به نامِ خدا

دانش‌گاهِ صنعتی‌ِ اصفهان ـ دانش‌کده‌ی ِ فیزیک

تصاویر فصل ۱۲

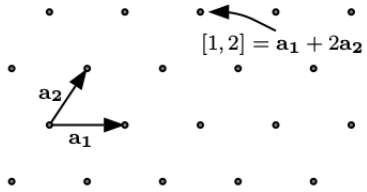


Fig. 12.1 A lattice is defined as integer sums of of primitive lattice vectors.

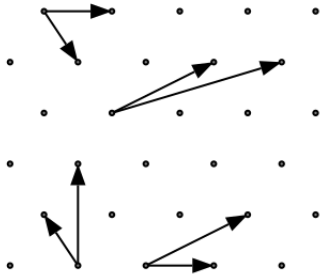


Fig. 12.2 The choice of primitive lattice vectors for a lattice is not unique. (Four possible sets of primitive lattice vectors are shown, but there are an infinite number of possibilities!)

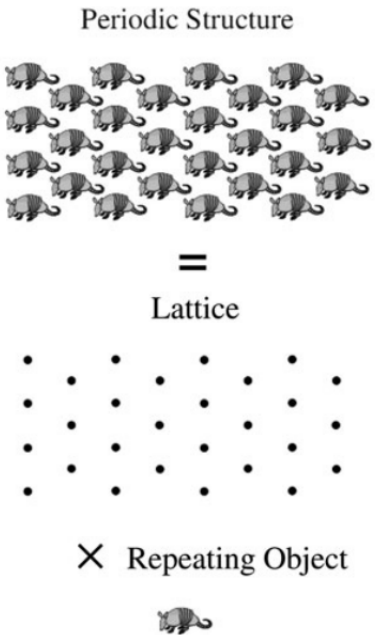


Fig. 12.3 Any periodic structure can be represented as a lattice of repeating motifs.

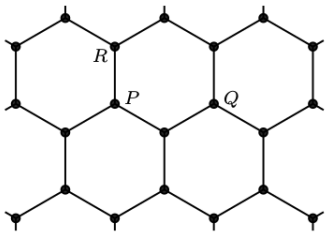


Fig. 12.4 The honeycomb is not a lattice. Points P and R are inequivalent (points P and Q *are* equivalent).

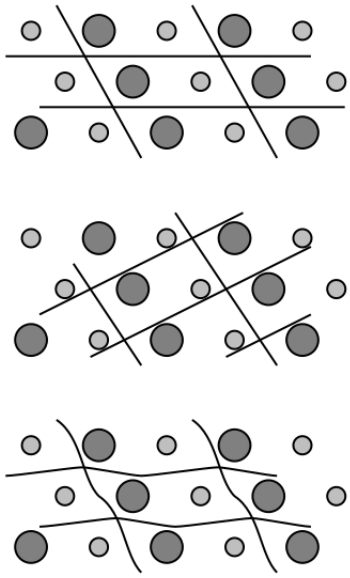


Fig. 12.5 The choice of a unit cell is not unique. All of these unit cells can be used as "tiles" to perfectly reconstruct the full crystal.

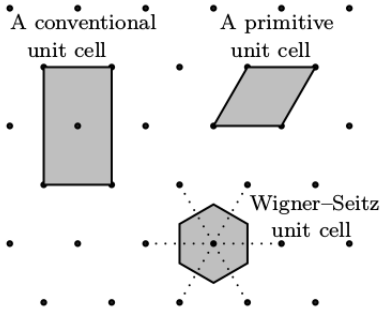


Fig. 12.6 Some unit cells for the triangular lattice.

