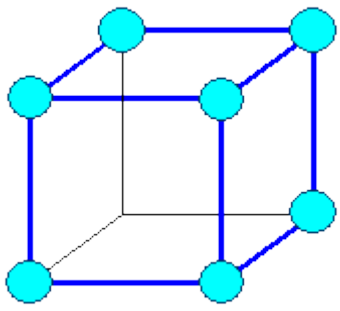
## BRAVAIS LATTICES

- Bravais in 1948 showed that 14 types of unit cells under seven crystal systems are possible. They are commonly called as *`Bravais lattices'*.

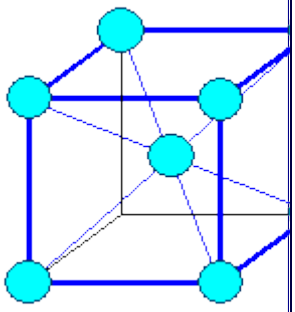
| S.No. | Crystal system | Axial length | Interfacial angles | Example |
|---|---|---|---|---|
| 1. | Cubic | a=b=c | = = = 90° | NaCl, $CaF_2$, Au, Cu |
| 2. | Tetragonal | a=b c | = = = 90° | Ordinary white, tin, Indium, $SnO_2$ |
| 3. | Orthorhombic | a b c | = = = 90° | Sulphur, Topaz, BaSO4, $KNO_3$ |
| 4. | Monoclinic | a b c | = = 90°; 90° | $Na_2So_4$, $FeSo_4$, Gypsum |
| 5. | Triclinic | a b c | 90° | CuSo4, $K_2Cr_2O_7$ |
| 6. | Rhombohedral | a = b = c | = = 90° | Calcite, Sb, Bi. |
| 7. | Hexagonal | a=b c | = = 90°; = 120° | Quartz, Zn, Mg. |

**Cubic**

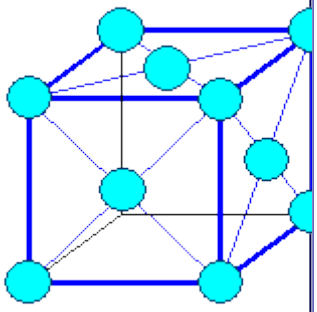
**$a_1 = a_2 = a_3 = a$ = lattice constant = = = $90^0$**



cubic primitive

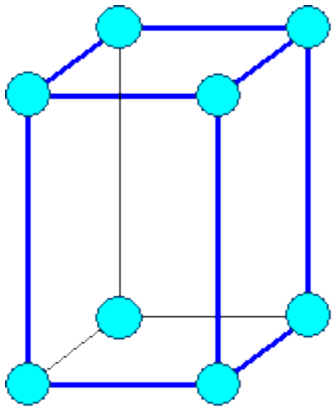
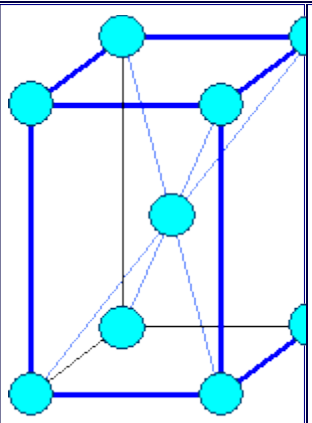
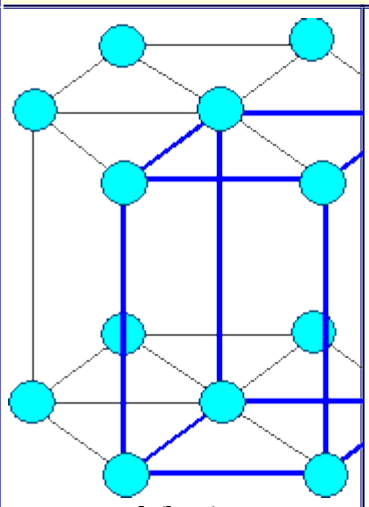


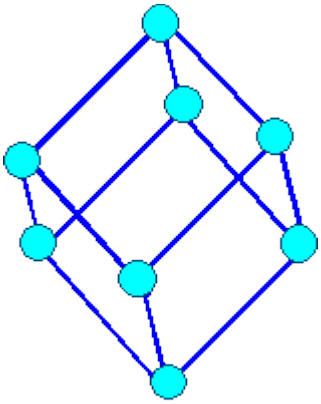
cubic body centered (bcc)



cubic face centered (fcc)

**Tetragonal**

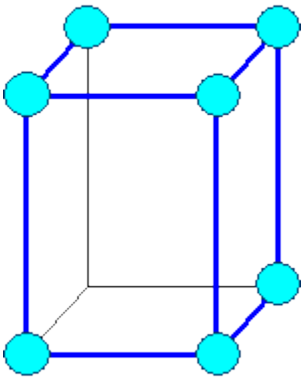
| | | |
|---|---|---|
| $a_1 = a_2 \neq a_3$ $\quad = \quad = 90^0$ | | |
|  tetragonal primitive |  tetragonal body centered | |
| **Hexagonal** $a_1 = a_2 \neq a_3$ $\quad = \quad = 90^0, \quad = 120^0$ Typical: $a_3 = c$ | | |
|  Hexagonal (hex) | (expanded to show hex symmetry) | |
| **Rhombohedral** or **Trigonal** $a_1 = a_2 = a_3$ $\quad = \quad = \neq 90^0$ | | |



