Introduction

Though they are neighbors in the periodic table, boron and carbon differ dramatically. Carbon forms the backbone of life. Boron is not essential to support life except in trace amounts for some plants. When boron finds a medicinal application, as in boron neutron capture therapy (BNCT), the healing process actually involves killing malignant cells by the high-energy $^4\text{He}^2$ ions formed by the decomposition of the $^{10}\text{B}$ nucleus by thermal neutron absorption. Carbon is a key player in boron-rich solids present extreme complexity. Nevertheless, many similarities exist between the chemical structures of boron and carbon. This Account adds novel relationships of consequence in this area.

Familiar two-dimensional aromatic compounds such as C$_3$H$_3$$^+$, C$_5$H$_5$$^-$, and C$_6$H$_6$ are governed by Hückel’s $(4n + 2)$ $\pi$ electron rule, where $n$ is zero or any integer. At a simple level, the $(4n + 2)$ $\pi$ electron rule is applicable to condensed systems: benzene, naphthalene, and anthracene have 6, 10, and 14 $\pi$ electrons ($n = 1, 2,$ and 3), respectively. Polycarbyne in two dimensions leads to graphite. Similar direct relationships between compounds of boron and elemental boron do not exist. The boranes, hydrocarbon equivalents, are well known for their electron deficiency and multicenter bonding, and are characterized by deltahedral structures, B$_n$$^+H$_{2n}$ (n = 5–12), which are aromatic. In this connection, a deltahedron is a polyhedron in which all faces are triangles. The deltahedral borane structures with all vertices intact are called closo structures; nido and arachno borane structures are more open, with one and two missing vertices, respectively. Wade’s $(n + 1)$ skeletal electron pair rule, which explains the electronic requirements for closo-deltahedral boranes, is the boron equivalent of Hückel’s rule of organic chemistry. Here $n$ is the number of vertices. Thus, the icosaheiral B$_{12}H$_{12} has two negative charges. Wade’s $(n + 1)$ skeletal electron pair rule is applicable only to monopolyhedral boranes. We have recently extended Wade’s rule to explain the electronic requirements of condensed polyhedral boranes. The $(4n + 2)$ $\pi$ electron rule is a special case of our new rule called the mno rule. Despite their complexity, structural connections between boranes and elemental boron continue to emerge. While the familiar benzene-to-graphite connection appears to be far removed from the relationship between icosaheiral boranes and elemental boron, there are several analogies that are discernible. This Accounts attempts to bring out many similarities not noticed earlier.

Obvious Connections

The isoelectronic relationships between the two sets CH$_3$$^+$, CH$_4$, CH$_5$$^-$, CH$_6$$^-$ and BH$_3$, BH$_4$$^-$, BH$_5$$^-$, BH$_6$$^-$ are obvious. Equally obvious, but of rather recent origin, is the connection between C and B$^-$ in extended binary structures. The adjacent stacks of boron and lithium synthesized by Nesper are indeed structurally reminiscent of polycarbyne: the crystal structure shows a linear boronyl chain (B$^-$)$_n$, isoelectronic to polycarbyne. While the extent of charge transfer can be debated, the connection to sp-hybridized carbon is obvious in this one-dimensional structure. The graphite equivalent of boron was forgotten in the literature until Akimitsu brought it into the limelight in 2001: the structure of the superconductor MgB$_2$ provides a close analogy to the graphite structure. The graphite-like boron sheets (B$^-$)$_n$, alternating with a similar sheet of magnesium (Mg$^{2+}$) with hexagons twice as large, establish the link stereophotograph (Figure 1, 1). Indeed, the discovery of superconductivity of MgB$_2$ has brought renewed interest in boron-rich metal borides.
Moving beyond Two Dimensions

Diamondoid structures are difficult for boron, as it is not easy to find a metal ion of the appropriate charge and size to fill the holes in a $B_6$ diamond lattice. A diamond-like structure of a metal boride has not been reported, yet three-dimensional structures are not foreign to boron: they form the mainstay of its chemistry and physics. The large family of three-dimensional polyhedral structures represented by $B_nH_{2n-2}$ and $C_2B_nH_{2n}$ is well known. Several connections between polyhedral boranes and carbocations are recognized (Figure 1).