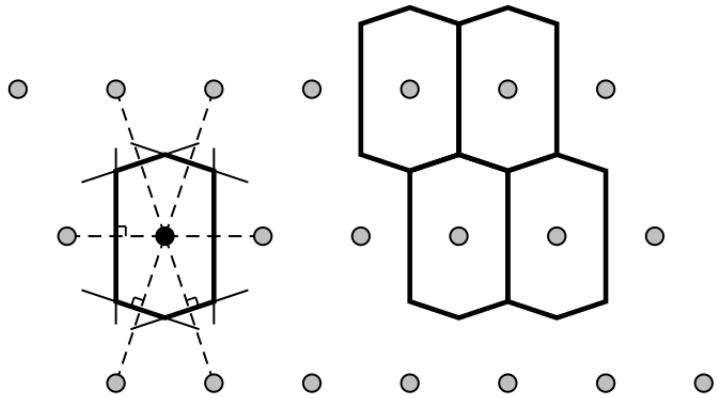
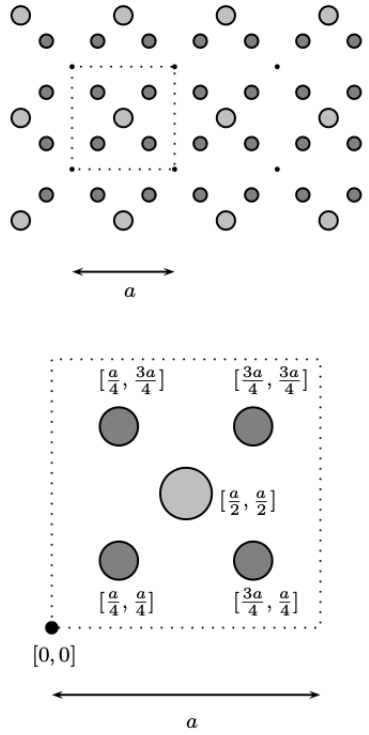


Fig. 12.7 The Wigner–Seitz construction for a lattice in two dimensions. On the left perpendicular bisectors are added between the darker point and each of its neighbors. The area bounded defines the Wigner–Seitz cell. On the right it is shown that the Wigner–Seitz cell is a primitive unit cell. (The cells on the right are exactly the same shape as the bounded area on the left!)



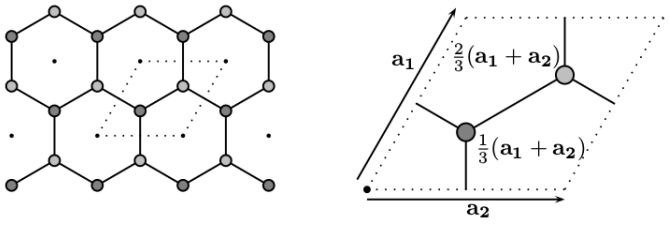


Fig. 12.9 Left: The honeycomb from Fig. 12.4 is shown with the two inequivalent points of the unit cell given different shades. The unit cell is outlined dotted and the corners of the unit cell are marked with small black dots (which form a triangular lattice). **Right:** The unit cell is expanded and coordinates are given with respect to the reference point at the lower left corner.

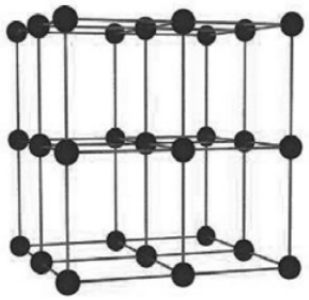


Fig. 12.10 A cubic lattice, otherwise known as cubic "P" or cubic primitive.

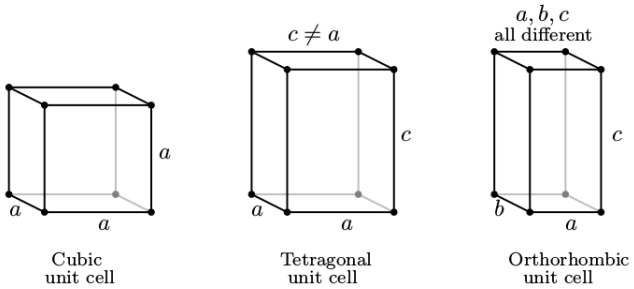
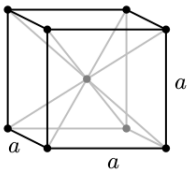
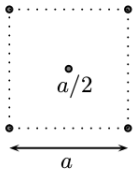


Fig. 12.11 Unit cells for cubic, tetragonal, and orthorhombic lattices.

Fig. 12.12 Conventional unit cell for the body-centered cubic (I) lattice. **Left:** 3D view. **Right:** A plan view of the conventional unit cell. Unlabeled points are both at heights 0 and a.



