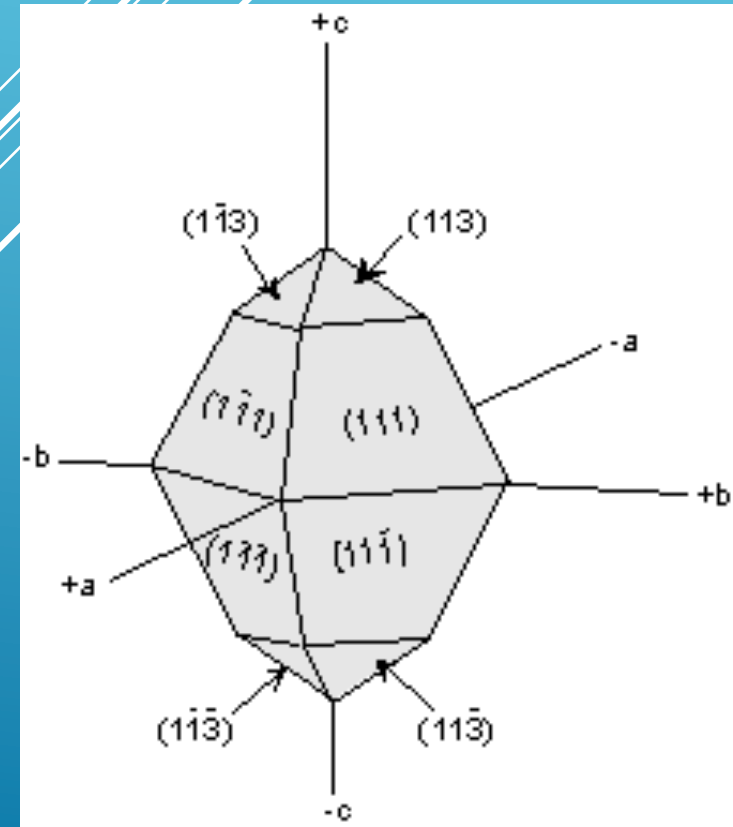


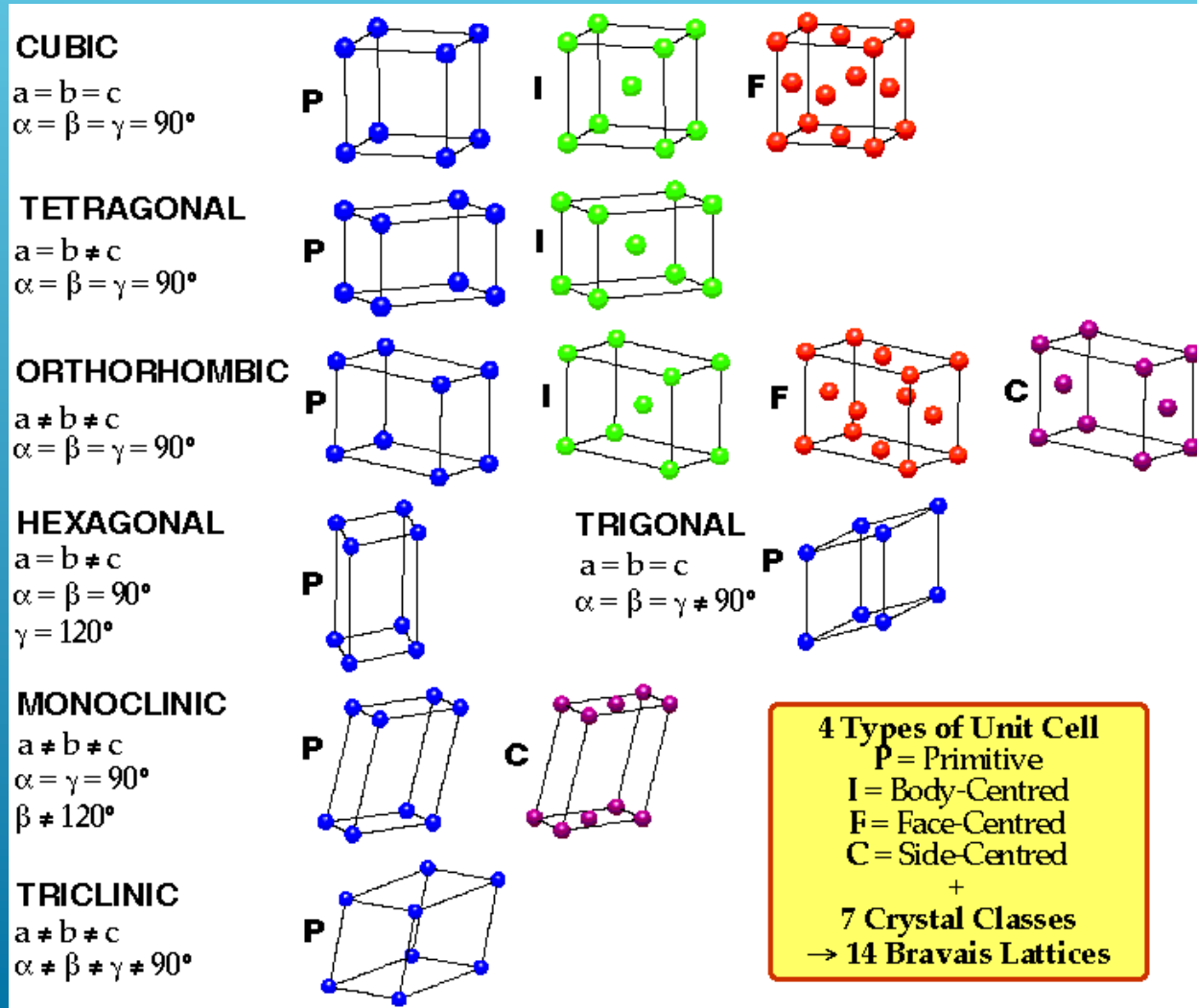
# CHAPTER 4: THE 32 CRYSTAL CLASSES AND THE MILLER INDICES

Sarah Lambart



# RECAP CHAP. 3

## ► 7 Crystal systems & 14 Bravais lattice



# RECAP CHAP. 3

## ▶ Elements of symmetry

▶ **Rotations:** 1 fold, 2 fold, 3 fold, 4 fold, 6 fold

▶ **Mirror**

▶ **Center of symmetry**

▶ **Rotoinversions:** 1 fold, 2 fold, 3 fold, 4 fold, 6 fold

▶ **Combination of symmetry:** introduction to the 32 crystal classes

# CONTENT CHAP. 4

- ▶ **Part 1: the 32 crystal classes**
  - ▶ **Part 2: Miller indices and crystal forms**
- 