Schematically, we can remove electrons from benzene and get $C_6H_6^{2+}$ (Figure 1). While there are several structures that may be envisaged for the dication, the one that relates to boron most easily is the pyramidal structure. Replacement of one or more carbons by $B_-$ results in $C_5BH_6^{+}$, $C_4B_2H_6$, and $B_6H_{10}$ (Brønsted $B_6H_6^{2-}$ with four bridging hydrogens to neutralize the charge), all known experimentally with pentagonal pyramidal structure. When another pair of electrons is taken away, we have $C_6H_6^{4+}$, unrealistic in view of the high charge. Replacing four carbons by four $B_-$ and the neutral $C_2B_4H_6$ gives an octahedral structure; another all-boron octahedron has two negative charges ($B_6H_6^{2-}$), compensated by an accompanying cation. A similar procedure of removing electrons and arriving at three-dimensional structures can be applied to the cyclopentadienyl anion as well. Removal of two electrons from $C_6H_6^{2-}$ leads to square pyramidal $C_3H_5^{2+}$; the closo-$B_6H_6^{2-}$ is known with four bridging hydrogens. Removal of another electron pair leads to $C_3H_5^{2+}$; the closo-$B_6H_6^{2-}$ is theoretically predicted to have a closo-trigonal bipyramidal structure, and its neutral analogue, isostructural $C_3B_3H_5$, is well known. We saw the relationship between benzene and the periodic two-dimensional sheet structure of $MgB_2$. A three-dimensional structure is easily seen for the $B_6^{2-}$ octahedra, where each $B$ atom bonds to another $B$ atom of the adjacent $B_6$ unit by a two-center, two-electron (2c-2e) bond. Divalent metal ions in the interstitial space of this ($B_6^{2-}$) solid make a neutral $MB_6$ network. Molecular structures with an empirical formula of $MB_6$ are well known with divalent metals such as Ca, Sr, and Ba; the crystal structure consists of an octahedral $B_6$ unit surrounded by eight metal atoms at each corner of the cubic unit cell. It is only a question of time until $MgB_6$ is also studied structurally.

Condensation Modes for Polyhedral Boranes

While $B_6H_6^{2-}$ could condense to give periodic structures through 2c-2e bonds, the electronic requirement for condensation of pentagonal pyramidal $B_7H_6^{2-}$ or $C_3B_3H_5$ is less obvious. In general, condensation between polyhedral borane cages can occur through sharing of one,
two, three, or four vertices. The electronic requirements of these condensation pathways are important in many ways; for example, this could help in understanding the structure of elemental boron.\textsuperscript{5d} We have formulated an electron counting rule, the \textit{mno} rule for this purpose; according to this, the number of electron pairs needed for a stable condensed polyhedral structure is given by the sum of the number of cages (\(m\)), the number of vertices (\(n\)), and the number of single vertex shared atoms (\(o\)).\textsuperscript{4} This is demonstrated in Chart 1 using the icosahedral skeleton.

(i) Four-vertex sharing. Condensation of two icosahedral \(B_{20}H_{12}^{-2}\) sharing four vertices leads to \(B_{20}H_{16}^{+}\). According to the \textit{mno} rule, 22 electron pairs (\(m = 2, n = 20, o = 0\)) are needed by this structure (Chart 1).\textsuperscript{22} Sixteen BH vertices provide one electron pair each, and the 4 shared boron atoms give 3 valence electrons each, making the structure neutral. The structure of \(B_{20}H_{16}\) has been well known for many years.\textsuperscript{22} Further condensation by four-vertex sharing leads to a structure \(B_{30}H_{20}\), with the \textit{mno} count of 31 (\(m = 3, n = 28, o = 0\)). Twenty BH vertices and 8 shared boron atoms contribute 32 electron pairs, making the structure electron excess by 2 units. This structure is not known. The \textit{mno} rule leads to the homologous series with the molecular formula \(B_{3m+4}H_{4m+6}^{2m-4}\). Thus, each condensation involving the sharing of four vertices reduces the charge by two units.

(ii) Face or three-vertex sharing. For the condensed product \(B_{21}H_{18}\), formed by the face sharing of two icosahedra, the \textit{mno} rule demands 23 electron pairs (\(m = 2, n = 21, o = 0\)). The structure has 18 electron pairs from 18 BH vertices, and 4.5 electron pairs from the three shared boron atoms. Thus, \(B_{21}H_{18}\) should have unit negative charge. Further condensation leads to the neutral \(B_{30}H_{24}\) (\(m = 3, n = 30, o = 0\)). Face condensation thus leads to a homologous series with the molecular formula \(B_{9m+3}H_{6m+6}^{2m-3}\). The decrease of charge by one unit with each condensation is to be contrasted to the decrease of two charges by the four-vertex shared condensation. Though these face-sharing closo structures are not experimentally characterized, the face sharing is observed in boron-rich solids.\textsuperscript{23,24} There are several examples of condensed nido boranes sharing triangular faces.\textsuperscript{25} These follow the \textit{mno} rule.