Body-centered cubic unit cell



Plan view

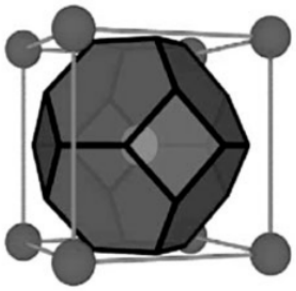


Fig. 12.13 The Wigner–Seitz cell of the bcc lattice (this shape is a "truncated octahedron"). The hexagonal face is the perpendicular bisecting plane between the lattice point (shown as a sphere) in the center and the lattice point (also a sphere) on the corner. The square face is the perpendicular bisecting plane between the lattice point in the center of the unit cell and a lattice point in the center of the neighboring unit cell.

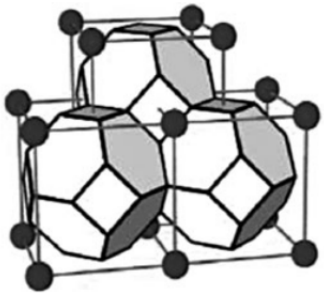
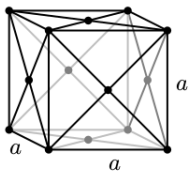
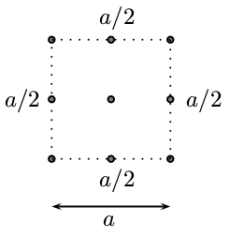


Fig. 12.14 The Wigner–Seitz cells of the bcc lattice pack together to tile all of space. Note that the structure of the bcc lattice is that of two interpenetrating simple cubic lattices.

Fig. 12.15 Conventional unit cell for the face-centered cubic (F) lattice. **Left:** 3D view. **Right:** A plan view of the conventional unit cell. Unlabeled points are both at heights 0 and a.



Face-centered cubic
unit cell



Plan view

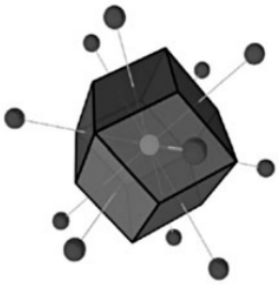


Fig. 12.16 The Wigner–Seitz cell of the fcc lattice (this shape is a "rhombic dodecahedron"). Each face is the perpendicular bisector between the central point and one of its 12 nearest neighbors.

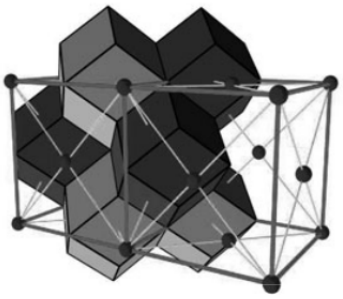


Fig. 12.17 The Wigner–Seitz cells of the fcc lattice pack together to tile all of space. Also shown in the picture are two conventional (cubic) unit cells.

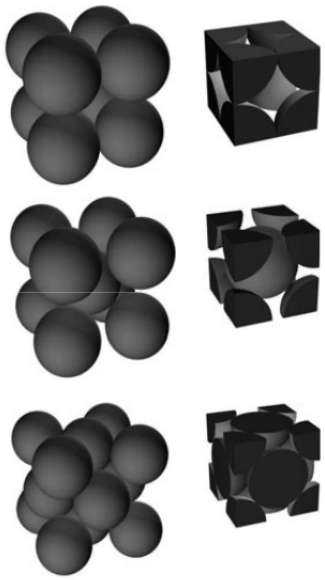


Fig. 12.18 Top: Simple cubic, **Middle:** bcc, **Bottom:** fcc. The left shows packing of spheres into these lattices. The right shows a cutaway of the conventional unit cell exposing how the fcc and bcc lattices leave much less empty space than the simple cubic.

proven until 1998! Note however that there is another lattice, the *hexagonal close packed* lattice which achieves precisely the same packing density for spheres as the fcc lattice.