# PART 1: THE 32 CRYSTAL CLASSES

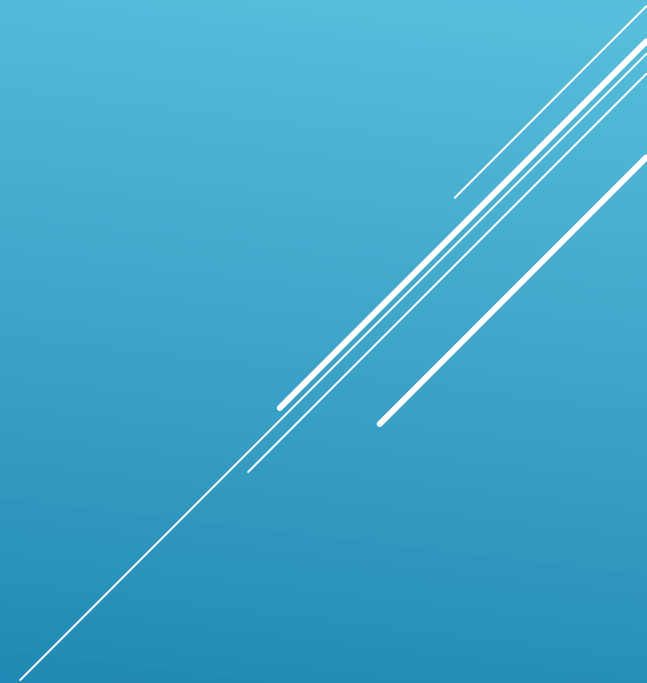
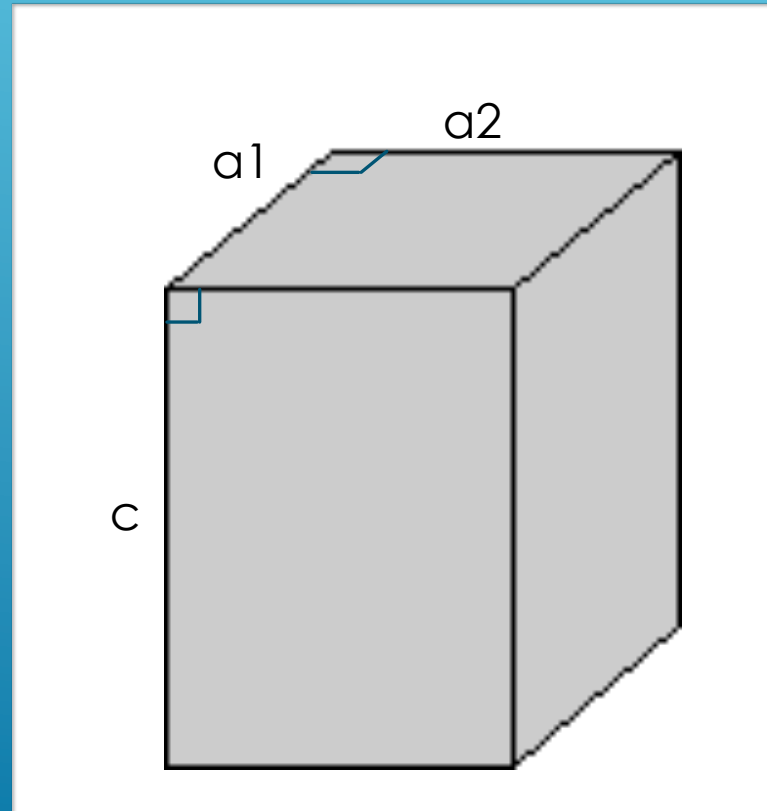
A decorative graphic consisting of several parallel white lines of varying lengths, slanted diagonally from the bottom-left towards the top-right, located in the lower right quadrant of the slide.

# CRYSTAL SYMMETRY

In crystals there are 32 possible combinations of symmetry elements: the **32 Crystal Classes**.

$$a = b \neq c$$

$$\alpha = \beta = \gamma = 90^\circ$$



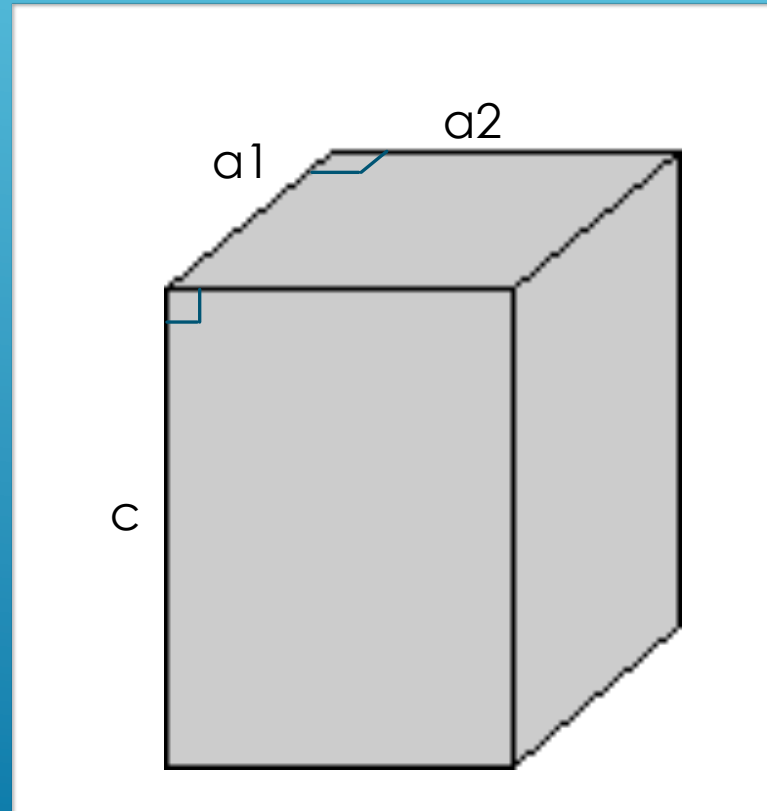
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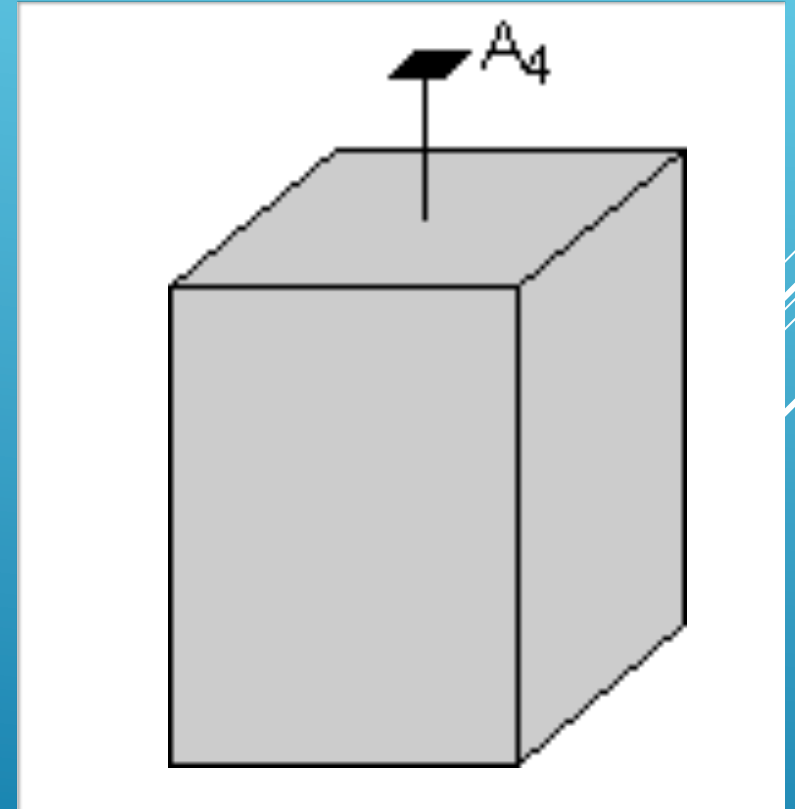
$$\alpha = \beta = \gamma = 90^\circ$$

