Crystal morphology: The angular relationships, size, and shape of faces on a crystal.

Steno's law '*The angles between equivalent faces of crystals of the same substance, measure at the same temperature, are constant.*'

Crystal axis:

Imaginary reference lines parallel to the intersection edges of major crystal faces. They are designated plus or minus at the end of each axis, where

+a front ⇔ -a back

+b right ⇔ -b left

+c upper ⇔ -c lower

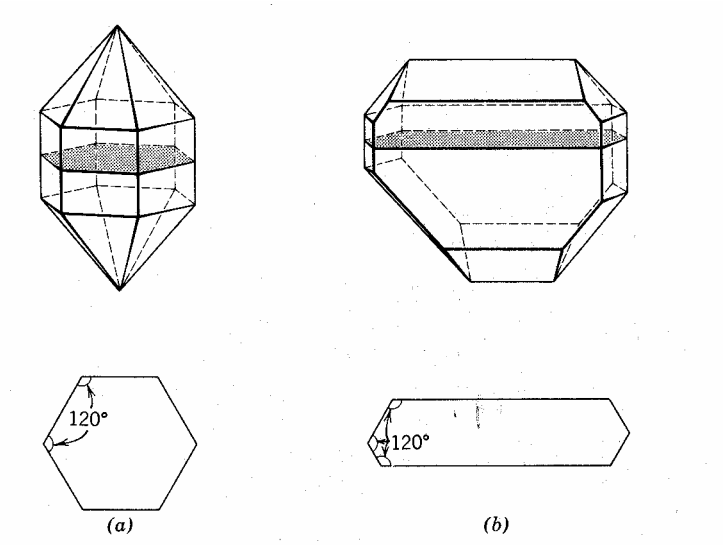


FIG. 2.23. Constancy of interfacial angles as shown in the comparison of a well-formed and highly symmetric quartz crystal *(a)* and a distorted quartz crystal *(b)*. The sections across the direction of elongation show identical interfacial angles of 120° in both, irrespective of the asymmetric habit in *(b)*.

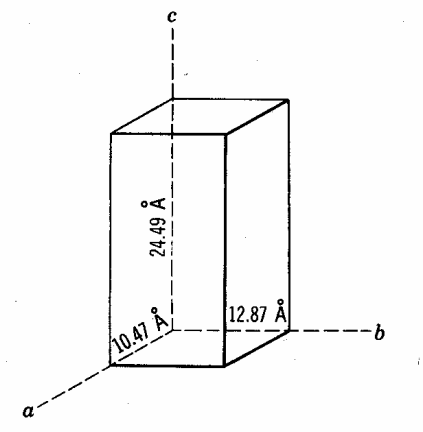
- Three axes: a, b, c

  Triclinic, Monoclinic, Orthorhombic, Tetragonal, Isometric
- Four axes: a_1, a_2, a_3, c in Hexagonal

Axial ratios: a/b : b/b : c/b $X : 1 : Y$

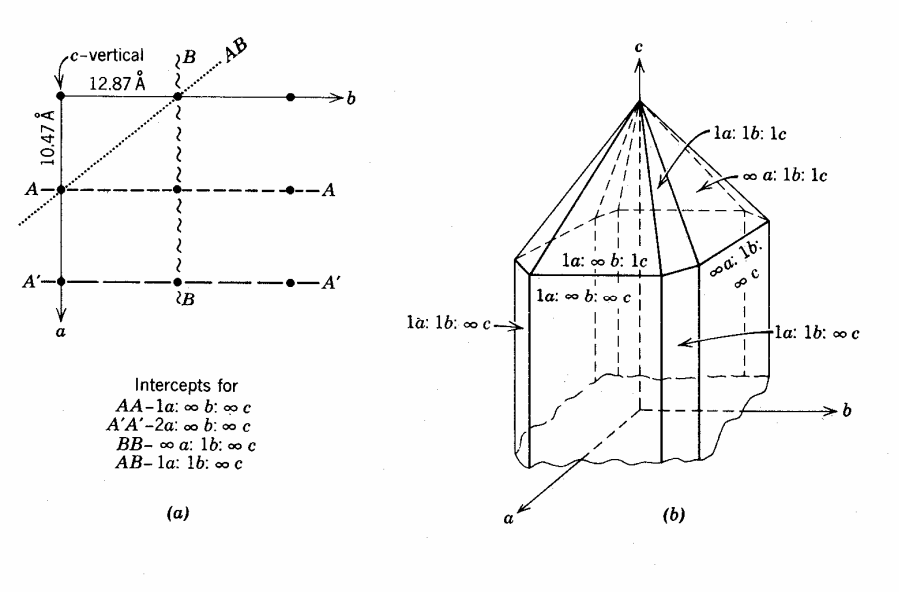
Sulphur crystal a = 10.47Å, b = 12.87Å, c = 24.49Å

a: b: c = 0.813 : 1 : 1.903



The orthorhombic unit cell of sulfur.

