GY 302 Crystallography and Mineralogy
Supplementary Lecture Notes 2
## Crystal Systems and Symmetry

	Crystal System	Axes	Angles between axes	Mineral examples
1	**Cubic**			Halite, Galena, Pyrite
2	**Tetragonal**			Zircon
3a	**Hexagonal**			Apatite
3b	**Trigonal**			Quartz, Calcite
4	**Orthorhombic**			Aragonite, Staurolite
5	**Monoclinic**			Gypsum, Orthoclase
6	**Triclinic**			Plagioclase

Isometric Crystal   Tetragonal Crystal   Hexagonal Crystal   Orthorhombic Crystal   Monoclinic Crystal
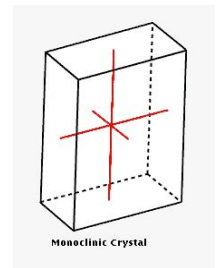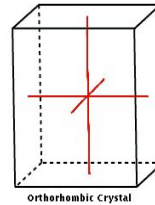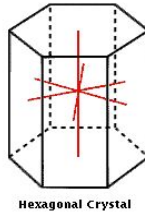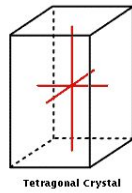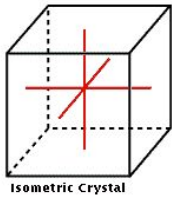
Symmetry explanations below are from http://www.cartage.org.lb

2-fold Rotation Axis - If an object appears identical after a rotation of 180°, that is twice in a 360° rotation, then it is said to have a 2-fold rotation axis (360/180 = 2).
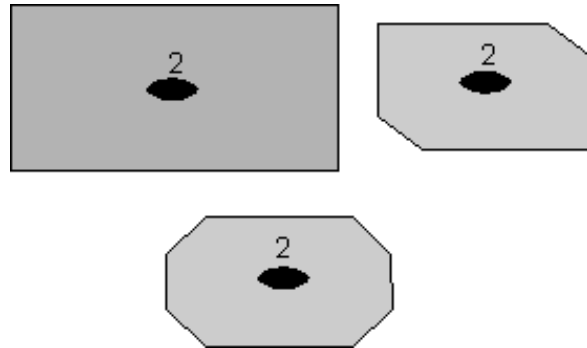
Note that in these examples the axes we are referring to are imaginary lines that extend toward you perpendicular to the page or blackboard. A filled oval shape represents the point where the 2-fold rotation axis intersects the page.

3-fold Rotation Axis - Objects that repeat themselves upon rotation of 120° are said to have a 3-fold axis of rotational symmetry (360/120 =3), and they will repeat 3 times in a 360° rotation. A filled triangle is used to symbolize the location of 3-fold rotation axis.
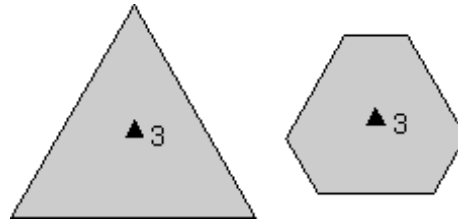
4-fold Rotation Axis - If an object repeats itself after 90o of rotation, it will repeat 4 times in a 360o rotation, as illustrated previously. A filled square is used to symbolize the location of 4-fold axis of rotational symmetry.
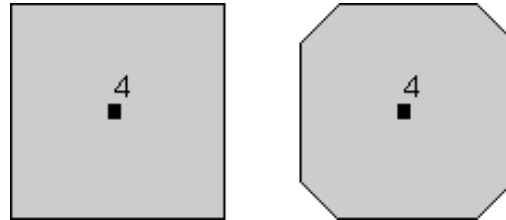
6-fold Rotation Axis -If rotation of 60° about an axis causes the object to repeat itself, then it has 6-fold axis of rotational symmetry (360/60=6). A filled hexagon is used as the symbol for a 6-fold rotation axis.
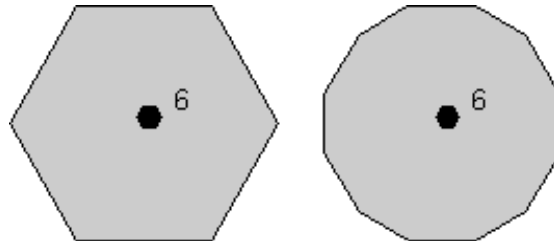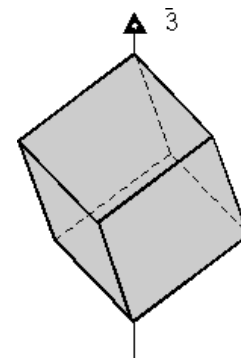
2-fold Rotoinversion - The operation of 2-fold rotoinversion involves first rotating the object by 180 degrees then inverting it through an inversion center.