tetragonal



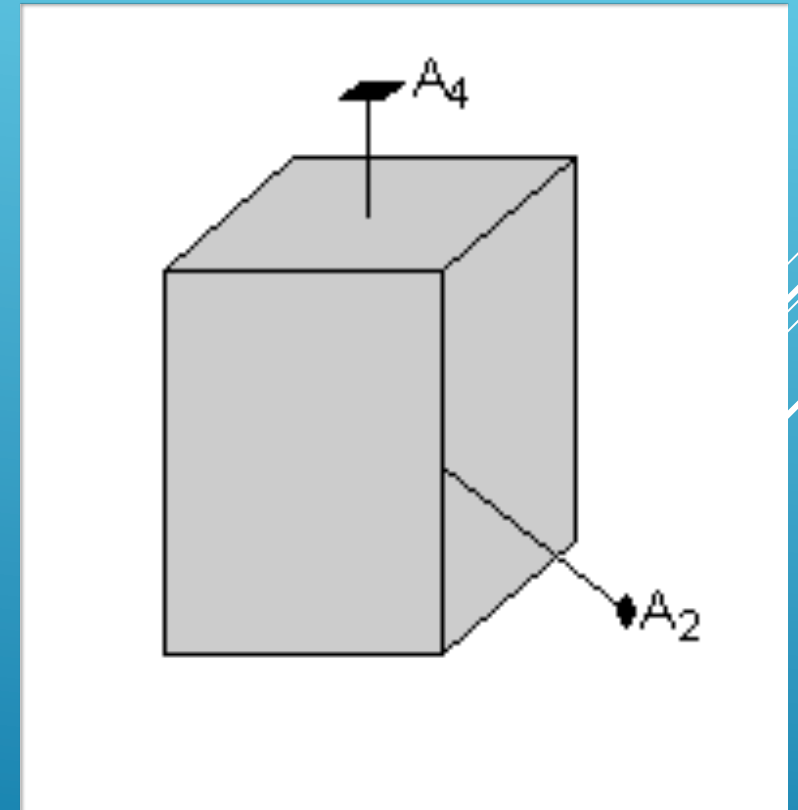
# CRYSTAL SYMMETRY

- ▶ Square-shaped top
  - ▶ 4 fold rotation axis



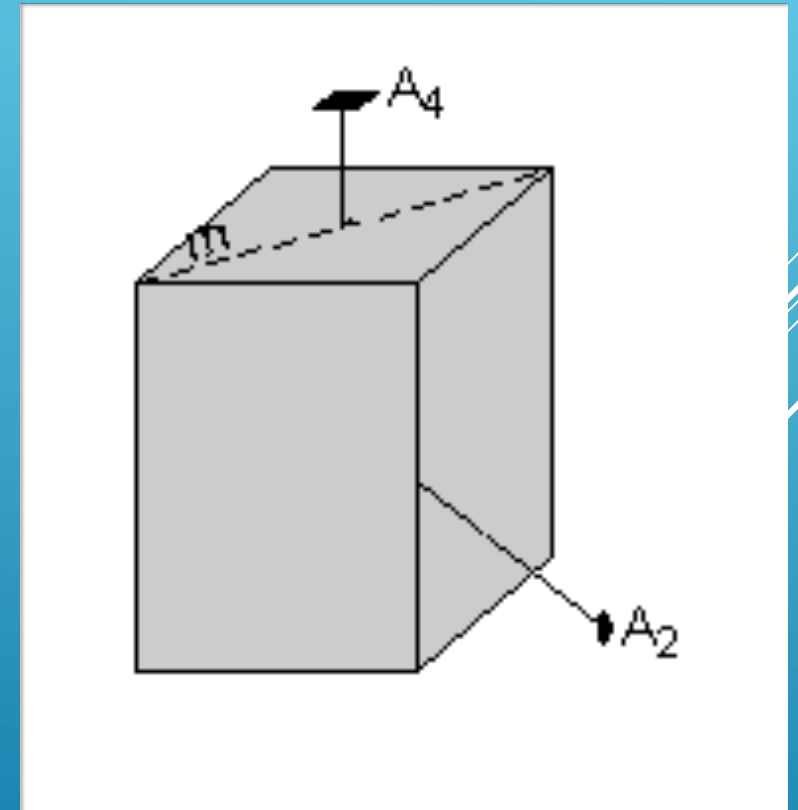
# CRYSTAL SYMMETRY

- ▶ Square-shaped top
  - ▶ 4 fold rotation axis
  - ▶ A 2-fold axis that cuts diagonally through



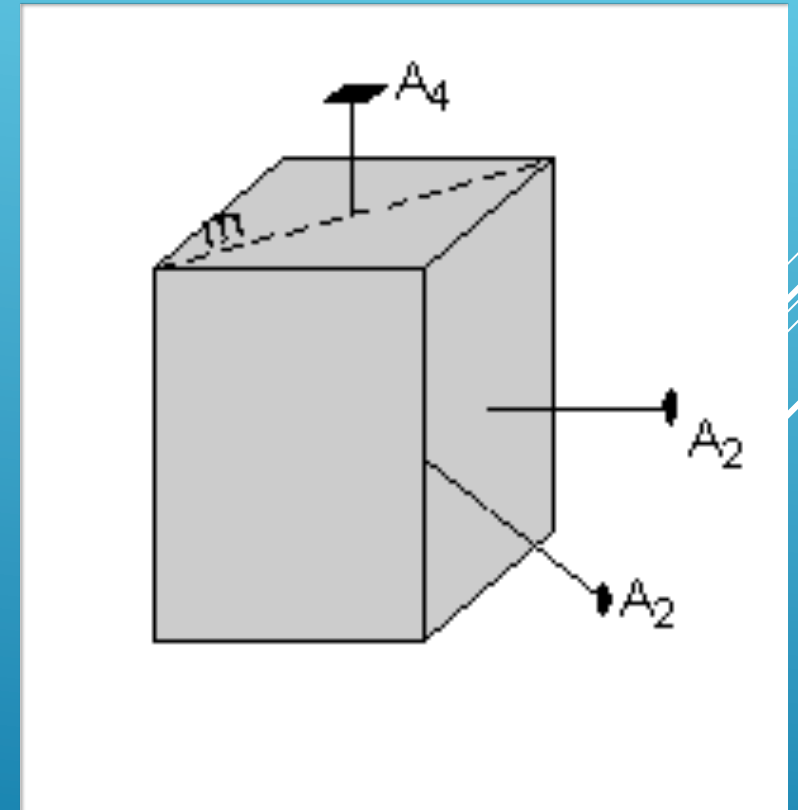
# CRYSTAL SYMMETRY

- ▶ **Square-shaped top**
  - ▶ 4 fold rotation axis
  - ▶ A 2-fold axis that cuts diagonally through
  - ▶ Mirror plan through the diagonal



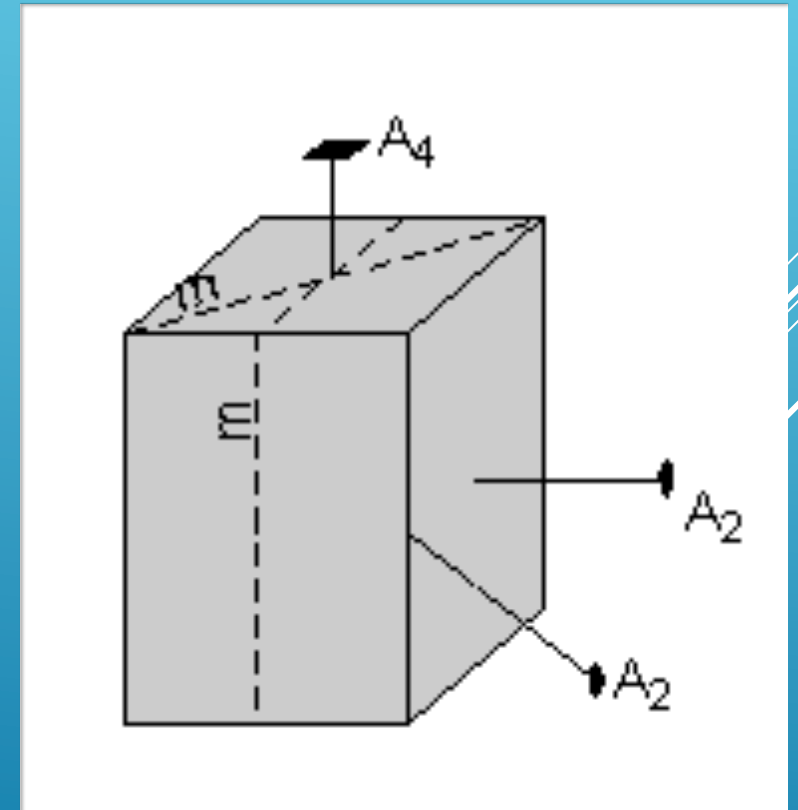
# CRYSTAL SYMMETRY

- ▶ **Rectangular faces:**
  - ▶ 2-fold rotation axis perpendicular to the rectangular face.