Face intercepts: The relation of crystal faces to the crystallographic axes in terms of the interception



Miller indices: Inversions of intercept numbers, as a result, fraction is cleared.

: use ( )

: use, only in case of two-digit number appear e.g. (1, 14, 3)

: indices on negative intercept use ¯ e.g. (1 $\bar{1}$ 1)

: hexagonal system use 4-digit number with (h k $\bar{i}$ l) always

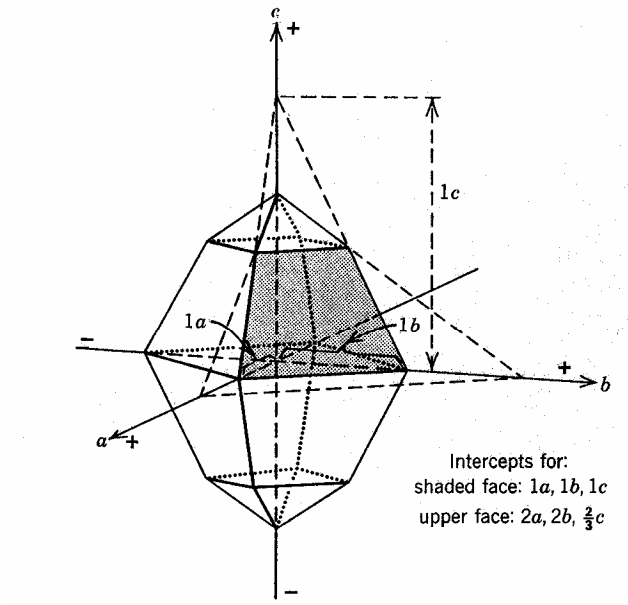


FIG. 2.30. Relative intersections of faces on an orthorhombic crystal, all of which cut three crystallographic axes.

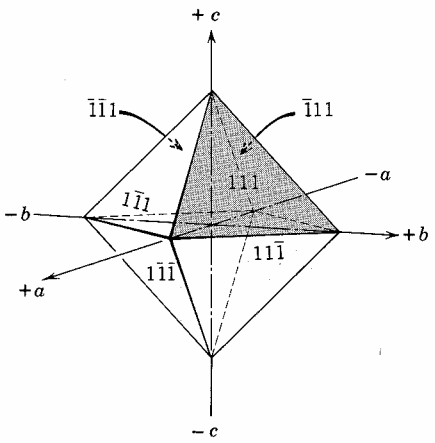
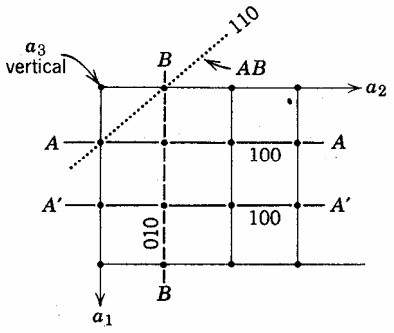


FIG. 2.32. Miller indices with respect to positive and negative ends of crystallographic axes.

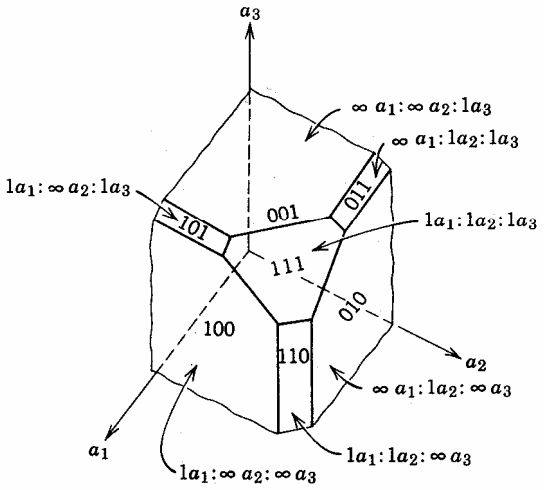
FIG. 2.31. *(a)* Intercepts and Miller indices for some planes in an isometric lattice. *(b)* Intercepts and Miller indices of some faces modifying the corner of a cube.



