1. Complete the following phrases:

- Ionization energy decreases from the top to the bottom in a group.
- Electron affinity increases from the left to the right within a period.
- Atomic radius increases from the top to the bottom in a group.
- Electronegativity increases from the left to the right within a period.
- The metallic character of an element decreases from the left to the right within a period.
- Cations are smaller than the atoms from which they form.
- In isoelectronic anions the radius increases as the charge increases (becomes more negative).

2. What is the difference between Electron affinity and electronegativity of an element?

Electronegativity is the ability of an atom in a compound to attract shared electrons to itself. Electron affinity is an atomic property (measures the energy change when an isolated gaseous atom gains an electron).

3. Write an equation for the third ionization energy of tin.

\[ \text{Sn}^{2+} + \rightarrow \text{Sn}^{3+} + e^- \]

4. What is the effective nuclear charge in a nitrogen atom?

The effective nuclear charge is the portion of the nuclear charge that the valence electrons effectively experience due to the screening of the inner electrons (the core electrons).

\[ Z_{\text{eff}} = \text{atomic number} - \# \text{ of inner electrons} \]

5. How many Valence electrons do the following elements possess: He, Si, Br, K

He (2), Si (4), Br (7), K (1)

6. Arrange the following ions in order of increasing size: F\(^{-}\), O\(^{2-}\), Al\(^{3+}\) and Na\(^{+}\)

Al\(^{3+}\) < Na\(^{+}\) < F\(^{-}\) < O\(^{2-}\) (all ions have 8 VE, so the greater the number of protons in the nucleus, the greater the attraction of the electrons, the smaller the radius)

7. Using the periodic table arrange the following in the expected order of increasing first ionization energy: B, Li, N, K

K < Li < B < N
8. Arrange the following atoms in order of increasing atomic radii: Mg, Si, Sr, S

S < Si < Mg < Sr

9. Using the periodic table alone, predict the formulas for:
   a) the chloride of tin \( \text{SnCl}_4 \)
   b) the oxide of indium \( \text{In}_2\text{O}_3 \)
   c) the sulfate of barium \( \text{BaSO}_4 \)
   d) the hydride of phosphorus \( \text{PH}_3 \)

10. Draw the Lewis symbols (Lewis structures) of the following species: Mg, C, F, S\(^2^-\), O

    \[
    \begin{align*}
    &\text{Mg} &\text{C} &\text{F} &\text{S}^2- &\text{O} = \text{O} \\
    \end{align*}
    \]

11. Draw Lewis structures of the following molecules: \( \text{SCl}_3 \), HCN, SOCl\(_2\) (sulfur is the central atom) COCl\(_2\) (carbon is the central atom)

12. Draw Lewis structures for the following species. Show lone pairs as pairs of dots and show any non-zero formal charges:

    \[
    \begin{align*}
    &\text{H}_2\text{O} \\
    \end{align*}
    \]
PCl₅

N₂H₄
(The molecule has a N-N single bond)

[ClO₂]⁻

XeF₂

13. Draw all possible Lewis structures for the phosphate ion and the pyrazolate ion [C₃H₃N₂]⁻ (see skeletal structure below). Indicate in each case which Lewis structures are equivalent and which are the best Lewis structures.

Skeletal structure of the pyrazolate
The best Lewis structures are the framed four structures (also equivalent). The Lewis structure without any double bonds obeys the octet for all atoms but has too many formal charges.