This operation is equivalent to having a mirror plane perpendicular to the 2-fold rotoinversion axis.
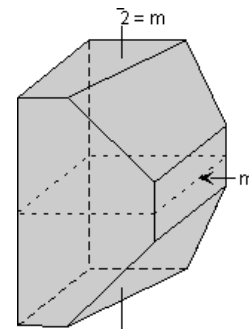
3-fold Rotoinversion - This involves rotating the object by 120° (360/3 = 120), and inverting through a center. A cube is good example of an object that possesses 3-fold rotoinversion axes.
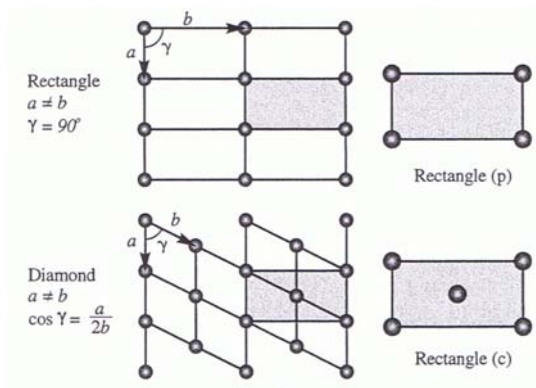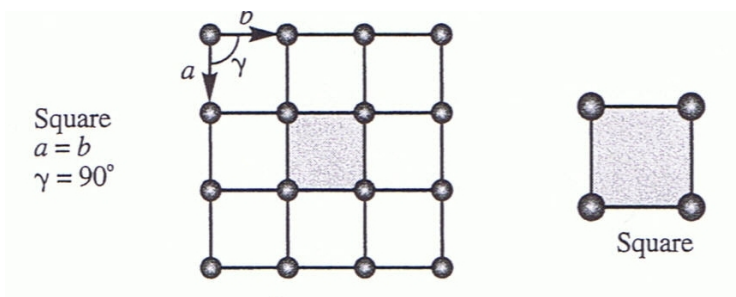
4-fold Rotoinversion - This involves rotation of the object by 90º then inverting through a center.
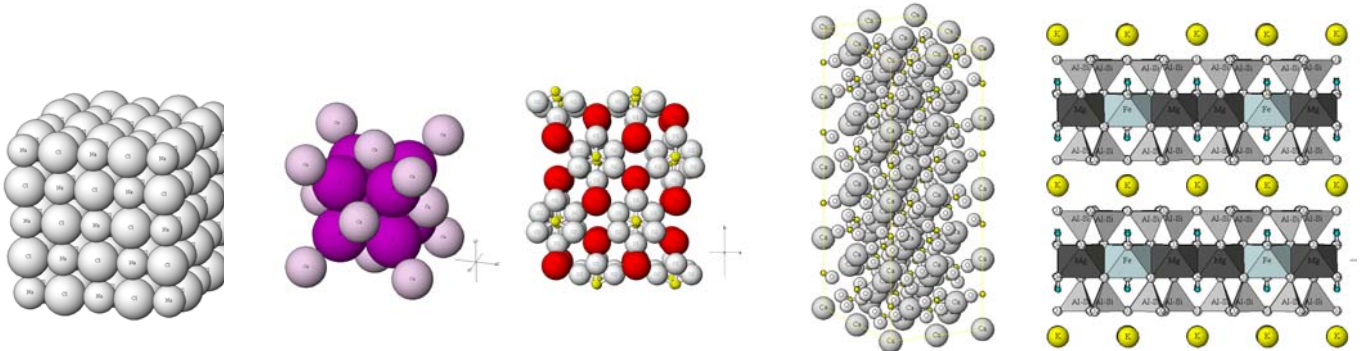
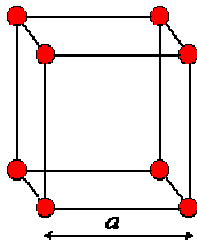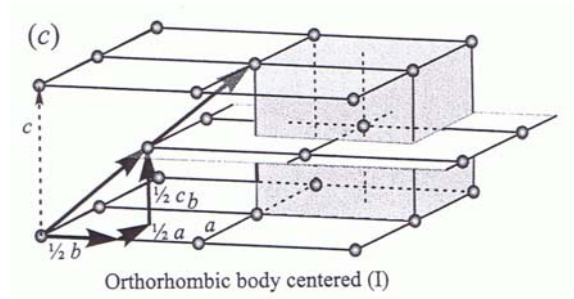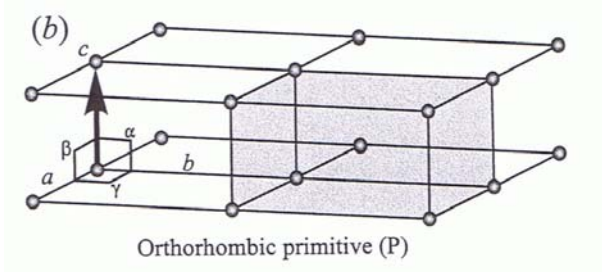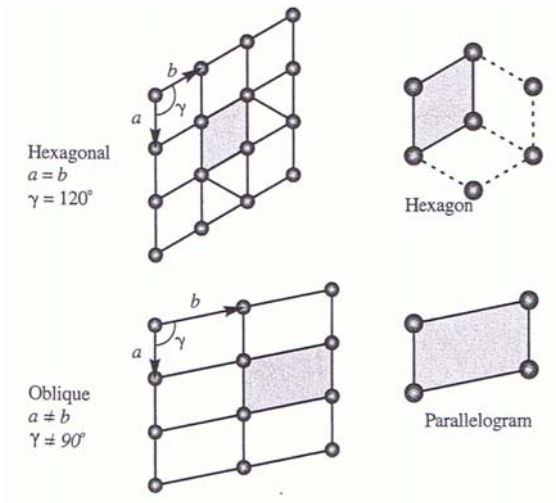Note that an object possessing a 4- fold rotoinversion axis will have two faces on top and two identical faces upside down on the bottom, if the axis is held in the vertical position.

