25. The Flatlandian Periodic Table

**Time**

1–1.5 h.

**Curriculum links**

- Principle quantum numbers.

**Group size**

1–3.

**Commentary**

This problem is challenging! It probes the students’ understanding of quantum numbers, bonding and the Periodic Table. The answers are:

**a) The Flatlandian periodic table:**

<table>
<thead>
<tr>
<th>1</th>
<th>1s(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>1s(^2)</td>
</tr>
<tr>
<td>3</td>
<td>02s(^1)</td>
</tr>
<tr>
<td>4</td>
<td>02s(^2)</td>
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<tr>
<td>5</td>
<td>02s(^2) 02p(^1)</td>
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<tr>
<td>6</td>
<td>02s(^2) 02p(^2)</td>
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<tr>
<td>7</td>
<td>02s(^2) 02p(^3)</td>
</tr>
<tr>
<td>8</td>
<td>02s(^2) 02p(^4)</td>
</tr>
<tr>
<td>9</td>
<td>03s(^1)</td>
</tr>
<tr>
<td>10</td>
<td>03s(^2)</td>
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<tr>
<td>11</td>
<td>03s(^2) 03p(^1)</td>
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<td>12</td>
<td>03s(^2) 03p(^2)</td>
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<td>13</td>
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<td>16</td>
<td>04s(^2)</td>
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<td>17</td>
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<td>04s(^2) 03d(^2)</td>
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<td>19</td>
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<td>20</td>
<td>04s(^2) 03d(^4)</td>
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<td>21</td>
<td>04s(^2) 03d(^4) 04p(^1)</td>
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<td>22</td>
<td>04s(^2) 03d(^4) 04p(^2)</td>
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<td>23</td>
<td>04s(^2) 03d(^4) 04p(^3)</td>
</tr>
<tr>
<td>24</td>
<td>04s(^2) 03d(^4) 04p(^4)</td>
</tr>
</tbody>
</table>

**b)**

- sp\(^1\)
- sp\(^2\)
The element of life: 5

There are no aromatic ring compounds.

c) Sextet rule
   14 electron rule

d) The ionisation energies and the trends in electronegativity:
e) The molecular orbital diagram of the homonuclear $X_2$ molecules:

The energies of the molecular orbitals of homonuclear diatomic molecules

\[
\begin{align*}
2p & \quad 2p \\
3s & \quad 4s \\
5s & \quad 6s \\
7s & \quad 8s \\
\end{align*}
\]

f) The Lewis structures and geometries:

Lewis structures

\[
\begin{align*}
3 : 1 & \quad 1 : 4 : 1 & \quad 1 : 1 & \quad 1 : 6 & \quad 7 : 1 \\
\end{align*}
\]

Geometry

\[
\begin{align*}
3 - & \quad 4 - \\
5 & \quad 6 - \\
7 & \\
\end{align*}
\]

3D-analogue

\[
\begin{align*}
\text{LiH} & \quad \text{BeH}_2 & \quad \text{BH}_3 \text{ or } \text{CH}_4 & \quad \text{H}_2 \text{O or } \text{NH}_3 & \quad \text{F}_2 \\
\end{align*}
\]

Acknowledgement

The activity is based on a question set at the final of the International Chemistry Olympiad held in Finland during July 1988.
25. **The Flatlandian Periodic Table**

The periodic system of the elements in our three dimensional world is based on the four electron quantum numbers $n = 1,2,3\ldots$, $l = 0, 1\ldots$, $n-1$; $m_l = 0, \pm 1, \pm 2 \ldots$, $\pm l$; and $m_s = \pm \frac{1}{2}$. Let us move to Flatlandia. It is a two dimensional world where the periodic system of the elements is based on three electron quantum numbers: $n = 1,2,3\ldots$; $m = 0, \pm 1, \pm 2 \ldots, \pm (n-1)$; and $m_s = \pm \frac{1}{2}$. $m$ plays the combined role of $l$ and $m_l$ of the three dimensional worlds (i.e., $s,p,d\ldots$ levels are related to $m$). The following tasks and the basic principles relate to this two dimensional Flatlandia where the chemical and physical experience obtained from our common three dimensional world are applicable.

a) Draw the first four periods of the Flatlandian Periodic Table of the elements. Use the atomic number ($Z$) as the symbol of the element. Number the elements according to their nuclear charge. Give the electron configuration of each element.

b) Draw the hybrid orbitals of the elements with $n=2$. Which element is the basis for organic chemistry in Flatlandia? Give the Flatlandian analogues for ethane, ethene and cyclohexane. What kind of aromatic ring compounds are possible in Flatlandia?

c) Which rules in Flatlandia correspond to the octet and 18-electron rules in the three dimensional world?

d) Predict graphically the trends in the first ionisation energies of the Flatlandian elements with $n=2$. Show graphically how the electronegativities of the elements increase in the Flatlandian Period Table.

e) Draw the molecular orbital energy diagrams of the neutral homonuclear diatomic molecules of the elements with $n=2$. Which of these molecules are stable in Flatlandia?

f) Consider simple binary compounds of the elements ($n=2$) with the lightest element ($Z=1$). Draw their Lewis structures, predict geometries and propose analogues for them in the three dimensional world.

g) Consider elements with $n<3$. Propose an analogue and write the chemical symbol from our three dimensional world for each Flatlandian element. On the basis of this chemical and physical analogy predict which two dimensional elements are solid, liquid or gas at the normal pressure and temperature.