12.2.4 Other Lattices in Three Dimensions

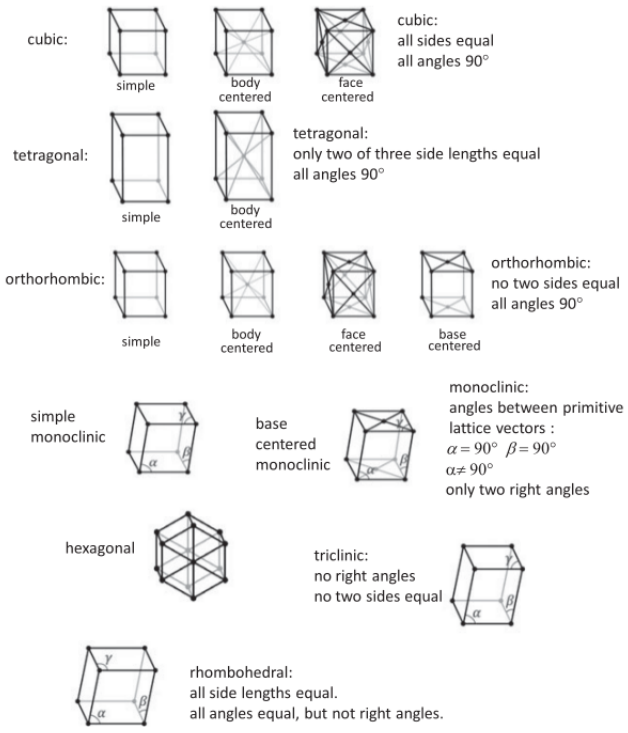
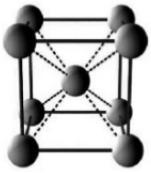
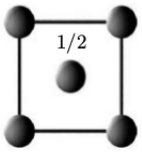


Fig. 12.19 Conventional unit cells for the fourteen Bravais lattice types. Note that if you tried to construct a "face-centered tetragonal" lattice, you would find that by turning the axes at 45 degrees it would actually be equivalent to a body-centered tetragonal lattice. Hence face-centered tetragonal is not listed as a Bravais lattice type (nor is base-centered tetragonal for a similar reason, etc.).

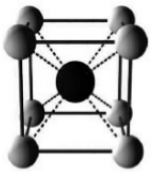
Sodium (Na)
Lattice = Cubic-I (bcc)
Basis = Na at [000]



Plan view
unlabeled points at $z = 0, 1$



Caesium chloride (CsCl)
Lattice = Cubic-P
Basis = Cs at [000]
and Cl at $[\frac{1}{2}\frac{1}{2}\frac{1}{2}]$



Plan view
unlabeled points at $z = 0, 1$

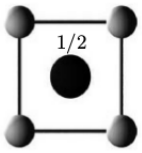
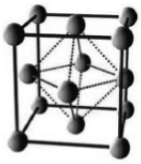


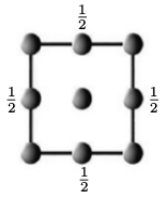
Fig. 12.20 Top: Sodium forms a bcc lattice. **Bottom:** Caesium chloride forms a cubic lattice with a two atom basis. Note carefully: CsCl is *not* bcc! In a bcc lattice all of the points (including the body center) must be identical. For CsCl, the point in the center is Cl whereas the points in the corner are Cs.

and almost certainly in any real material the primitive lattice vector lengths would actually have slightly different values if measured more closely.

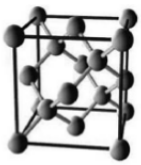
Copper(Cu)
Lattice = Cubic-F (fcc)
Basis = Cu at [000]



Plan view
unlabeled points at $z = 0, 1$



Diamond (C); also Si and Ge
Lattice = Cubic-F (fcc)
Basis = C at [000]
and C at $[\frac{1}{4}\frac{1}{4}\frac{1}{4}]$



Plan view
unlabeled points at $z = 0, 1$

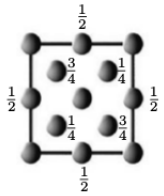


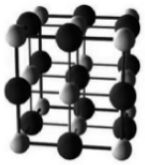
Fig. 12.21 Some crystals based on the fcc lattice. **Top:** Copper forms an fcc lattice. **Middle:** Diamond (carbon) is an fcc lattice with a two-atom basis. **Bottom:** NaCl (salt) is also an fcc lattice with a two atom basis. Note that in every case, a conventional unit cell is shown but the basis is given for the primitive unit cell.

Sodium Chloride (NaCl)

Lattice = Cubic-F (fcc)

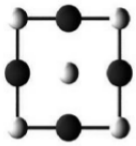
Basis = Na at [000]

and Cl at $[\frac{1}{2}\frac{1}{2}\frac{1}{2}]$



Plan view

$z = 0, 1$ layer



$z = \frac{1}{2}$ layer