_2$ both N have FC = zero  

In the azide ion formal charges are as shown, note that the total of the formal charges is (-1).

(b) Predict the shape of each species ($N_2$ and $N_3^-$).

Both of these species are linear.

(c) Predict the hybridization, and draw the hybrid energy levels [filled with arrows for the electrons] for each distinct type of N in each structure. HINT: you might want to label the N atoms [for example as a, b, c] in the azide ion structure in part “a” above.

In $N_2$ both of the N atoms is $sp$ hybridized with five electrons allocated to each N:

**hybrid orbitals** $sp$ ($\uparrow\downarrow$) ($\uparrow$)  

unhybridized $p$’s ($\uparrow$ ($\uparrow$)

used for . . . lone pair, $\sigma$  

unhybridized $p$ and $\pi$

In azide the central N is sp hybrized while BOTH of the terminal N are sp2 hybridized

**CENTRAL** hybrid orbitals $sp$ ($\uparrow$) ($\uparrow$)  

unhybridized $p$’s ($\uparrow$ ($\uparrow$

used for . . . $\sigma$ and $\sigma$  

$\pi$ and $\pi$

**TERMINAL** hybrid orbitals $sp^2$ ($\uparrow\downarrow$)($\uparrow\downarrow$)($\uparrow\uparrow$)unhybridized $p$ ($\uparrow$

used for . . . 2 lone pair and $\sigma$  

$\pi$

(d) Azides decompose violently to form nitrogen. Discuss the reason for this decomposition reaction by examination of the electron configurations around the nitrogens in nitrogen vs. azide.

$2 \text{N}_3^-(g) \to 3 \text{N}_2(g) \quad \Delta H = \text{very exothermic (i.e.} - \text{kJ)}$

THIS MATERIAL WILL BE COVERED IN UNIT 7 . . . omit from next quiz and exam
(15 points) This material will be covered AFTER THE QUIZ but before the EXAM!!!!

12. Fill in the MO energy diagrams for the species listed below [valence level electrons only!]. The answer the questions that appear under the MO energy diagram of each species.

<table>
<thead>
<tr>
<th>disulfide</th>
<th>S(_2)(^{-2})</th>
<th>14 e-</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\sigma*3p)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>↑↓ (\pi*3p)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>↑↓ (\pi3p)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>↑↓ (\sigma3p)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>↑↓ (\sigma*3s)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>↑↓ (\sigma3s)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>carbide</th>
<th>C(_2)(^{-2})</th>
<th>10 e-</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(\sigma*2p)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>↑↓ (\pi*3p)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>↑↓ (\pi2p)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>↑↓ (\pi3p)</td>
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<td>↑↓ (\pi2p)</td>
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<tr>
<td></td>
<td>↑↓ (\sigma2p)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>↑↓ (\sigma*2s)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>↑↓ (\sigma2s)</td>
<td></td>
</tr>
</tbody>
</table>

Note: this type of carbide is called an acetylide.

Show the calculation of the bond order for the disulfide ion. **Two choices:**
(a) \(w/\sigma3s\) and \(\sigma*3s\); Bond order = (8-6)/2 = 1
(b) \(w/out\) 3s level; Bond order = (6-4)/2 = 1

Show the calculation of the bond order for the carbide ion. **Two choices:**
(a) \(w/\sigma2s\) and \(\sigma*2s\); Bond order = (8-2)/2 = 3
(b) \(w/out\) 2s level; Bond order = (6-0)/2 = 3

Is the disulfide ion diamagnetic or paramagnetic? Explain your answer. **All the electrons in the molecular orbitals are paired so the ion is diamagnetic.**

Is the carbide ion diamagnetic or paramagnetic? Explain your answer. **All the electrons in the molecular orbitals are paired so the ion is diamagnetic.**

Draw the Lewis structure of the disulfide ion.

```
-1 . . -1
:S ——— S:
  . .
```

Draw the Lewis structure for the carbide ion.

```
-1 :C ——— C: -1
```

Does the bond order for the disulfide ion from the Lewis structure match the bond order from the MO diagram? Yes, each predicts a single bond.

Does the bond order for the carbide ion from the Lewis structure match the bond order from the MO diagram? Yes, each predicts a triple bond.

Which should have the longer, weaker bond; the disulfide ion or the carbide ion? Explain your choice! **Disulfide because it is a single bond holding together two like (-1 each) charges.**
For the following two species complete the tasks specified below in a - d.

i. CH₃COOH

a. Draw the best Lewis structures.

b. Specify the hybridization of both the C atoms and the O atom specified in (i) and the C atoms in (ii)?

C in CH₃: sp³

C in CO: sp²

O between CO and H: sp³

C in CH: sp

C in CH₃

C in CO

C in CH

C in CH

C in CH

C in CH

C in CH

C in CH

C in CH

C in CH

O [the COH angle]

A bit less than 109.5°

(see next page for bonus)
BONUS (for up to 7.5 points)

For the skeleton structure below: (a) complete the Lewis structure by adding unshared pairs and multiple bonds where appropriate (DO NOT ADD OTHER ATOMS!!), (b) specify the hybridization on the atoms labeled a - e, and (c) draw the hybridized orbital energy diagram for each atom a - f (filling each the correct number of electrons).

\[
\begin{array}{c}
\text{H} : \text{O} : \\
| \quad | \\
\text{H} - \text{C}_a = \text{C}_b - \text{C}_c - \text{O}_d - \text{C} - \text{N}_e - \text{C} - \text{H} \\
| \quad | \\
\text{H} \quad \text{H} \quad \text{H} \quad \text{H}
\end{array}
\]

- \( \text{C}_a \) is \( sp \) \( (\uparrow)(\uparrow) \) unhybridized \( p \)'s \( (\uparrow)(\uparrow) \) used for . . . \( \sigma \) and \( \sigma \) \( \pi \) and \( \pi \)

- \( \text{C}_b \) is \( sp^3 \) \( (\uparrow)(\uparrow)(\uparrow)(\uparrow) \) used for . . . \( 4 \sigma \) bonds

- \( \text{C}_c \) is \( sp^2 \) \( (\uparrow)(\uparrow)(\uparrow) \) unhybridized \( p \) \( (\uparrow) \) used for . . . \( 3 \sigma \) bonds and a \( \pi \) bond

- \( \text{O}_d \) is \( sp^3 \) \( (\uparrow\downarrow)(\uparrow\downarrow)(\uparrow\downarrow)(\uparrow\downarrow) \) used for . . . \( 2 \) lone pairs and \( 2 \sigma \) bonds

- \( \text{N}_e \) is \( sp^3 \) \( (\uparrow\downarrow)(\uparrow)(\downarrow)(\downarrow) \) used for . . . \( 1 \) lone pair and \( 3 \sigma \) bonds