---

\textbf{Chart 1. Application of the \textit{mno} Rule: Variation of Charge as a Function of Increasing Condensation of Polyhedra with One-, Two-, Three-, and Four-Atom Sharing\textsuperscript{a}}

<table>
<thead>
<tr>
<th>Type of Condensation</th>
<th>4-Vertex sharing ((B_{8m+4}H_{4m+6}^{2m-4}))</th>
<th>Face sharing ((B_{9m+3}H_{6m+6}^{m-3}))</th>
<th>Edge sharing ((B_{10m+2}H_{8m+4}^{-2}))</th>
<th>Single vertex sharing ((B_{11m+1}H_{10m+2}^{-3m+1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>(m=1)</td>
<td><img src="image1" alt="Diagram" /></td>
<td><img src="image2" alt="Diagram" /></td>
<td><img src="image3" alt="Diagram" /></td>
<td><img src="image4" alt="Diagram" /></td>
</tr>
<tr>
<td>(m=2)</td>
<td><img src="image5" alt="Diagram" /></td>
<td><img src="image6" alt="Diagram" /></td>
<td><img src="image7" alt="Diagram" /></td>
<td><img src="image8" alt="Diagram" /></td>
</tr>
<tr>
<td>(m=3)</td>
<td><img src="image9" alt="Diagram" /></td>
<td><img src="image10" alt="Diagram" /></td>
<td><img src="image11" alt="Diagram" /></td>
<td><img src="image12" alt="Diagram" /></td>
</tr>
<tr>
<td>(m=4)</td>
<td><img src="image13" alt="Diagram" /></td>
<td><img src="image14" alt="Diagram" /></td>
<td><img src="image15" alt="Diagram" /></td>
<td><img src="image16" alt="Diagram" /></td>
</tr>
</tbody>
</table>

\textbf{Increment in Charge} +2 +1 0 -3

\textbf{Known examples} closo-\(B_{20}H_{16}\)\textsuperscript{21}  \(nido-B_{20}H_{16}^{-}(NCCH_{3})_{2}\)\textsuperscript{22a}  \(nido-S_{2}B_{16}H_{16}\)\textsuperscript{22b}  \(nido-B_{22}H_{22}^{-2}\)\textsuperscript{3a}  \(nido-B_{22}H_{20}^{-2}\)\textsuperscript{23b}  bisnido-\(B_{16}H_{20}\)\textsuperscript{23b}  \(closo-[(B_{11}H_{11})_{2}Cu]^{3-}\)\textsuperscript{24}

\textsuperscript{a} The only sharing that does not change (neither increases nor decreases) charge is edge-sharing. This is involved in the polycondensation of benzenoid aromatics to graphite. Experimentally known examples of each condensation are also listed.
(iii) Edge-sharing condensation (the mno rule and the Hückel rule). The edge-sharing $B_{22}H_{20}$ ($m = 2, n = 22, o = 0$) and $B_{32}H_{28}$ ($m = 3, n = 32, o = 0$) are found to have 2$^-$ charges. The molecular formula of the homologous series, $B_{10m+2}H_{8m+4}^-$, shows that edge-sharing of closo structures does not change the charge. Icosahedral closo structures of this kind are not known owing to the nonbonding interaction between the adjacent atoms of fused cages. However, many edge-sharing nido systems have been synthesized.26 Edge-sharing bisarachno systems lead to the equivalence of the mno rule and Hückel’s $(4n+2)$ electron rule. This is demonstrated by the hypothetical hexagonal bipyramidal molecule, $B_6H_{12}^-$ (D$_{2d}$), and by the edge-sharing condensed system $B_{14}H_{12}^-$ ($m = 2, n = 14, o = 0$) (Figure 2). Removal of two vertices from $B_{14}H_{12}^-$ leads to a bisnido structure, $B_{12}H_{10}^-$, with a 6$^-$ charge (Figure 2). The bisarachno structure, with a 10$^-$ charge, obtained by the removal of two more vertices, is isoelectronic to naphthalene, $C_{10}H_{8}$. The difference between the electron counts comes from the skeletal $\sigma$-bonds, which are left out in the Hückel rule. Thus, Hückel’s $(4n + 2)$ rule is a special case of the mno rule for edge-sharing bisarachno systems. If the number of C–C $\sigma$ electrons is added to the number of $(4n + 2)$ $\pi$ electrons, we get the number of electrons demanded by the mno rule.

