(15) I. a. Write a Lewis dot structure for each of the following molecules or ions. b. What is the hybridization of the central atom for each?

\[
\begin{align*}
\text{BH}_4^- & \quad \text{CO}_2 & \quad \text{O}_3 & \quad \text{NH}_3 & \quad \text{ClO}_4^- \\
\text{[}\text{H} & \text{B} & \text{H}\text{]} & \quad \text{[}\text{O} & \text{C} & \text{O}\text{]} & \quad \text{[}\text{O} & \text{O} & \text{O}\text{]} & \quad \text{[}\text{N} & \text{H} & \text{H}\text{]} & \quad \text{[}\text{O} & \text{C} & \text{O}\text{]} \\
\text{[}\text{sp}^3 & \quad \text{sp} & \quad \text{sp}^2 & \quad \text{sp}^3 & \quad \text{sp}^3\text{]}
\end{align*}
\]

(20) II. When one electron is added to an oxygen molecule, a superoxide ion (O\textsubscript{2}\textsuperscript{-}) is formed. The addition of two electrons gives a peroxide ion (O\textsubscript{2}\textsuperscript{2-}).

a. Give the electron configuration for O\textsubscript{2}, O\textsubscript{2}\textsuperscript{-}, and O\textsubscript{2}\textsuperscript{2-}.

\[
\begin{align*}
\text{O}_2 & : (\sigma_\text{2s})^2 (\sigma^*_\text{2s})^2 (\pi_\text{2p})^2 (\pi^*_\text{2p})^4 (\pi^*_\text{2p})^2 \\
\text{O}_2^- & : (\sigma_\text{2s})^2 (\sigma^*_\text{2s})^2 (\pi_\text{2p})^2 (\pi^*_\text{2p})^4 (\pi^*_\text{2p})^3 \\
\text{O}_2^{2-} & : (\sigma_\text{2s})^2 (\sigma^*_\text{2s})^2 (\pi_\text{2p})^2 (\pi^*_\text{2p})^4 (\pi^*_\text{2p})^4
\end{align*}
\]

b. Give the bond order of each species.

\[
\begin{align*}
\text{O}_2 & : 2 & \quad \text{O}_2^- : 1\frac{1}{2} & \quad \text{O}_2^{2-} : 1
\end{align*}
\]

c. Predict which species are paramagnetic.

\[
\begin{align*}
\text{O}_2 & \quad \text{O}_2^- \quad \text{O}_2^{2-}
\end{align*}
\]

d. Predict the order of increasing bond dissociation energy among the three species.

\[
\text{O}_2^{2-} \quad \text{O}_2^- \quad \text{O}_2
\]
(25) III. Consider the element germanium, Ge.

a. What is the electron configuration for a neutral germanium atom, Ge, in the ground state?

\[ [Ar] 4s^2 3d^{10} 4p^2 \]

b. Fill in the following table with an acceptable set of quantum numbers for the two highest (last to be added to the atom) electrons in neutral Ge.

<table>
<thead>
<tr>
<th>electron</th>
<th>n</th>
<th>l</th>
<th>m(_l)</th>
<th>m(_s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>+(\frac{1}{2})</td>
</tr>
<tr>
<td>32</td>
<td>4</td>
<td>1</td>
<td>0</td>
<td>+(\frac{1}{2})</td>
</tr>
</tbody>
</table>

c. What is the name of the orbital which contains the highest energy electron in the ground state of Ge? What is the shape of the orbital?

4p dumbbell shape

d. Which of the following neutral atoms has the largest radius?

Si Ge As Sn

e. What is the electron configuration for Ge\(^{4+}\)?

\[ [Ar] 3d^{10} \]

f. Crystalline germanium is a semiconductor. If Ge is doped with As, describe the nature of the electrical conduction (i.e. what type of conductor is this?). Explain.

Since As is a Group V element, it has one more valence electron than Ge, therefore there would be extra electrons. This is an n-type semiconductor.

(20) IV. In a complete sentence or with a mathematical equation, briefly define each of the following:

Heisenberg Uncertainty Principle

There is a limit to how accurately you can simultaneously know both the position and momentum of an object. \(\Delta x \Delta p \geq \frac{h}{4\pi}\)

deBroglie waves

Any moving particle has wave particles \(\Delta x \Delta p \geq \frac{h}{4\pi}\)

Bohr model of the atom

The Bohr model is for a one electron atom with electron moving in a circular orbit about the nucleus with a definite energy.

Schroedinger model of the atom

In the Schroedinger model, the electrons are likely in regions of probability (called orbitals) which have a definite energy.
V. Shown below is the approximate energy level diagram for the emission spectrum of the hydrogen atom from your book. As discussed in class, the Balmer series corresponds to visible light.

![Energy Level Diagram]

a. Which of the lines in the diagram most likely corresponds to the red line in the visible spectrum of hydrogen? $n = 3 \rightarrow n = 2$

b. Which lines correspond to emission in the ultraviolet range? Lyman series

c. Your book indicates that transitions for hydrogen from $n = 110$ to $n = 109$ are in the microwave region of the spectrum. Is this consistent with this diagram? Why or why not? Yes, the energy levels become more closely spaced as $n$ increases. A transition from $n = 110$ to $n = 109$ would be very low energy. Microwave radiation is a low-energy form of electromagnetic radiation.

d. How would the diagram be different for the absorption spectrum of hydrogen? Transitions would be from higher levels to lower levels.

e. How would the diagram be different for the emission spectrum of Li$^{2+}$? The energies of the orbits would be different.

VI. a. What are CFCs? chlorofluorocarbons or Freons

b. Why are CFCs no longer used as refrigerants? Chlorofluorocarbons produce Cl, which depletes the ozone layer.

c. Name two classes of compounds currently used by refrigerator manufacturers to replace CFCs as refrigerants in refrigerators.

- HFC (hydrofluorocarbons)
- hydrocarbons

d. Give two advantages and two disadvantages for each of the two replacement refrigerants you listed in part c.

<table>
<thead>
<tr>
<th>HFC</th>
<th>hydrocarbons</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Non-flammable</td>
<td>A. Flammable</td>
</tr>
<tr>
<td>B. Non-toxic</td>
<td>B. Ineffective</td>
</tr>
<tr>
<td>C. Avoids liability problems</td>
<td>C. Can be manufactured locally</td>
</tr>
<tr>
<td>D. Not a greenhouse gas</td>
<td>D. Less efficient</td>
</tr>
<tr>
<td>E. Less expensive</td>
<td>E. Used in non-hygrosopic rubs</td>
</tr>
<tr>
<td>F. Requiues hygroscopic oil</td>
<td>F. Can be manufactured locally</td>
</tr>
</tbody>
</table>