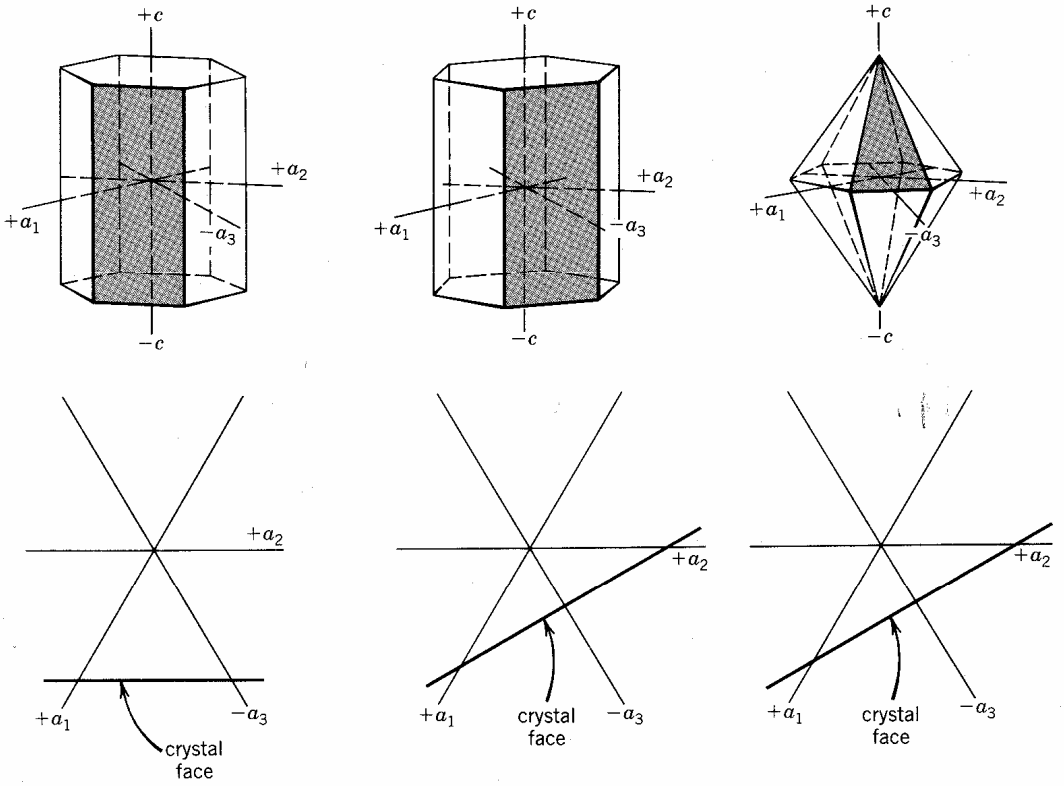
Intercepts for:
AA–$1:\infty:\infty$
$A'A'$–$2:\infty:\infty$
BB–$\infty:1:\infty$
AB–$1:1:\infty$

Miller indices for:
AA–$\frac{1}{1}\frac{1}{\infty}\frac{1}{\infty} = 100$
$A'A'$–$\left(\frac{1}{2}\frac{1}{\infty}\frac{1}{\infty}\right) \times 2 = 100$
BB–$\frac{1}{\infty}\frac{1}{1}\frac{1}{\infty} = 010$
AB–$\frac{1}{1}\frac{1}{1}\frac{1}{\infty} = 110$

(a)



(b)



Intercepts for shaded faces:

$1a_1, \infty a_2, 1a_3(-), \infty c$ | $1a_1, 1a_2, \frac{1}{2}a_3(-), \infty c$ | $1a_1, 1a_2, \frac{1}{2}a_3(-), 1c$

Miller-Bravais indices for shaded faces:

$\frac{1}{1}\ \frac{1}{\infty}\ \frac{\bar{1}}{1}\ \frac{1}{\infty}$ | $\frac{1}{1}\ \frac{1}{1}\ \frac{\bar{1}}{\frac{1}{2}}\ \frac{1}{\infty}$ | $\frac{1}{1}\ \frac{1}{1}\ \frac{\bar{1}}{\frac{1}{2}}\ \frac{1}{1}$

$1\ 0\ \bar{1}\ 0$ | $1\ 1\ \bar{2}\ 0$ | $1\ 1\ \bar{2}\ 1$

FIG. 2.33. Derivation of the four-digit Bravais-Miller index from the intercepts of three different crystal faces in the hexagonal system.