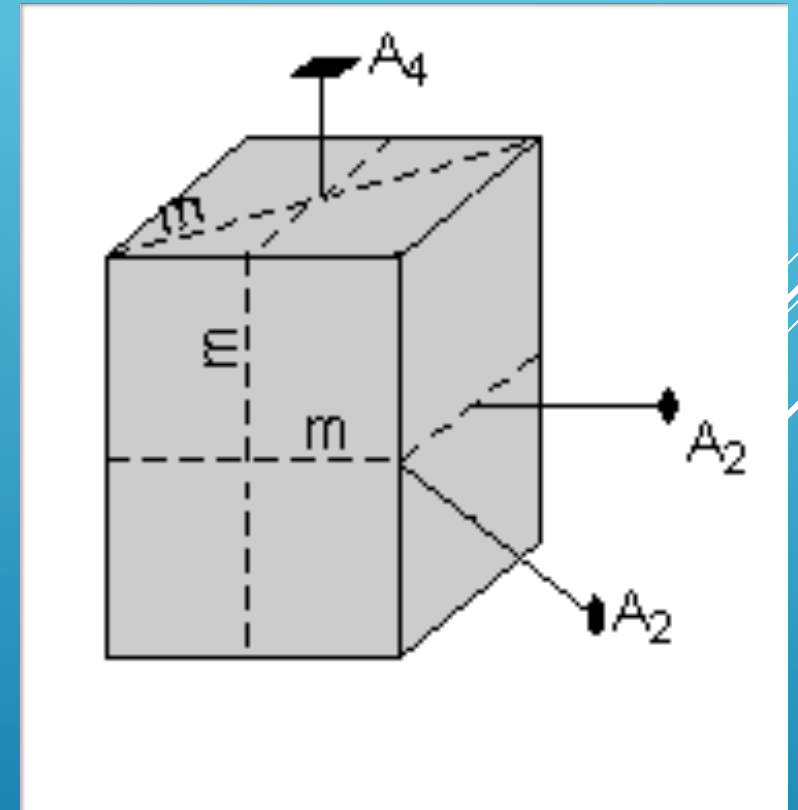
# CRYSTAL SYMMETRY

- ▶ **Square top + rectangular sides:**
  - ▶ mirror plan parallel to the 4-fold axis



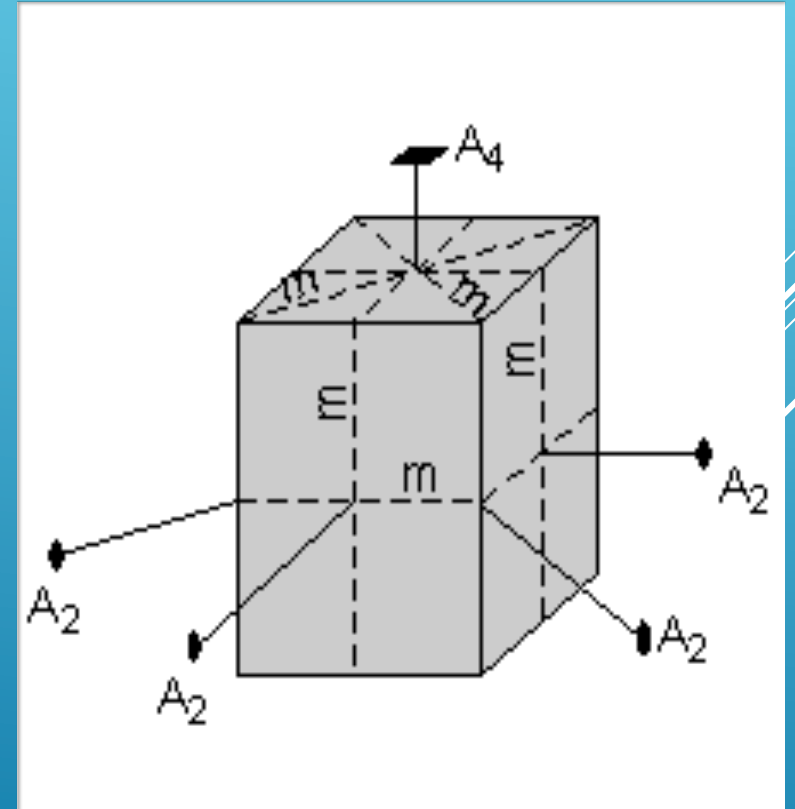
# CRYSTAL SYMMETRY

- ▶ **Square top + rectangular sides:**
  - ▶ mirror plan parallel to the 4-fold axis
  - ▶ mirror plan perpendicular to the 4-fold axis
  - ▶ One center of symmetry (not represented)



# CRYSTAL SYMMETRY

- ▶ **4-fold rotation axis:** same face every  $90^\circ$

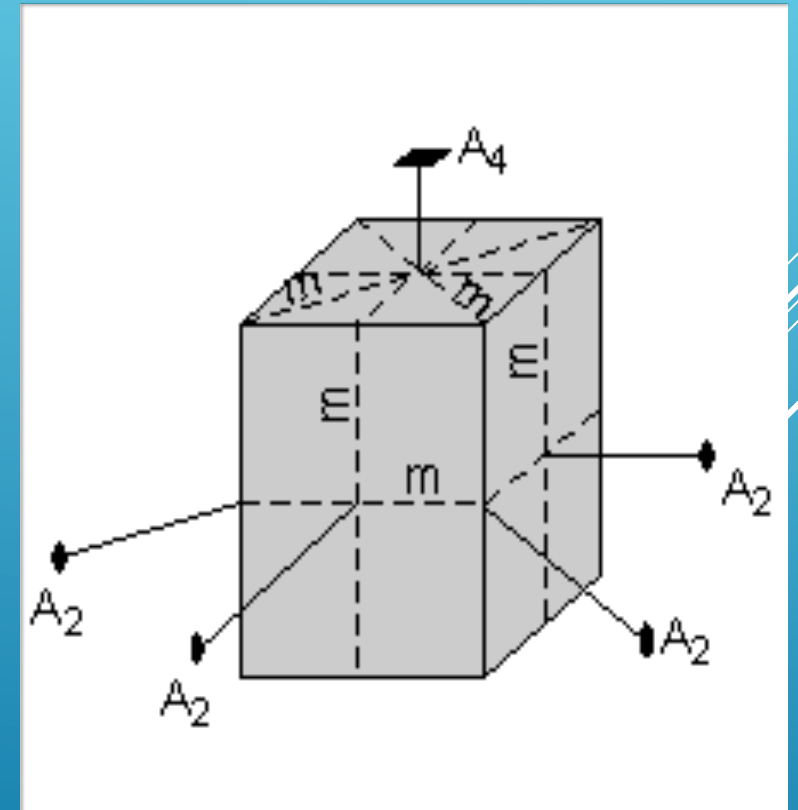


# CRYSTAL SYMMETRY

- ▶ **4-fold rotation axis:** same face every  $90^\circ$ 
  - ▶ 1 4-fold rotation axis
  - ▶ 4 2 fold rotation axes
  - ▶ 5 mirror plans
  - ▶ 1 center of symmetry