◆ $\bar{4}$

$\bar{6} = 3/m$

m
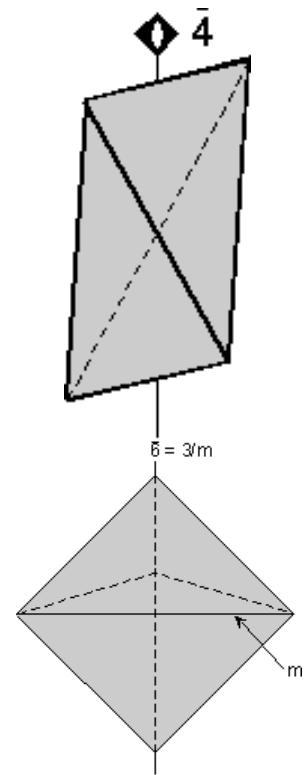
6-fold Rotoinversion - involves rotating the object by 60º and inverting through a center. Note that this operation is identical to having the combination of a 2-fold rotation axis perpendicular to a mirror plane.
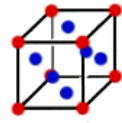
Diagrams below are from Ness, W. D., 2000. Introduction to Mineralogy. Oxford University Press, New York 442pp
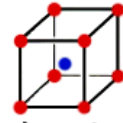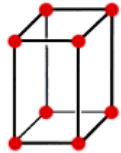
Square
$a = b$
$\gamma = 90°$

Square

Rectangle
$a \neq b$
$\gamma = 90°$

Rectangle (p)

Diamond
$a \neq b$
$\cos \gamma = \frac{a}{2b}$

Rectangle (c)

Hexagonal
$a = b$
$\gamma = 120°$

Hexagon

Oblique
$a \neq b$
$\gamma \neq 90°$

Parallelogram

(b)

c

β α
a b
γ

Orthorhombic primitive (P)

(c)

c

$\frac{1}{2} c_b$
$\frac{1}{2} a$
$\frac{1}{2} b$

Orthorhombic body centered (I)

a a a

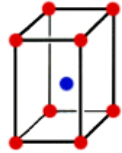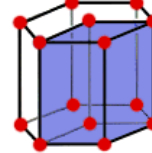(a)   (b)   (c)
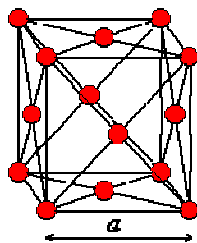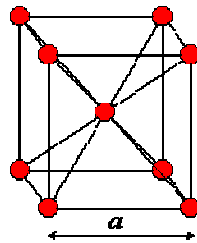
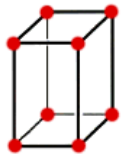**Simple
cubic**

**Face-centered
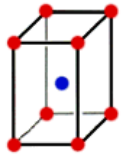cubic**

**Body-centered
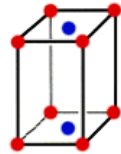cubic**

**Simple
tetragonal**

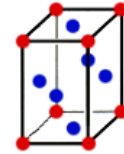**Body-centered
tetragonal**

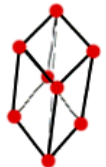**Hexagonal**

**Simple
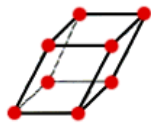orthorhombic**
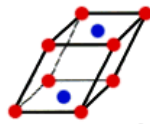
**Body-centered
orthorhombic**

**Base-centered
orthorhombic**

**Face-centered
orthorhombic**

Rhombohedral

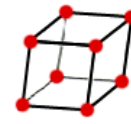**Simple
Monoclinic**

**Base-centered
monoclinic**

Triclinic