(iv) Single vertex sharing. The single-vertex-sharing system $B_{23}H_{22}$ ($m = 2, n = 23, o = 1$) requires 5$^-$ charges for the skeletal bonding, and further condensation increases this requirement to 8$^-$, as in $B_{35}H_{32}$ ($m = 3, n = 34, o = 0$). The molecular formula of this homologous series is $B_{11m+1}H_{10m+3}^-$ ($3m+1$). Such single-vertex-sharing systems are known with heavier elements at the shared position; an all-boron sandwiched structure is unrealistic due to the high charges.27 In addition, a larger atom at the shared position ensures minimal steric interactions between the ring atoms on either side of it.

Thus, the charge requirement for condensation depends on the number of shared vertices (Chart 1). The mno rule also helps to find the combinations of condensations that retain the charge during polycondensation, such as three face sharings for every single atom sharing, etc. It is also important to note that such condensations are possible in principle between combinations of different polyhedra.

Armed with these rules, we return to $B_6H_{12}^-$ (C$_{5v}$) and its polycondensation. By the mno rule, an edge-shared bisnido polyhedral borane $B_{10}H_{18}$ should have a charge of 6$^-$ ($m = 2, n = 10, o = 0, p$ (no. of missing vertices) = 2) (Figure 3). A second condensation leads to $B_{14}H_{10}^-$ $B_{10}H_{18}$. Thus, condensation of each pentagonal pyramid results in the addition of a $B_4$ unit and an increase of 2$^-$ charges. An
analysis of this process also suggests the structure of MgB$_4$. The chains of pentagonal pyramidal units are connected to each other by removing the hydrogen atoms of the remaining BH bonds and forming 2c-2e B–B bonds to complete the three-dimensional structure of MgB$_4$. Thus, we find the relationship between the three organics-based structures and metal borides in terms of MgB$_{2-y}$, MgB$_{4-y}$, and MgB$_{6-y}$-based structures (Figure 1). The superconducting MgB$_2$ has distinct $\alpha$ and $\pi$ frameworks. It will be intriguing to see the changes when the structure is varied to a pentagonal pyramid, as in MgB$_4$, or an octahedron, as in MgB$_6$.

**Fullerene (C$_{60}$) and $\beta$-Rhombohedral Boron**

Icosahedral B$_{12}H_{12}^{2-}$ is the most stable among the polyhedral borane anions, and so it is natural for nature to construct elemental boron from B$_{12}$ icosahedra. The options available to satisfy the electron count are surprisingly numerous and contribute to the variety of structures available to elemental boron. Here, boron is far more versatile than carbon. The simplest, though not thermodynamically most stable, form of boron has a unit cell of icosahedral B$_{12}$, where six boron atoms form 2c-2e bonds with the neighboring B$_{12}$ units. The remaining six boron atoms form the electron-saving 3c-2e bonds (Figure 4). This saves two electrons (1/3 $\times$ 6 = 2) per icosahedron, so that Wade’s rule for the individual B$_{12}$ unit is satisfied.

Three-center, two-electron bonds are not the strongest. The structure of the most stable polymorph, $\beta$-rhombohedral boron, starts out in the most natural way by building 12 icosahedra around an icosahedron. However, there are many problems with this perfect packing, as it cannot lead to three-dimensional periodicity. (Incidentally, 12 B$_{12}$ around a B$_{12}$ is indeed a part of boron chemistry, but to sustain this arrangement requires electron donors in the form of metals, as in YB$_{66}$. The 12 outer icosahedra are not completed in $\beta$-boron; only the pentagonal pyramidal half is retained (Figure 5), so that a B$_{84}$ unit is generated (B$_{12}$@B$_{12}$@B$_{60}$, Figure 6). We will come to the close similarity of the outer B$_{60}$ surface of B$_{84}$ to C$_{60}$ shortly. Let us consider the way $\beta$-boron is built. When two of these B$_{84}$ units come together, two half-icosahedra form a new icosahedron (Figure 7). The size of B$_{84}$ restricts the total number of