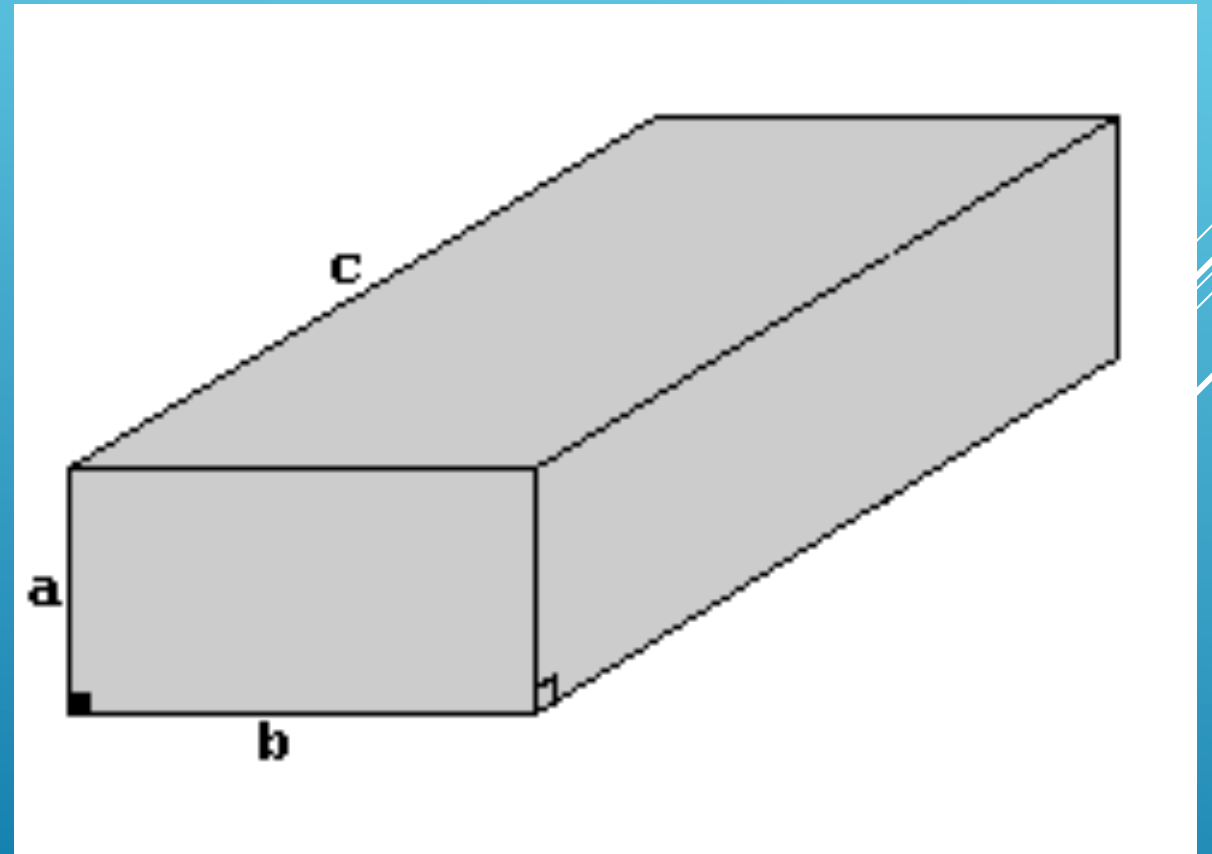
$A_4, 4A_2, 5m, i \Leftrightarrow 4/m2/m2/m$

*the ditetragonal dipyramidal class*



# HERMANN-MAUGUIN SYMBOLS

- ▶ **Hermann-Mauguin symbols** or **international symbols** are used to describe the crystal classes from the symmetry content.



# HERMANN-MAUGUIN SYMBOLS

▶ **Hermann-Mauguin symbols** or **international symbols** are used to describe the crystal classes from the symmetry content.

▶ **Rules:**

▶ **Write a number** representing **each of the unique rotation axes** present:

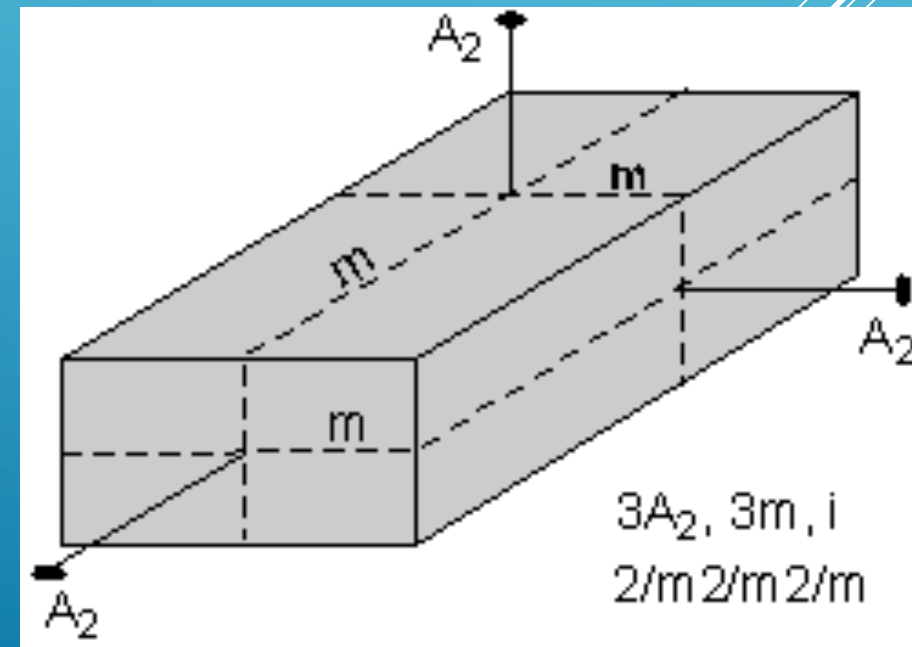
2 2 2

▶ Next we write an "m" for each unique mirror plane.

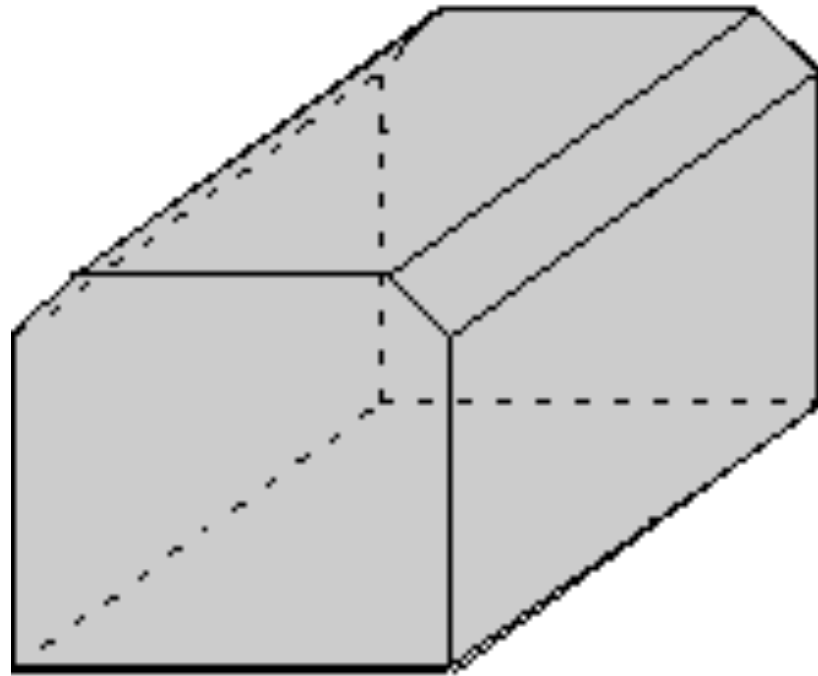
2m 2m 2m

▶ If any of the axes are perpendicular to a mirror plane we put / between the rotation axis and the mirror plane.  $2/m2/m2/m$

