Sample Multiple Choice Questions

1) Which of the following has eight valence electrons?
   A) Ti$^{4+}$
   B) Kr
   C) Cl$^-$
   D) Na$^+$
   E) all of the above

2) In ionic bond formation, the lattice energy of ions ________ as the magnitude of the ion charges ________ and the radii __________.
   A) increases, decrease, increase
   B) increases, increase, increase
   C) decreases, increase, increase
   D) increases, increase, decrease
   E) increases, decrease, decrease

3) Of the atoms below, __________ is the most electronegative.
   A) Si
   B) Cl
   C) Rb
   D) Ca
   E) S

4) The Lewis structure of N$_2$H$_2$ shows __________.
   A) a nitrogen-nitrogen triple bond
   B) a nitrogen-nitrogen single bond
   C) each nitrogen has one nonbonding electron pair
   D) each nitrogen has two nonbonding electron pairs
   E) each hydrogen has one nonbonding electron pair

5) There are __________ valence electrons in the Lewis structure of CH$_3$OCH$_2$CH$_3$.
   A) 18
   B) 20
   C) 26
   D) 32
   E) 36

6) In the nitrite ion (NO$_2^-$), __________.
   A) both bonds are single bonds
   B) both bonds are double bonds
   C) one bond is a double bond and the other is a single bond
   D) both bonds are the same
   E) there are 20 valence electrons
7) For resonance forms of a molecule or ion, __________.
A) one always corresponds to the observed structure
B) all the resonance structures are observed in various proportions
C) the observed structure is an average of the resonance forms
D) the same atoms need not be bonded to each other in all resonance forms
E) there cannot be more than two resonance structures for a given species

For the questions that follow, consider the BEST Lewis structures of the following oxyanions:

(i) NO$_2^-$ (ii) NO$_3^-$ (iii) SO$_3^{2-}$ (iv) SO$_4^{2-}$ (v) BrO$_3^-$

8) There can be four equivalent best resonance structures of __________.
A) (i)  
B) (ii)  
C) (iii)  
D) (iv)  
E) (v)

9) In which of the ions do all X-O bonds (X indicates the central atom) have the same length?
A) none  
B) all  
C) (i) and (ii)  
D) (iii) and (v)  
E) (iii), (iv), and (v)

10) A valid Lewis structure of __________ cannot be drawn without violating the octet rule.
A) NF$_3$  
B) IF$_3$  
C) PF$_3$  
D) SbF$_3$  
E) SO$_4^{2-}$

11) Of the bonds C–C, C= C, and C= C, the C–C bond is __________.
A) strongest/shortest  
B) strongest/longest  
C) weakest/longest  
D) weakest/shortest  
E) intermediate in both strength and length

12) As the number of covalent bonds between two atoms increases, the distance between the atoms ________ and the strength of the bond between them ________.
A) increases, increases  
B) decreases, decreases  
C) increases, decreases  
D) decreases, increases  
E) unpredictable
13) Given the electronegativities below, which covalent single bond is most polar?
Element: H  C  N  O
Electronegativity:  2.1  2.5  3.0  3.5
A) C--H  B) N--H  C) O--H  D) O--C  E) O--N

14) In the Lewis structure of ClF, the formal charge on Cl is ________ and the formal charge on F is ________.
A) -1, -1  B) 0, 0  C) 0, -1  D) +1, -1  E) -1, +1

15) Using the table of average bond energies below, the ΔH for the reaction is ________ kJ.

\[ \text{H--C≡C--H (g) + H--I (g) → H}_2\text{C=CHI (g)} \]

<table>
<thead>
<tr>
<th>Bond</th>
<th>C≡C</th>
<th>C=C</th>
<th>H--I</th>
<th>C--I</th>
<th>C--H</th>
</tr>
</thead>
<tbody>
<tr>
<td>D (kJ/mol):</td>
<td>839</td>
<td>614</td>
<td>299</td>
<td>240</td>
<td>413</td>
</tr>
</tbody>
</table>
A) +506  B) -931  C) -506  D) -129  E) +129

16) Using the table of average bond energies below, the ΔH for the reaction is ________ kJ.

\[ \text{C=O (g) + 2H}_2\text{ (g) → H}_3\text{C--O--H (g)} \]

<table>
<thead>
<tr>
<th>Bond</th>
<th>C--O</th>
<th>C=O</th>
<th>C≡O</th>
<th>C--H</th>
<th>H--H</th>
<th>O--H</th>
</tr>
</thead>
<tbody>
<tr>
<td>D (kJ/mol):</td>
<td>358</td>
<td>799</td>
<td>1072</td>
<td>413</td>
<td>436</td>
<td>463</td>
</tr>
</tbody>
</table>
A) +276  B) -276  C) +735  D) -735  E) -116

17) The basis of the VSEPR model of molecular bonding is ________.
A) regions of electron density on an atom will organize themselves so as to maximize s-character
B) regions of electron density in the valence shell of an atom will arrange themselves so as to maximize overlap
C) atomic orbitals of the bonding atoms must overlap for a bond to form
D) electron domains in the valence shell of an atom will arrange themselves so as to minimize repulsions
E) hybrid orbitals will form as necessary to, as closely as possible, achieve spherical symmetry
18) In counting the electron domains around the central atom in VSEPR theory, a _________ is not included.
A) nonbonding pair of electrons
B) single covalent bond
C) core level electron pair
D) double covalent bond
E) triple covalent bond

19) The electron-domain geometry of __________ is tetrahedral.
A) CBr₄
B) PH₃
C) CCl₂Br₂
D) XeF₄
E) all of the above except XeF₄

20) Of the following species, __________ will have bond angles of 120°.
A) PH₃
B) ClF₃
C) NCl₃
D) BCl₃
E) All of these will have bond angles of 120°.