![FIGURE 4. Structure of the $\alpha$-rhombohedral boron. Six vertices lying close to the plane of the paper form the 3c-2e bonds among the icosahedral B$_{12}$'s, as shown, and the remaining vertices form a 2c-2e bond with the B$_{12}$ above and below.](image)

![FIGURE 5. Fragment of B$_{84}$ which shows the construction of B$_{84}$. Each vertex of B$_{12}$ is connected to one pentagonal pyramidal B$_6$ unit, thus leading to the formation of a B$_{84}$ unit.](image)

![FIGURE 6. The B$_{84}$ fragment of $\beta$-rhombohedral boron and fullerene are related structurally and electronically. The replacement of 12 pentagonal pyramidal B$_6^{4-}$ by 12 C$_5^{5-}$ and removal of the inner B$_{12}$ unit of the B$_{84}$ leads to the fulleride anion, C$_{60}^{12-}$.](image)
units that can come around any one B\textsubscript{84} in this fashion to six. Nature finds a way to generate icosahedra out of the remaining six half-icosahedra of B\textsubscript{84} by adding a B\textsubscript{10} unit which, by its unusual symmetry, provides three half-icosahedra (Figure 8). Three B\textsubscript{84} units can be brought around this B\textsubscript{10} unit. Two of these giant (B\textsubscript{84})\textsubscript{3}B\textsubscript{10} units are connected to each other by a single boron atom.

Removing the symmetry-related atoms, one gets the unit cell $84 + 10 + 10 + 1 = 105$. This also generates a new structural type that can be separated by breaking $2c$-2e bonds, the B\textsubscript{84} unit B\textsubscript{28}–B–B\textsubscript{28} (Figure 9). The electron requirement for this large structure is worked out using the mno rule by adding hydrogens to the dangling valencies.$^{5d}$ According to this, the B\textsubscript{57} unit has three extra electrons and should have a 3\textsuperscript{+} charge (the mno count of the B\textsubscript{57}H\textsubscript{36} molecule is $8 + 57 + 1 = 66$; 36 electron pairs are obtained from BH vertices, and 31.5 electron pairs are provided by the remaining boron vertices, making the molecule in excess of 3 electrons), which is confirmed computationally as well.$^{5d}$ The remaining B\textsubscript{48} unit (out of the B\textsubscript{105}) has four icosahedral B\textsubscript{12} units and must have 8\textsuperscript{−} charge. Thus, the unit cell, B\textsubscript{105}, will be deficient by 5 (\(= 8 - 3\)) electrons. An early band structure

FIGURE 7. Arrangement of two B\textsubscript{84} units in the $\beta$-rhombohedral boron. The six pentagonal pyramidal B\textsubscript{6} units on the surface of B\textsubscript{84} complete the icosahedral framework, with similar B\textsubscript{6} units on other B\textsubscript{84} units, as shown.

FIGURE 8. The six B\textsubscript{6} units on the B\textsubscript{84} surface form an icosahedron with B\textsubscript{6} units of the B\textsubscript{10} fragments.

FIGURE 9. B\textsubscript{57} unit in the $\beta$-rhombohedral boron. It consists of two B\textsubscript{28} units which are connected through one boron atom. Each B\textsubscript{28} unit has three icosahedral B\textsubscript{12}’s, with each B\textsubscript{12} sharing a face with the other two B\textsubscript{12}’s.

FIGURE 10. Structure of the well-known B\textsubscript{6}H\textsubscript{10}. The charge of B\textsubscript{6}H\textsubscript{4}\textsuperscript{−} is compensated by four bridging hydrogens.

FIGURE 11. Structure of B\textsubscript{84}H\textsubscript{50}. The electron deficiency of B\textsubscript{84} is compensated by adding 50 bridging hydrogens.
calculated by Bullet confirmed this deficiency in the B_{105} structure.\textsuperscript{32} However, the properties of elemental boron do not support this. More recent X-ray studies indicate that the unit cell is B_{106.66} and there are 20 symmetry-equivalent atomic positions in the unit cell, of which 6 are partially occupied.\textsuperscript{24} Among these, one has six-fold symmetry and a partial occupancy of about 5/6 and belongs to the B_{57} part. This missing boron atom, with its three valence electrons, takes care of the 3+ charge. The unit cell still requires eight electrons; these are provided by the extra occupancy of 2.66 (106.66 – 104) boron atoms in the many holes inside B_{84} (2.66 \times 3 \approx 8). Counterions can also impart neutrality to the structure. Lithium boride (LiB_{13}), with \beta-rhombohedral structure, is known experimentally.\textsuperscript{33} Here the deficiency of electrons is taken care of by lithium atoms (LiB_{16}4). This points to the possibility of MgB_{36} with a \beta-rhombohedral structure, thus adding one more candidate to the list of magnesium borides discussed earlier.