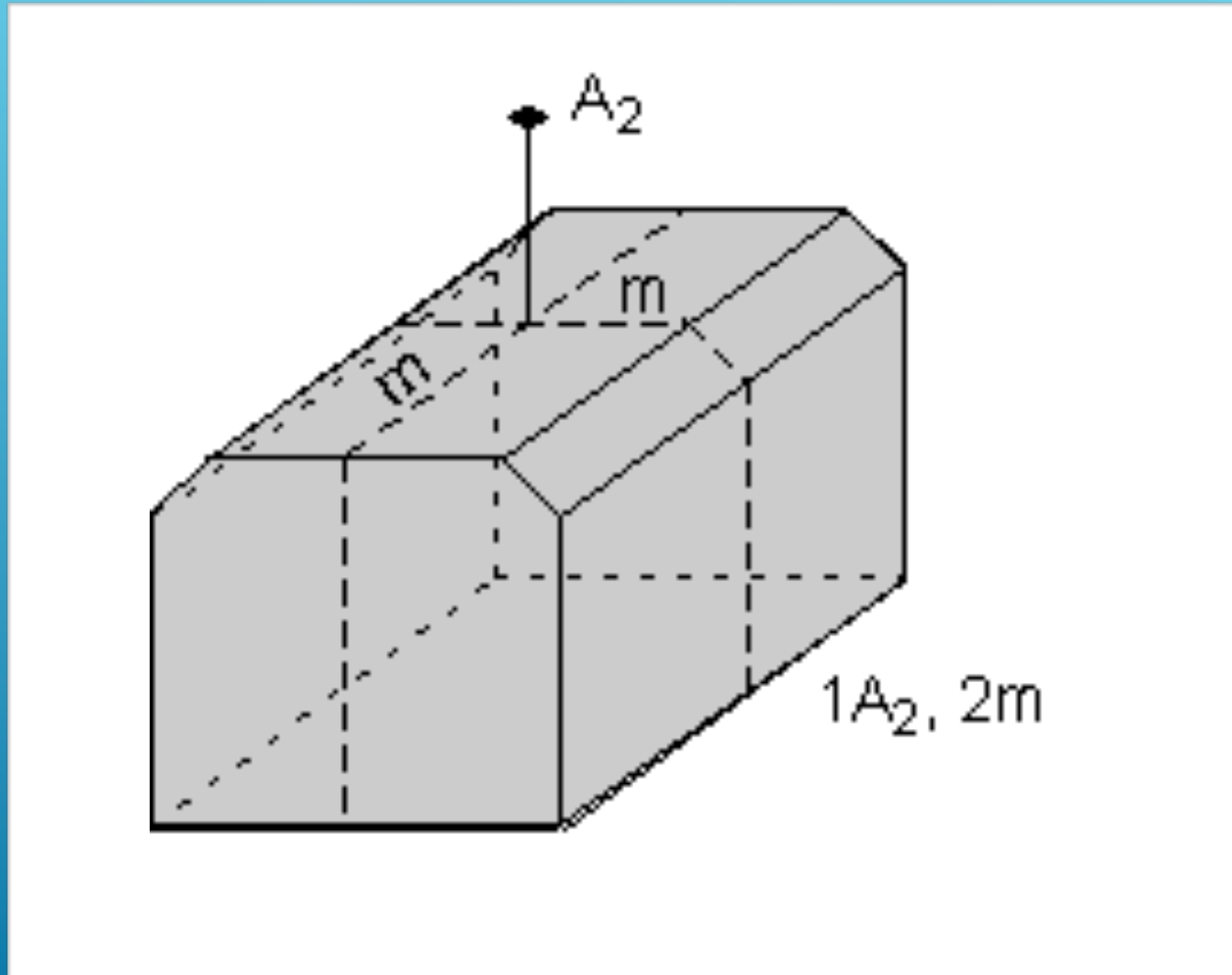
Rhombic-dipyramidal class



# HERMANN-MAUGUIN SYMBOLS



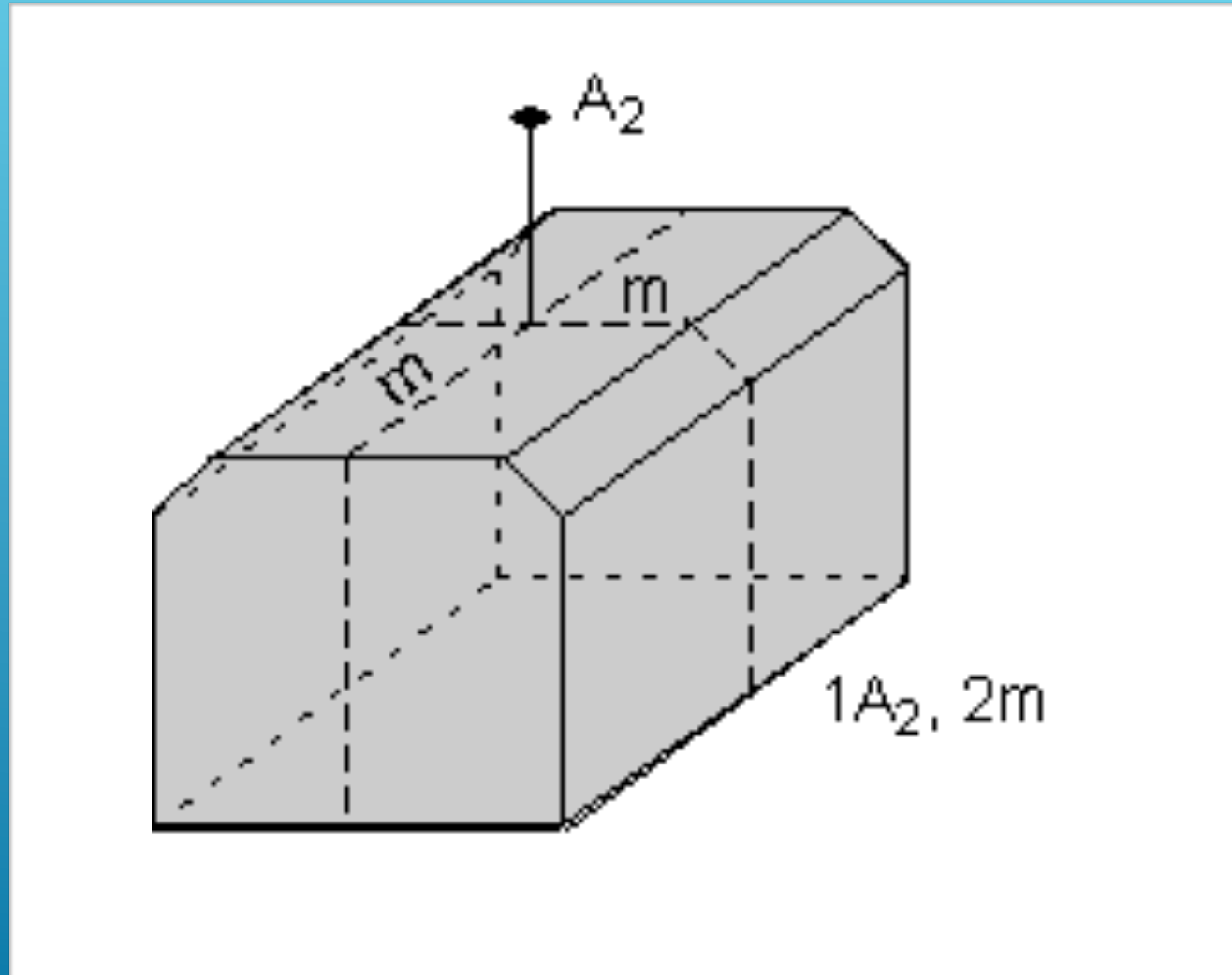
# HERMANN-MAUGUIN SYMBOLS



2mm

# HERMANN-MAUGUIN SYMBOLS

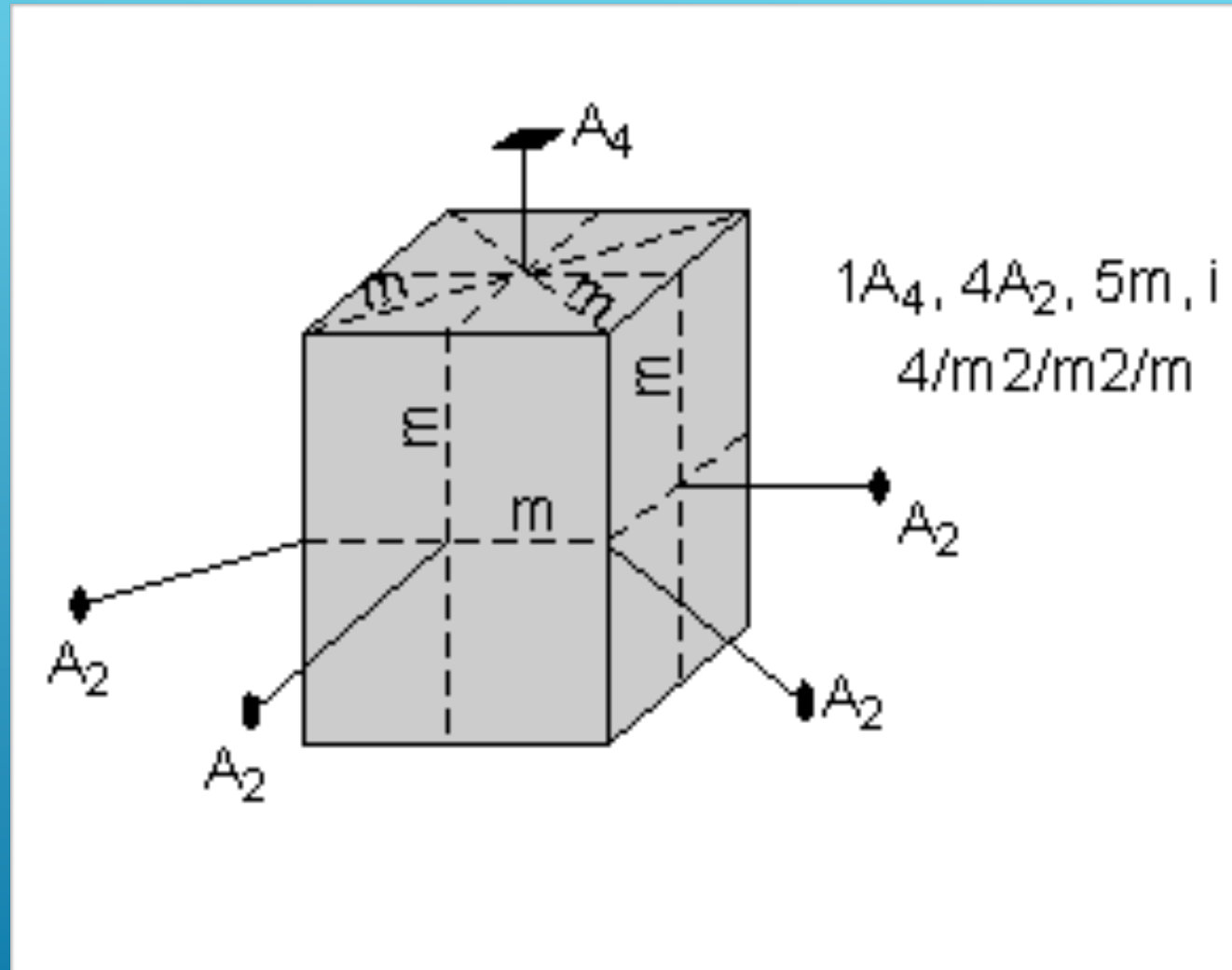
Rhombic-  
pyramidal  
class



~~$2C_4$~~   
 $mm2$

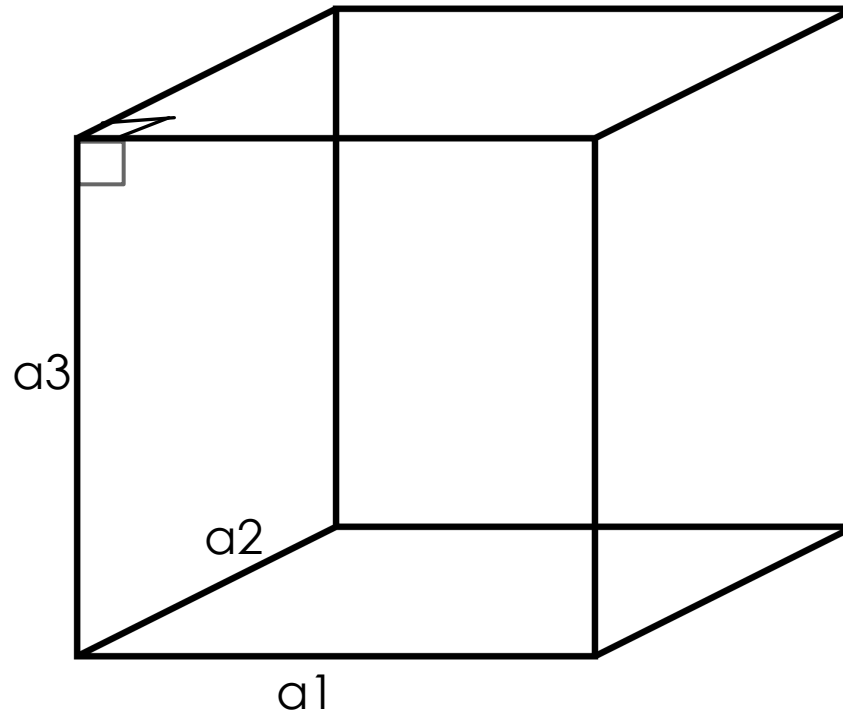
# HERMANN-MAUGUIN SYMBOLS

Ditetragonal-  
dipyramidal class



# HERMANN-MAUGUIN SYMBOLS

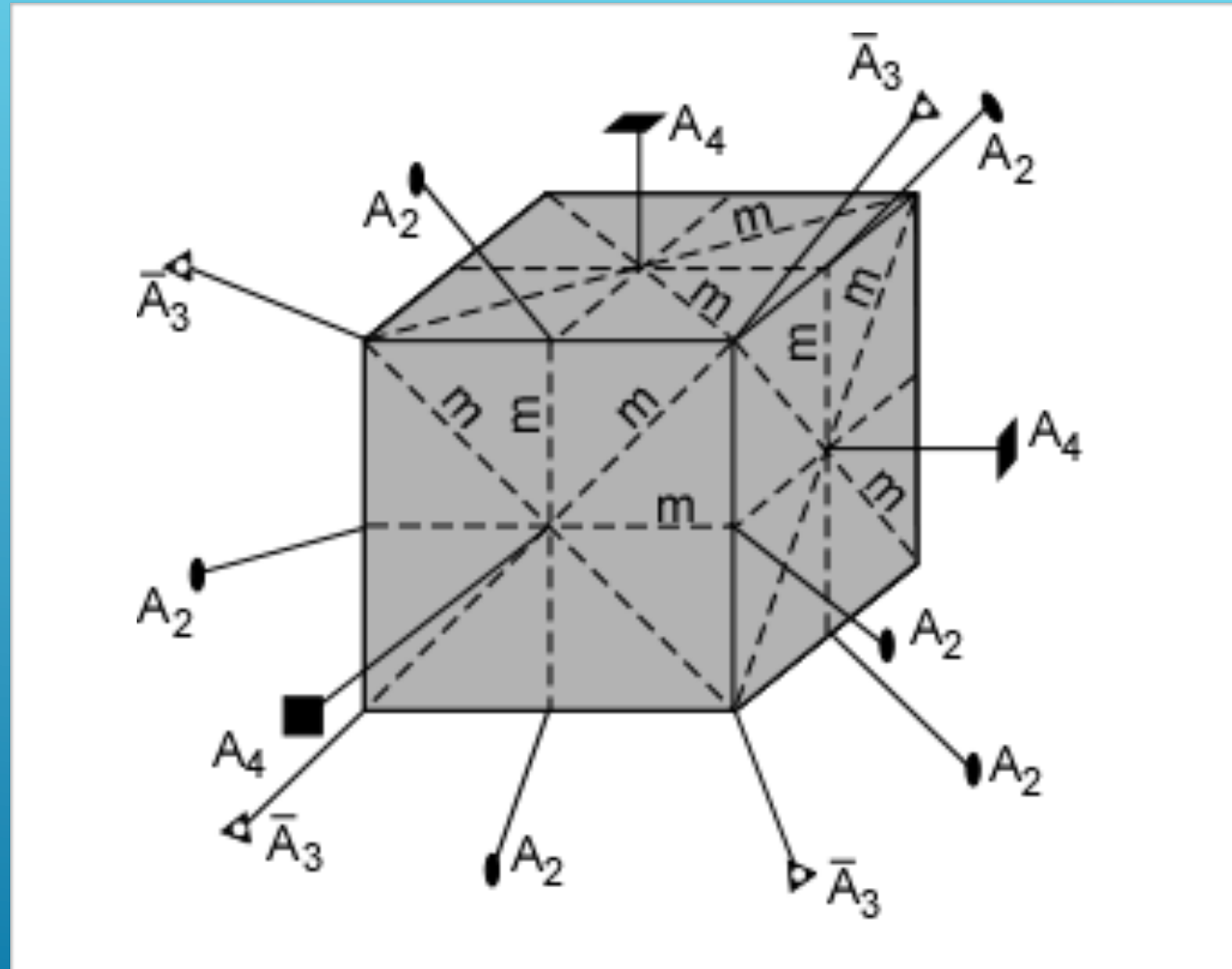
Cube



# HERMANN-MAUGUIN SYMBOLS

## ► Cube:

- 3  $A_4$
- 4  $\bar{A}_3$
- 6  $A_2$
- 9  $m$
- $i$



# HERMANN-MAUGUIN SYMBOLS

## ► Cube:

- 3  $A_4$

- 4  $\bar{A}_3$

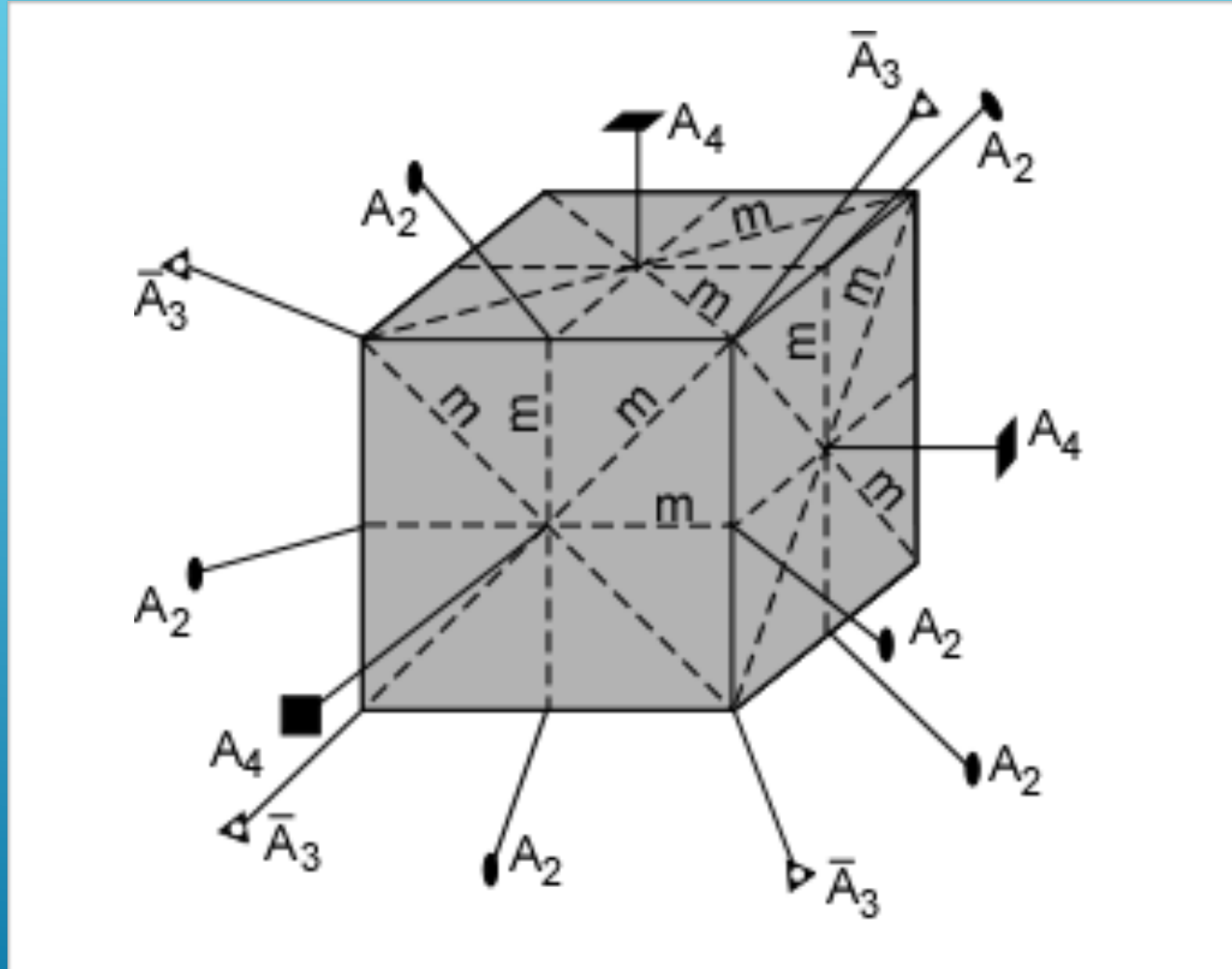
- 6  $A_2$

- 9  $m$

-  $i$

$4/m\bar{3}2/m$

hexoctahedral  
crystal class.



# THE 32 CRYSTAL CLASSES

Crystal System	Crystal Class	Symmetry	Name of Class
Triclinic	1	none	Pedial
	$\bar{1}$	i	Pinacoidal
Monoclinic	2	1A <sub>2</sub>	Sphenoidal
	m	1m	Domatic
	2/m	i, 1A <sub>2</sub> , 1m	Prismatic