21) The molecular geometry of the BrO₃⁻ ion is __________.
A) trigonal pyramidal
B) trigonal planar
C) bent
D) tetrahedral
E) T-shaped

22) An electron domain consists of _________
   a) a nonbonding pair of electrons
   b) a single bond
   c) a multiple bond

A) a only
B) b only
C) c only
D) a, b, and c
E) b and c

23) The electron-domain geometry and the molecular geometry of a molecule of the general formula ABᵣ will always be the same if __________.
A) there are no lone pairs on the central atom
B) there is more than one central atom
C) n is greater than four
D) n is less than four
E) the octet rule is obeyed
24) PCl₅ has __________ electron domains and a __________ molecular arrangement.
A) 6, trigonal bipyramidal
B) 6, tetrahedral
C) 5, square pyramidal
D) 5, trigonal bipyramidal
E) 6, seesaw

25) Of the molecules below, only __________ is polar.
A) SbF₅
B) AsH₃
C) I₂
D) SF₆
E) CH₄

Consider the following species when answering the following question:
(i) PCl₃  (ii) CCl₄  (iii) TeCl₄  (iv) XeF₄  (v) SF₆

26) For which of the molecules is the molecular geometry (shape) the same as the VSEPR electron domain arrangement (electron domain geometry)?
A) (i) and (ii)
B) (i) and (iii)
C) (ii) and (v)
D) (iv) and (v)
E) (v) only

27) The molecular geometry of the BeCl₂ molecule is __________, and this molecule is __________.
A) linear, nonpolar
B) linear, polar
C) bent, nonpolar
D) bent, polar
E) trigonal planar, polar

28) For molecules with only one central atom, how many lone pairs on the central atom guarantees molecular polarity?
A) 1
B) 2
C) 1 or 2
D) 3
E) 1 or 3

29) The electron-domain geometry of a carbon-centered compound is tetrahedral. The hybridization of the central carbon atom is __________.
A) sp
B) sp²
C) sp³
D) sp³d
E) sp³d²
30) The sp$^3$d$^2$ atomic hybrid orbital set accommodates ________ electron domains.
A) 2  
B) 3  
C) 4  
D) 5  
E) 6

31) The hybridizations of bromine in BrF$_5$ and of arsenic in AsF$_5$ are _________ and _________, respectively.
A) sp$^3$, sp$^3$d  
B) sp$^3$d, sp$^3$d$^2$  
C) sp$^3$d, sp$^3$  
D) sp$^3$d$^2$, sp$^3$d  
E) sp$^3$d$^2$, sp$^3$d$^2$

32) When four atomic orbitals are mixed to form hybrid orbitals, how many hybrid orbitals are formed?
A) one  
B) six  
C) three  
D) four  
E) five

33) The blending of one s atomic orbital and two p atomic orbitals produces _________.
A) three sp hybrid orbitals  
B) two sp$^2$ hybrid orbitals  
C) three sp$^3$ hybrid orbitals  
D) two sp$^3$ hybrid orbitals  
E) three sp$^2$ hybrid orbitals

34) The hybridization of the terminal carbons in the H$_2$C=CH$_2$ molecule is _________.
A) sp  
B) sp$^2$  
C) sp$^3$  
D) sp$^3$d  
E) sp$^3$d$^2$

35) For a molecule with the formula AB$_2$ the molecular shape is _________.
A) linear or bent  
B) linear or trigonal planar  
C) linear or T-shaped  
D) T-shaped  
E) trigonal planar
Sample Free Response Questions

1. Consider the following chemical species: the nitrogen molecule, the nitrite ion, and the nitrate ion.
   a. Write the chemical formulas for each of the species.
   b. Draw Lewis structures for each of the species. Where appropriate, draw resonance structures for each.

2. Carbon dioxide gas is bubbled into water to form carbonic acid.
   a. Write and balance a chemical equation to describe the process.
   b. Draw the Lewis structures of the reactants and products.
   c. Given the following bond enthalpies, estimate the enthalpy of the reaction.

<table>
<thead>
<tr>
<th>Bond</th>
<th>Bond enthalpy (kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H—H</td>
<td>436</td>
</tr>
<tr>
<td>H—O</td>
<td>463</td>
</tr>
<tr>
<td>O—O</td>
<td>146</td>
</tr>
<tr>
<td>C—O</td>
<td>358</td>
</tr>
<tr>
<td>C = O</td>
<td>799</td>
</tr>
<tr>
<td>C≡O</td>
<td>1072</td>
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</tbody>
</table>

   d. Are the C—O bonds in the reactant stronger or weaker than those in the product? Explain. Is your explanation consistent with the sign of the enthalpy change you estimated?

3. Consider each of these molecules: C₃H₄, C₃H₆, and C₃H₈.
   a. Draw the Lewis structure for each molecule and identify the orbital hybridization of each carbon atom.
   b. Specify the geometry of each central carbon atom.