The two underlined Lewis structures are the best Lewis structures since the negative formal charge is on the most electronegative atom (nitrogen). The two best Lewis structures are also equivalent Lewis structures, so are the two structures on the right (top right and bottom right).
14. Hydrogen peroxide (atom connectivity H-O-O-H) is a reactive substance that usually does not exceed 30% vol. H₂O₂ in aqueous solution commercially available. Pure hydrogen peroxide has rocket fuel properties. Using the bond energy values from the table provided at the end of the chapter 2 handout evaluate which of the two reaction pathways given below is responsible for the instability of this molecule. Estimate the energy change that occurs with each decomposition reaction.

\[ \text{H}_2\text{O}_2 \rightarrow \text{H}_2 + \text{O}_2 \]

\[ 2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2 \]

Let’s rewrite the equations a bit so we can see the bonds that need to be broken and the bonds that form more easily starting with the top equation:

\[ \text{H-O-O-H} \rightarrow \text{H-H} + \text{O=O} \]

We need to break two O-H bonds and one O-O bond which will cost 2 x 464 kJ/mol + 142 kJ/mol = 1070 kJ/mol to produce two hydrogen atoms and two oxygen atoms. We get energy back by forming one H-H and one O=O bond as summarized in the table bellow.

<table>
<thead>
<tr>
<th>Energy required for bond breaking:</th>
<th>2 mol H-O bonds we need</th>
<th>2 x 464 kJ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 mol O-O bonds we need</td>
<td>142 kJ</td>
</tr>
</tbody>
</table>

Total bond breaking energy required to atomize one mol of H₂O₂: 1070 kJ

<table>
<thead>
<tr>
<th>Energy released in bond forming:</th>
<th>1 mol H-H bonds we get</th>
<th>-436 kJ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 mol of O=O bonds we get</td>
<td>-498 kJ</td>
</tr>
</tbody>
</table>

Total energy released in forming 1 mol H₂ and 1 mol O₂ from isolated atoms: -934 kJ

Energy change that occurs in the reaction H₂O₂ → H₂ + O₂ 136 kJ

This means 135 kJ are required to decompose one mol of hydrogen peroxide into the elements. This reaction is endothermic.

Let’s now consider the decomposition into water and oxygen:

\[ 2\text{H-O-O-H} \rightarrow 2\text{H}_2\text{O} + \text{O=O} \]

<table>
<thead>
<tr>
<th>Energy required for bond breaking:</th>
<th>4 mol H-O bonds we need</th>
<th>4 x 464 kJ</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2 mol O-O bonds we need</td>
<td>2 x 142 kJ</td>
</tr>
</tbody>
</table>

Total bond breaking energy required to atomize two mol of H₂O₂: 2140 kJ
Energy released in bond forming:

4 mol HO bonds we get \(4 \times 464 \text{ kJ}\)

1 mol of O=O bonds we get \(-498 \text{ kJ}\)

Total energy released in forming 2 mol H\(_2\)O and 1 mol O\(_2\) from isolated atoms: \(-2354 \text{ kJ}\)

Energy change that occurs in the reaction \(2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2\) \(-214 \text{ kJ}\)

This means 214 kJ are released if two mol of hydrogen peroxide decompose into water and oxygen. This reaction is exothermic and we would suggest that this is the pathway by which hydrogen peroxide decomposes. This is indeed the observed reaction. Hydrogen peroxide solutions decompose into oxygen and water and are generally stored in the fridge to slow down the decomposition.

15.

<table>
<thead>
<tr>
<th>Lewis Structure</th>
<th>EGG</th>
<th>Parent shape</th>
<th>molecular shape</th>
<th>polar (Yes or No)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\text{SO}_2)</td>
<td>3</td>
<td>trigonal planar</td>
<td>bent</td>
<td>Yes</td>
</tr>
</tbody>
</table>

\[\text{SO}_2\]

| \([\text{NO}_2]^+\) | 2   | linear       | linear          | No               |

\([\text{NO}_2]^+\)
\[ \text{[CO}_3\text{]}^2^- \]

\begin{align*}
\text{trigonal planar} & \quad 3 \\
\text{trigonal planar} & \quad \text{No}
\end{align*}

\[ \text{XeF}_2 \]

\begin{align*}
\text{trigonal bipyramidal} & \quad 5 \\
\text{linear} & \quad \text{No}
\end{align*}

\[ \text{SF}_4 \]

\begin{align*}
\text{trigonal bipyramidal} & \quad 5 \\
\text{see saw} & \quad \text{Yes}
\end{align*}