Since the discovery of fullerenes, chemists have been fascinated by the endohedral chemistry possible by encapsulating large atoms inside the vacant cavity (stuffing). Were the B_{84} (B_{12}@B_{72}) (Figure 6) unit electron sufficient, it would be a remarkably stable stuffed boron fullerene similar to the endohedral fullerenes with 24 boron atoms inside borafullerene (B_{60}). The electron deficiency of B_{84} can be easily calculated. The 12 pentagonal pyramidal B_{6} units in B_{84} require four electrons each (a la C_{5}B_{5}H_{5}). Totaling 48 electrons. An additional two electrons are required for the central B_{12}. Thus, a B_{84}^{3-} should be appropriate! Therefore, we could anticipate a stable isoelectronic Si_{12}B_{34} with 50 Si atoms and 10B atoms on the fullene-like surface.\textsuperscript{34} The molecular species B_{84}H_{48} (C_{56}) could compensate the charge by replacing 4B\textsuperscript{-} by 4C\textsuperscript{3-} 15 an additional way that nature has found is to protonate four times, as in B_{6}H_{10} (Figure 10).\textsuperscript{16} An analogous B_{84}H_{48}^{2-} species, where each of the 12 five-membered B_{5} rings is quadruply protonated, must be electron sufficient.\textsuperscript{35} We have carried out PM3 calculations\textsuperscript{36} on B_{84}H_{32} structures obtained by adding two bridging hydrogen atoms to the B_{84}H_{48}^{2-} isomer with D_{5d} symmetry. (There are 1256602779 isomers possible for B_{84}H_{50} including geometrical and optical isomers, the number obtained from the enumeration of isomers reported for C_{60}H_{50}.\textsuperscript{37}) The calculations showed this isomer of neutral B_{84}H_{50} to be a minimum on the potential energy surface (Figure 11).

A more direct connection between fullerenes and \beta-boron is available through the arachno formulation of polyhedral boranes. Removal of the axial BH group from the nido pentagonal pyramid B_{84}H_{6}^{5-} leads to the arachno planar B_{84}H_{4}^{5-} (Figure 12). This is isoelectronic with the aromatic cyclopentadienyl anion C_{6}H_{5}\textsuperscript{3-}. If the central B_{12} of the B_{84} is removed and the 12 pentagonal pyramid B_{6} units are replaced by 12 C_{5} units, what remains is C_{60}^{12-} (Figure 6). This has already been generated from C_{60} as C_{60}Li_{12} and C_{60}K_{12}.\textsuperscript{38} There is also experimental evidence for the stable neutral structure C_{60}N_{12}.\textsuperscript{39} While there may be other structures that are lower in energy, the one with a nitrogen in each of the five-membered rings should be a good possibility. Once such a relation is established, it is possible to reverse the argument. It should be possible to design polyhedral boranes and even elemental boron polymorphs based on other fullerenes with the right electron count, even though individual stabilities will depend on many factors. Thus, even the fullerenes are not so far away from boron after all.

![FIGURE 12. The isoelectronic equivalence of arachno-B_{84}H_{6}^{5-}, derived from the closo-B_{12}H_{17}^{2-} by removing two vertices, with C_{6}H_{5}^{3-} is shown.](image)

We thank many of our present and former group members who contributed to the development of these ideas. They include Dr. P. N. V. Pavan kumar, Dr. G. Naga Srinivas, Dr. G. Subramanian, Dr. B. Kiran, Dr. M. M. Balakrishnarajan, Mrs. P. D. Pancharatna, and Mr. A. Anoop. We also thank the Council of Scientific and Industrial Research, and Department of Science and Technology, New Delhi, Board of Research in Nuclear Sciences, and the UPE program of UGC for assistance and facilities.

**References**


**Analogies between Boron and Carbon** Jemmis and Jayasree


Analogies between Boron and Carbon  Jemmis and Jayasree