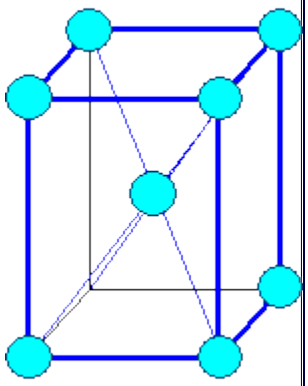
rhombohedral

## Orthorhombic

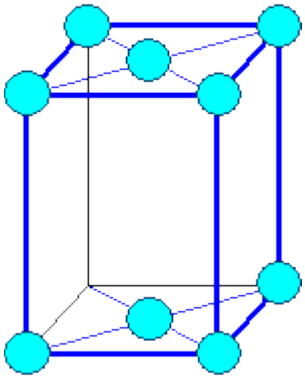
$a_1 \neq a_2 \neq a_3$ = = $= 90^0$



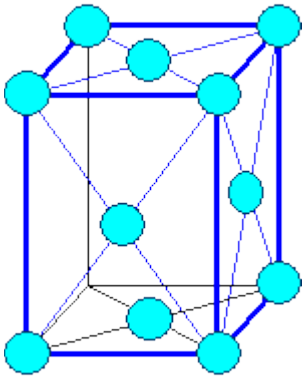
orthorhombic primitiv



orthorhombic body centered



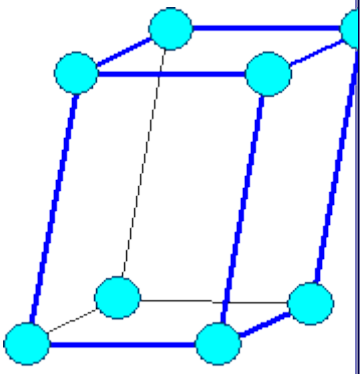
orthorhombic base face centered



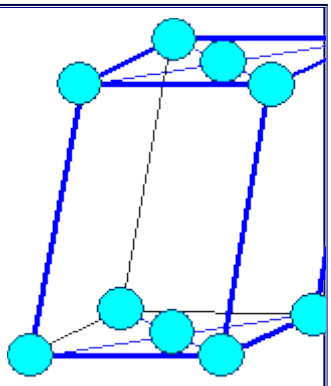
orthorhombic face centered

## Monoclinic

$a_1 \neq a_2 \neq a_3$ = $= 90^0$, $\neq 90^0$



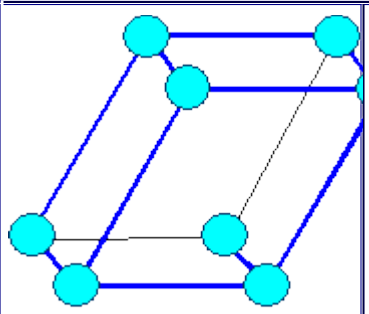
monoclinic primitive



monoclinic base face centered

**Triclinic**

$a_1 \neq a_2 \neq a_3 \quad \neq \quad \neq \quad \neq 90^0$



triclinic

**Bravais lattices**

(on occasion only "visible" lattice points (= blue circles) are shown)

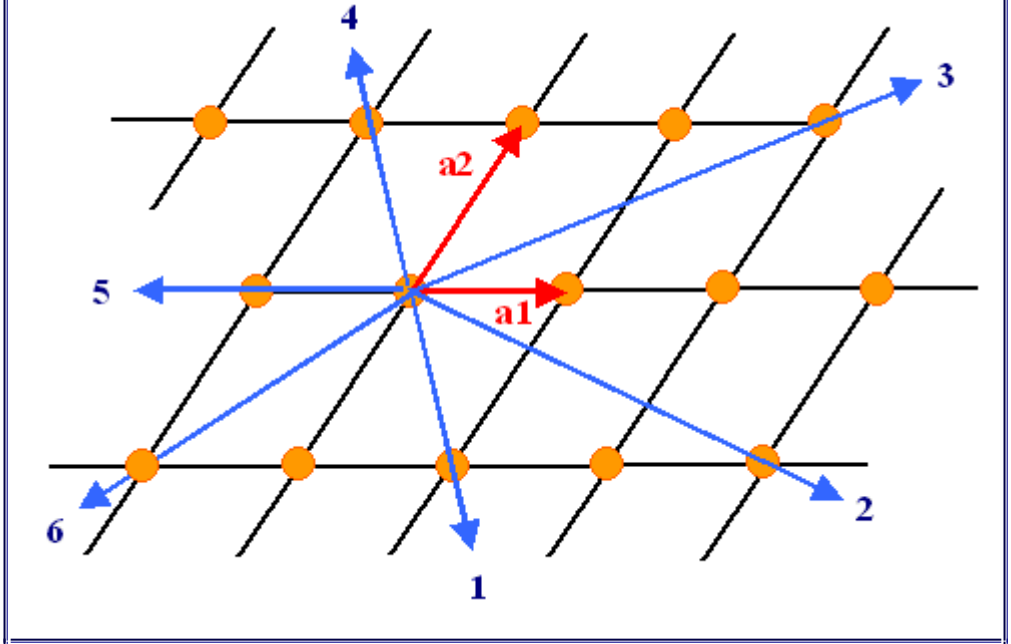
## Describing Directions and Planes by Miller Indices