Orthorhombic	222	3A <sub>2</sub>	Rhombic-disphenoidal
	mm2 (2mm)	1A <sub>2</sub> , 2m	Rhombic-pyramidal
	2/m2/m2/m	i, 3A <sub>2</sub> , 3m	Rhombic-dipyramidal
Tetragonal	4	1A <sub>4</sub>	Tetragonal-Pyramidal
	$\bar{4}$	$\bar{4}A_4$	Tetragonal-disphenoidal
	4/m	i, 1A <sub>4</sub> , 1m	Tetragonal-dipyramidal
	422	1A <sub>4</sub> , 4A <sub>2</sub>	Tetragonal-trapezohedral
	4mm	1A <sub>4</sub> , 4m	Ditetragonal-pyramidal
	$\bar{4}2m$	1 $\bar{4}A_4$ , 2A <sub>2</sub> , 2m	Tetragonal-scalenohedral
	4/m2/m2/m	i, 1A <sub>4</sub> , 4A <sub>2</sub> , 5m	Ditetragonal-dipyramidal
Hexagonal	3	1A <sub>3</sub>	Trigonal-pyramidal
	$\bar{3}$	1 $\bar{A}_3$	Rhombohedral
	32	1A <sub>3</sub> , 3A <sub>2</sub>	Trigonal-trapezohedral
	3m	1A <sub>3</sub> , 3m	Ditrigonal-pyramidal
	$\bar{3}2/m$	1 $\bar{A}_3$ , 3A <sub>2</sub> , 3m	Hexagonal-scalenohedral
	6	1A <sub>6</sub>	Hexagonal-pyramidal
	$\bar{6}$	1 $\bar{A}_6$	Trigonal-dipyramidal
	6/m	i, 1A <sub>6</sub> , 1m	Hexagonal-dipyramidal