Form: A group of crystal faces, all of which have the same relation to the elements of symmetry and display the same chemical and physical properties because all are underlain by like atoms in the same geometrical arrangement. : use {hkl}

General form: the faces of which intersect all of the crystallographic axes at the *different* length.

An {hkl} face will not be parallel or perpendicular to a symmetry axis or plane, regardless of the crystal system.

Special form: consists of faces that are parallel or perpendicular to any of the symmetry elements in the crystals

Open form: contains parallel faces and do not enclose space.

Closed form: form that encloses space

Zone: the arrangement of a group of faces with parallel in the intersections edges.

Zone axis: a line through the centre of the crystal that is paralleled to the lines of the face those intersections.

Classification of forms: 32 general forms

10 special closed forms of isometric

6 special open forms of tetra-, hexagonal

- Pedian: single faced form
- Pinacoid: two parallel faced form
- Dome: two nonparallel faced with mirror plane symmetry
- Sphenoid: two nonparallel faced with 2-fold rotation symmetry
- Prism: 3, 4, 6, 8, or 12 faces all are parallel to the same axis. Except certain prisms in monoclinic, axis is one of xtal axes
- Pyramid: 3, 4, 6, 8, or 12 nonparallel faces that meet at a point
- Dipyramid: closed form having 6, 8, 12, 16, or 24 faces formed from two pyramids by reflection of one of them across a horizontal mirror.
- Trapezohedron: 6, 8, or 12 with 3, 4, or 6 upper faces offset from lower faces.
- Scalenohedron: 8 or 12 faces grouped in symmetrical pairs.
- Rhombohedron: 6 faces of which 3 upper faces offset from 3 lower faces
- Disphenoid: 2 upper faces alternate with 2 lower faces, by 90°

Non-isometric forms

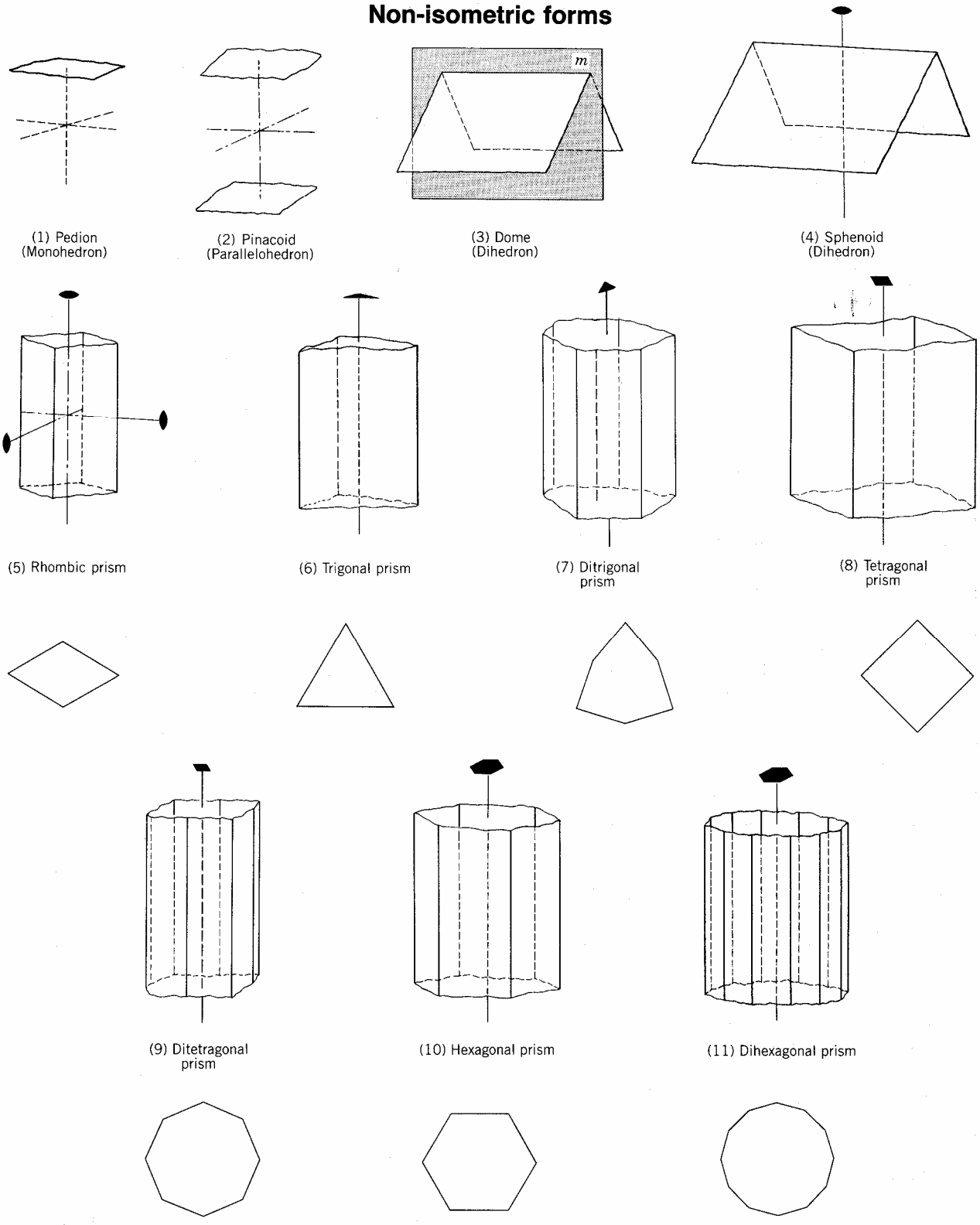
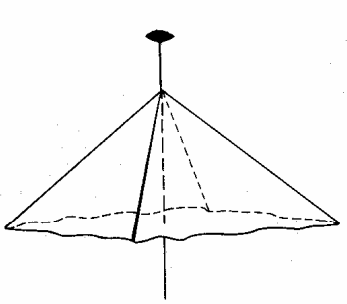