Working with lattices and crystals produces rather quickly the need to describe certain directions and planes in a simple and unambigous way. Stating that an elemental face-centered cubic crystal can be made by assigning one atom to any lattice point found on "that plane that runs somehow diagonally through the unit cell" just won't do it.
So **William Hallowes Miller** invented a system with a lot of power for doing that in 1839. What we do is to describe any direction or any plane by *three integer numbers* , called **Miller indices**.

- How to derive the Miller indices of a certain direction or plane is easy. Here is the recipe for directions (in 2 dimensions for simplicity); the figure below illustrates it:

  - Start the desired direction from the origin.
  - Express the direction as a vector given in integer multiples u, v, w of the base vectors.
  - Make sure the three integers have the smallest possible value.

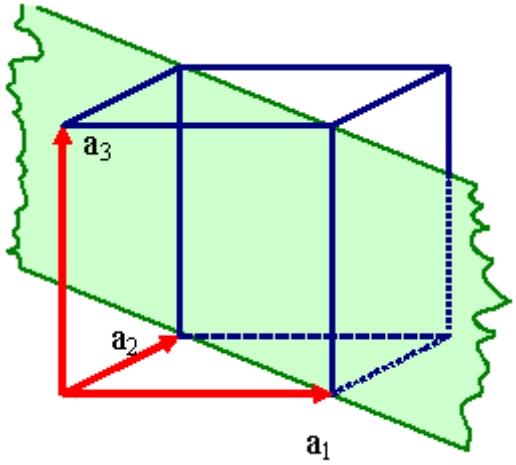
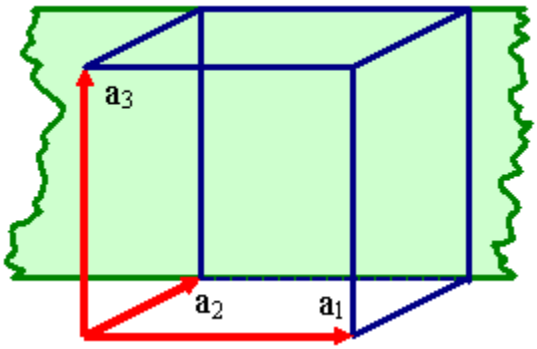
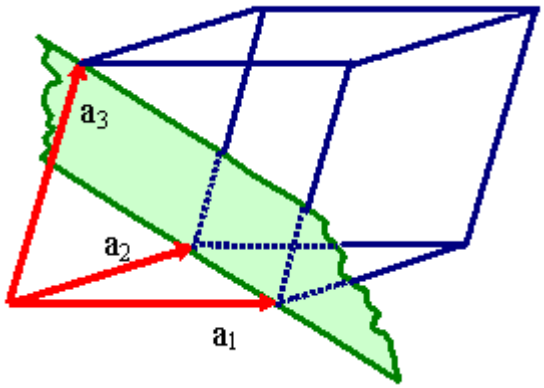
- Write the direction as [u v w] or  u v w  (we won't concern us here with the subtleties involved in using two kinds of brackets).
- Negative integer values are written with a dash on top of the number instead of the conventional "-" sign. (not possible in simple HTML)




**Six directions in a (2-dim) lattice and their Miller indices**

- Getting Miller indices for planes is a bit more involved. Here is how it's done; the figure below gives examples:

  - Put the origin *not* on the plane but on a neighboring plane.
  - Find the intersection points h', k', and l' of the plane with the (extended) base vectors. If there is none, the value is ∞ .
  - Form the reciprocal values of h', k', and l' and call them h, k, and l. If, for example, h' = ∞, you have h = (1/h') = 0.
  - The Miller indices of the plane to be indexed then are {hkl} or (hkl).

| | |
|---|---|
|  | Cubic lattice<br>Intersections at<br>**1, 1, ∞**<br>*Indices* **(110)** |
|  | Cubic lattice<br><br>Intersections at ∞, **1**, ∞<br>*Indices* **(010)** |
|  | Triclinic lattice<br>Intersections at<br>**1, 1, 1**<br>*Indizes* **(111)** |
| **Miller Indices for Planes** | |