Questions on front and back. Show work for partial credit. Your work and answers must fit in the boxes below each question. Responses outside the boxes will not be graded.

1. (6 points) The threshold frequency for cesium is $4.715 \times 10^{14}$ Hz. On the axes below, draw the graphs for (a) # of electrons vs. frequency and (b) kinetic energy of the ejected electrons vs. frequency.

(a) 
\[
\begin{array}{c}
\text{# of electrons ejected} \\
\hline
0 \\
0 \\
0 \\
0 \\
\hline
\end{array}
\]

(b) 
\[
\begin{array}{c}
\text{KE of ejected electrons} \\
\hline
0 \\
0 \\
0 \\
0 \\
\hline
\end{array}
\]

Each graph is worth 3 points for a total of 6 pts on this question:
+1 pt for NOT starting at the origin but at some frequency to the right of the origin
+2 points for the correct linear relationship (no slope in part a, positive slope in part b)

2. (7 points) A 301 student completed the following orbital diagram for a neutral atom.

(a) What are the possible quantum numbers associated with the circled electron?

| 3, 0, 0, ± ½ |
+ 1 pt for each quantum number for a total of 4 pts
Either + ½, - ½ or ± ½ will be accepted for the last quantum number

(b) What is the identity of the neutral atom?

\[ \text{Phosphorous OR the atomic symbol P} \]
+1 pt for correct answer or symbol

© Unfortunately, the orbital diagram was not completed properly. Which rule did the student forget?

\[ \text{Hund’s Rule or a correct description of Hund’s Rule meaning that the electrons do not pair in degenerate orbitals until each degenerate orbital has been filled with at least one electron} \]

+1 pt for correct answer or a correct description of Hund’s Rule

→ → Questions on front and back → →
(d) Is the atom paramagnetic or diamagnetic?

<table>
<thead>
<tr>
<th>Paramagnetic</th>
</tr>
</thead>
<tbody>
<tr>
<td>+1 pt for correct answer</td>
</tr>
</tbody>
</table>

3. (6 points) Draw the resonance structures of the carbonate ion and identify the formal charge on each atom in each structure.

![Resonance structures of carbonate ion]

The Formal Charge on each carbon is 0
The Formal Charge on each double-bonded oxygen is 0
The Formal Charge on each single-bonded oxygen is -1

Total of 6 points
If an incorrect resonance structure is drawn but the assigned formal charges are correct for the structure drawn, partial credit will be given.

4. (6 points) (a) Calculate $Z_{\text{eff}}$ for silicon, phosphorus, and germanium.

<table>
<thead>
<tr>
<th>Element</th>
<th>$Z_{\text{eff}}$ Calculation</th>
<th>$Z_{\text{eff}}$ Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si</td>
<td>$14 - 10 = +4$</td>
<td>+4</td>
</tr>
<tr>
<td>P</td>
<td>$14 - 10 = +5$</td>
<td>+5</td>
</tr>
<tr>
<td>Ge</td>
<td>$32 - 28 = +4$</td>
<td>+4</td>
</tr>
</tbody>
</table>

+ 1 pt for each correct $Z_{\text{eff}}$
(3 pts total)

(b) Using your answer from part a, please pictorially represent the trend in atomic radii for the three atoms.

Ge > Si > P
+1 pt for a pictorial representation that correctly displays the order of size

(c) Describe how $Z_{\text{eff}}$ affects atomic radius.

→ → Questions on front and back → →
As $Z_{\text{eff}}$ increases, the atomic radius decreases BECAUSE a higher $Z_{\text{eff}}$ indicates there are a greater number of protons in the nucleus than core electrons shielding the valence electrons compared to an atom with a smaller $Z_{\text{eff}}$. Therefore the valence electrons “feel” a stronger positive attractive force toward the nucleus and so the radius of the atom is smaller than for an atom with a smaller $Z_{\text{eff}}$.

+1 pt for the $Z_{\text{eff}}$ increases, Atomic Radius decreases relationship
+1 pt for a correct explanation of the observation
(Total of 2 pts)