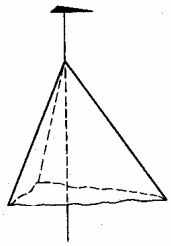
FIG. 2.36. The 48 (or 47) different crystal forms and some of their symmetry elements.

(continued)

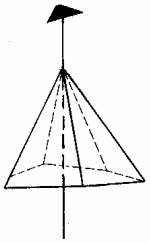
Non-isometric forms (cont'd)



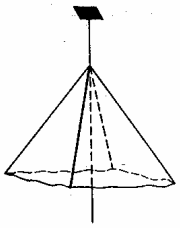
(12) Rhombic pyramid



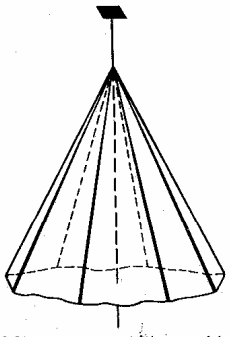
(13) Trigonal pyramid



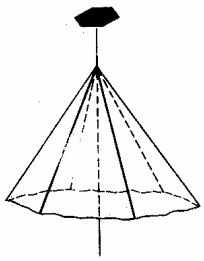
(14) Ditrigonal pyramid



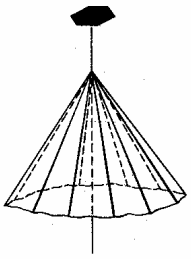
(15) Tetragonal pyramid



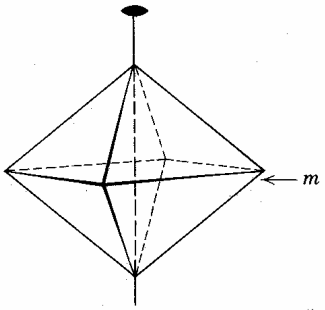
(16) Ditetragonal dipyramid



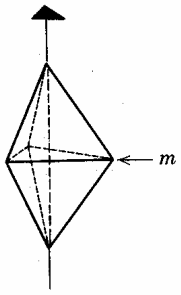
(17) Hexagonal pyramid



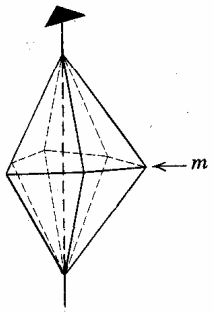
(18) Dihexagonal pyramid



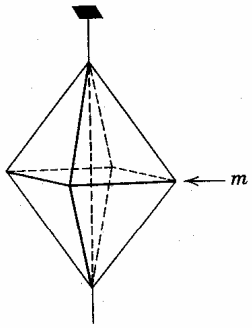
(19) Rhombic dipyramid



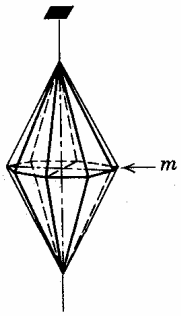
(20) Trigonal dipyramid



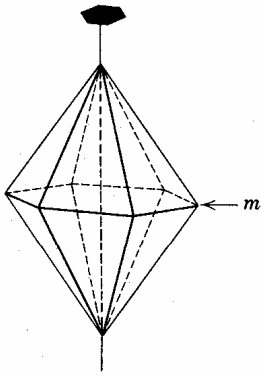
(21) Ditrigonal dipyramid



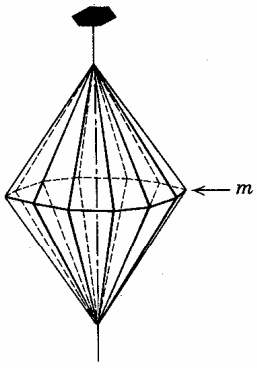
