When the unit cell does not reflect the symmetry of the lattice, it is usual in crystallography to refer to a 'conventional', non-primitive, crystallographic basis, \( \mathbf{a_c}, \mathbf{b_c}, \mathbf{c_c} \) instead of a primitive basis, \( \mathbf{a, b, c} \). This is done by adding lattice nodes at the center of the unit cell or at one or three faces. The vectors joining the origin of the unit cell to these additional nodes are called 'centering vectors'. In such a lattice \( \mathbf{a_c}, \mathbf{b_c} \) and \( \mathbf{c_c} \) with all their integral linear combinations are lattice vectors again, but there exist other lattice vectors \( \mathbf{t} \in \mathbf{L} \), \( \mathbf{t} = t_1 \mathbf{a_c} + t_2 \mathbf{b_c} + t_3 \mathbf{c_c} \); with at least two of the coefficients \( t_1, t_2, t_3 \) being fractional. The table below gives the various types of centering vectors and the corresponding types of centering. Each one is described by a letter, called the Bravais letter, which is to be found in the Hermann-Mauguin symbol of a space group.

The 'multiplicity', \( m \), of the centered cell is the number of lattice nodes per unit cell (see table).

The volume of the unit cell, \( V_c = (\mathbf{a_c}, \mathbf{b_c}, \mathbf{c_c}) \) is given in terms of the volume of the primitive cell, \( V = (\mathbf{a}, \mathbf{b}, \mathbf{c}) \), by:

\[
V_c = m \cdot V
\]

### Centered cells vs. "centered lattices"

A lattice being an infinite, symmetric and periodic collection of zero-dimensional nodes, rigorously speaking it is neither primitive nor centered. The expression "centered lattice" has to be considered as a shortcut for "lattice whose conventional cell is centered".

### Types of centered lattices

<table>
<thead>
<tr>
<th>Bravais letter</th>
<th>Centering type</th>
<th>Centering vectors</th>
<th>Multiplicity (number of nodes per unit cell)</th>
<th>Unit-cell volume ( V_c )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P )</td>
<td>Primitive</td>
<td>0</td>
<td>1</td>
<td>( V )</td>
</tr>
<tr>
<td>( A )</td>
<td>( A )-face centered</td>
<td>( \frac{1}{2} \mathbf{b_c} + \frac{1}{2} \mathbf{c_c} )</td>
<td>2</td>
<td>( 2V )</td>
</tr>
<tr>
<td>( B )</td>
<td>( B )-face centered</td>
<td>( \frac{1}{2} \mathbf{c_c} + \frac{1}{2} \mathbf{a_c} )</td>
<td>2</td>
<td>( 2V )</td>
</tr>
<tr>
<td>( C )</td>
<td>( C )-face centered</td>
<td>( \frac{1}{2} \mathbf{a_c} + \frac{1}{2} \mathbf{b_c} )</td>
<td>2</td>
<td>( 2V )</td>
</tr>
<tr>
<td>( I )</td>
<td>body centered (Innenzentriert)</td>
<td>( \frac{1}{2} \mathbf{a_c} + \frac{1}{2} \mathbf{b_c} + \frac{1}{2} \mathbf{c_c} )</td>
<td>2</td>
<td>( 2V )</td>
</tr>
<tr>
<td>( F )</td>
<td>All-face centered</td>
<td>( \frac{1}{2} \mathbf{a_c} + \frac{1}{2} \mathbf{b_c} ), ( \frac{1}{2} \mathbf{b_c} + \frac{1}{2} \mathbf{c_c} ), ( \frac{1}{2} \mathbf{c_c} + \frac{1}{2} \mathbf{a_c} )</td>
<td>4</td>
<td>( 4V )</td>
</tr>
</tbody>
</table>
The letter $S$ is also used to indicate a single pair of centred faces. This happens in the monoclinic and orthorhombic crystal families.

- In the monoclinic crystal family, b-unique axis, the centered cells $mA$, $mC$, $mI$ and $mF$ are equivalent in the sense that a different choice of axes in the (010) plane interchanges these centerings. The letter $mS$ is sometimes used to collectively indicate any of these cells. The cell $mB$ is instead equivalent to the cell $mP$.
- In the orthorhobic crystal family, the centred cells $oA$, $oB$ and $oC$ are transformed one into the other when the axes are permuted. The symbol $oS$ is sometimes used to collectively indicate these three equivalent cells.

See also

- Sections 1.2 and 9 of *International Tables of Crystallography, Volume A*
- Section 1.1 of *International Tables of Crystallography, Volume C*

Contributors

- [Online Dictionary of Crystallography](https://www.crystallography.net)