(22) Tetragonal dipyramid



(23) Ditetragonal dipyramid



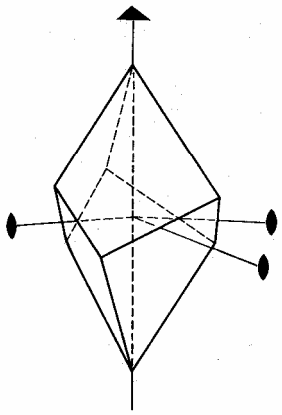
(24) Hexagonal dipyramid



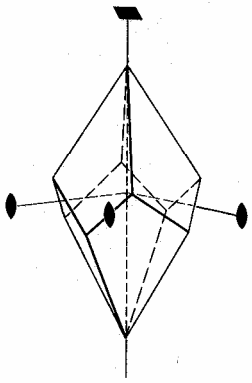
(25) Dihexagonal dipyramid

FIG. 2.36. *(continued)*

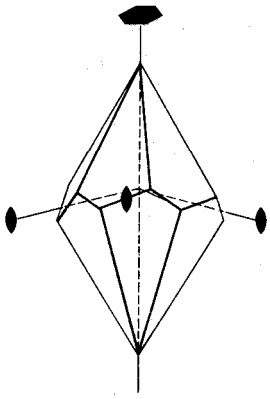
Non-isometric forms (cont'd)



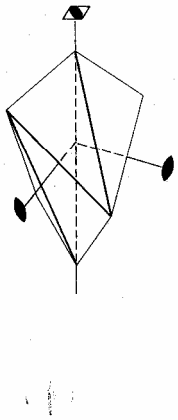
(26) Trigonal trapezohedron



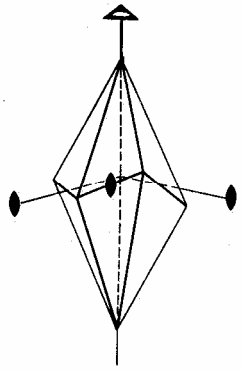
(27) Tetragonal trapezohedron



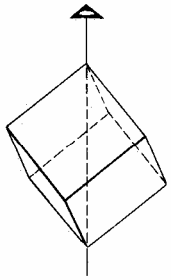
(28) Hexagonal trapezohedron



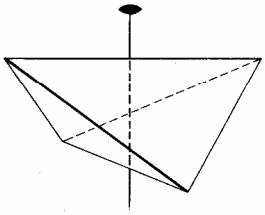
(29) Tetragonal scalenohedron (Rhombic scalenohedron)



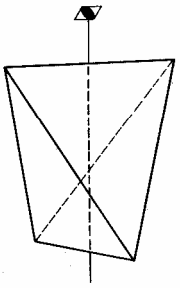
(30) Hexagonal scalenohedron (Ditrigonal scalenohedron)



(31) Rhombohedron

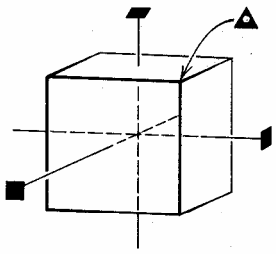


(32) Rhombic disphenoid (Rhombic tetrahedron)

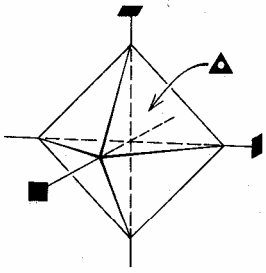


(33) Tetragonal disphenoid (Tetragonal tetrahedron)

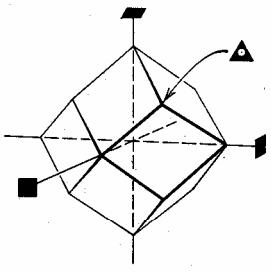
Isometric forms



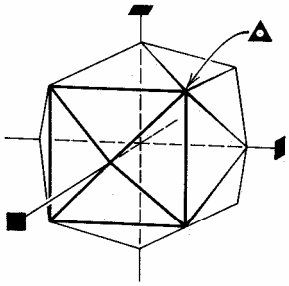
(34) Cube (Hexahedron)



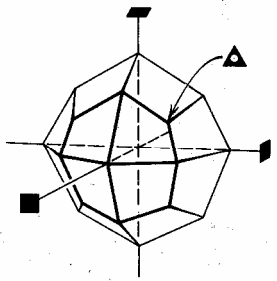
(35) Octahedron



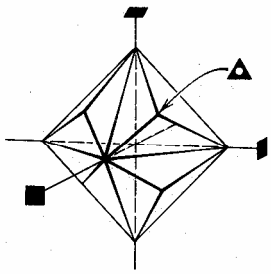
(36) Dodecahedron (Rhomb-dodecahedron)



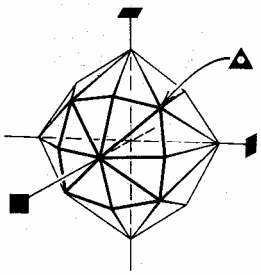
(37) Tetrahexahedron



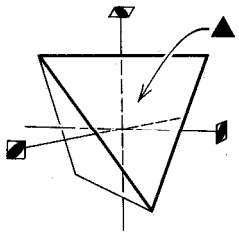
(38) Trapezohedron (Tetragon-trioctahedron)



(39) Trisoctahedron (Trigon-trioctahedron)



(40) Hexoctahedron (Hexaoctahedron)



(41) Tetrahedron

FIG. 2.36. *(continued)*

(continued)

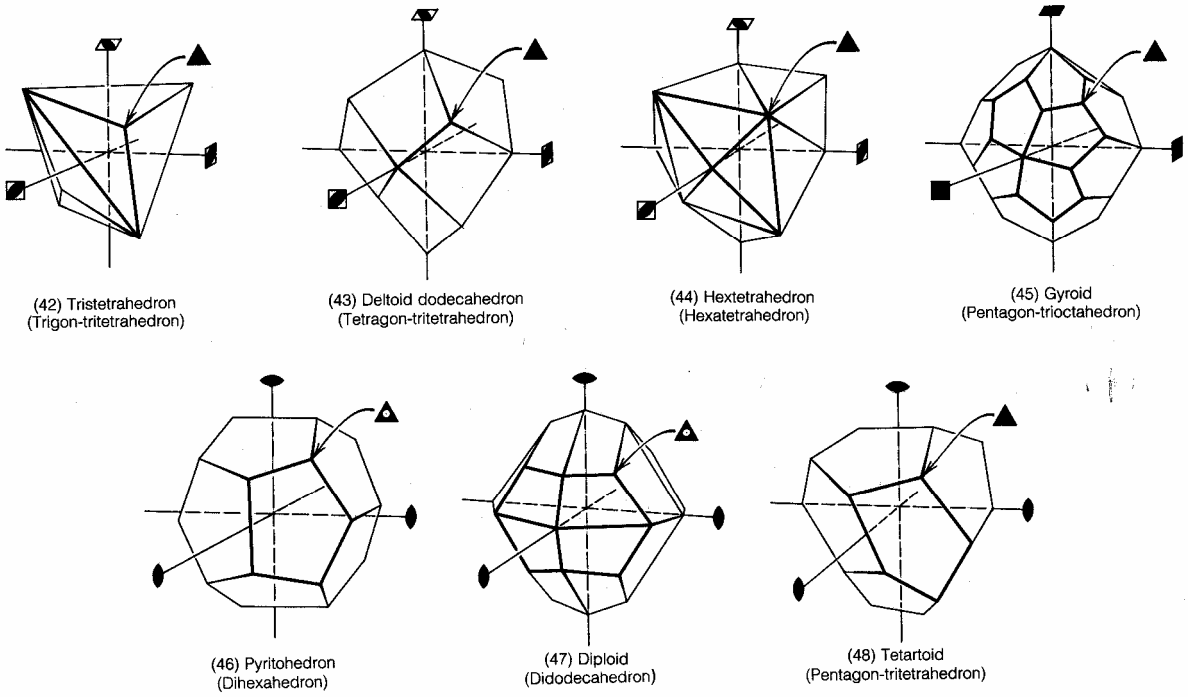


FIG. 2.36. *(continued)*

Crystal habit: denotes the general shapes of crystal such as *cubic, octahedral, prismatic.* Hence, crystal habit is controlled by the environment during the growth of crystal, it may vary with locality >>> Ideal developed vs. distorted

Zone: the arrangement of a group of faces with parallel in the intersections edges.

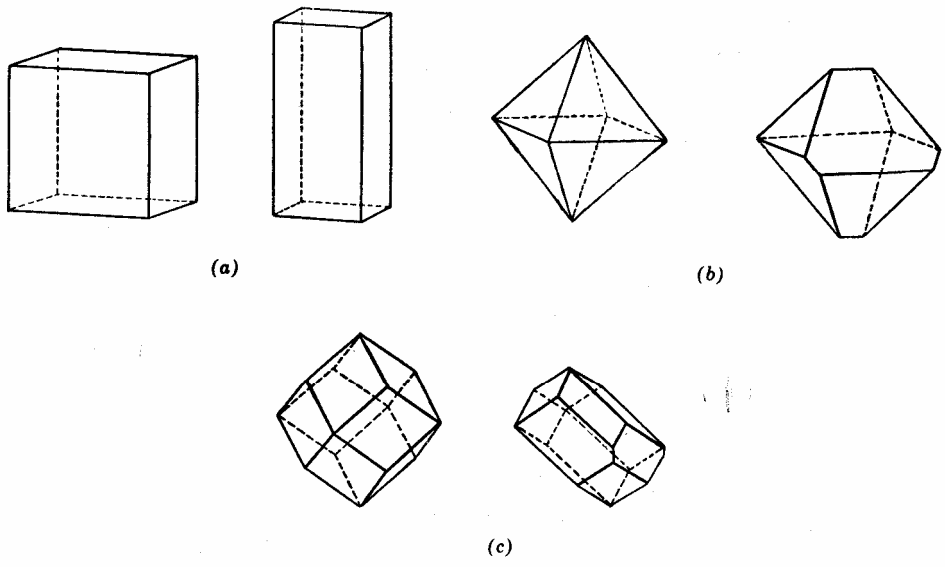


FIG. 2.39. Examples of some crystal habits in the isometric system. *(a)* Cube and distorted cube. *(b)* Octahedron and asymmetric octahedron. *(c)* Dodecahedron and distorted dodecahedron.

Zone axis: a line through the centre of the crystal that is paralleled to the lines of the face those intersections.

FIG. 2.37. Conventional lettering of forms on crystal drawings.

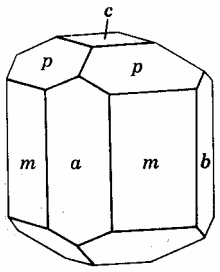
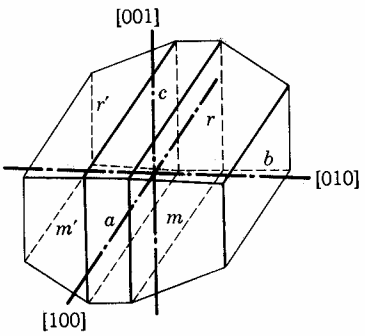
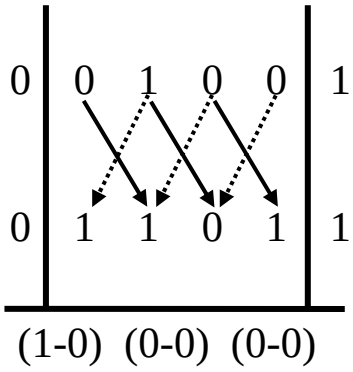


FIG. 2.38. Crystal zones and zone axes.

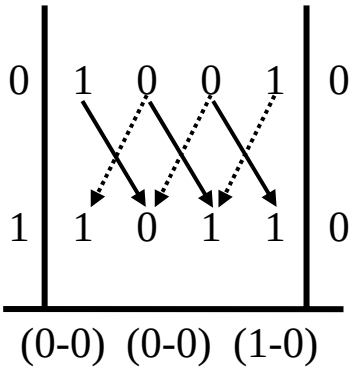


Example: c (001) vs r (011)



Zone axis **[100]**

b (010) vs m (110)



Zone axis **[001]**