	622	1A <sub>6</sub> , 6A <sub>2</sub>	Hexagonal-trapezohedral
	6mm	1A <sub>6</sub> , 6m	Dihexagonal-pyramidal
	$\bar{6}m2$	1 $\bar{A}_6$ , 3A <sub>2</sub> , 3m	Ditrigonal-dipyramidal
6/m2/m2/m	i, 1A <sub>6</sub> , 6A <sub>2</sub> , 7m	Dihexagonal-dipyramidal	
Isometric	23	3A <sub>2</sub> , 4A <sub>3</sub>	Tetaroidal
	2/m $\bar{3}$	3A <sub>2</sub> , 3m, 4 $\bar{A}_3$	Diploidal
	432	3A <sub>4</sub> , 4A <sub>3</sub> , 6A <sub>2</sub>	Gyroidal
	$\bar{4}3m$	3 $\bar{A}_4$ , 4A <sub>3</sub> , 6m	Hextetrahedral
	4/m $\bar{3}2/m$	3A <sub>4</sub> , 4 $\bar{A}_3$ , 6A <sub>2</sub> , 9m	Hexoctahedral

# RECAP

## ▶ 32 crystal classes in 6 (or 7) crystal systems:

- ▶ Isometric syst.: Four  $A_3$  or four  $\overline{A}_3$
- ▶ Tetragonal syst.: One  $A_4$  or  $\overline{A}_4$
- ▶ Orthorhombic syst.: several  $A_2$ , or at least one  $A_2$  and two  $m$
- ▶ Hexagonal syst.:
  - ▶ Trigonal: One  $A_3$  or  $\overline{A}_3$
  - ▶ Hexagonal: One  $A_6$  or  $\overline{A}_6$
- ▶ Monoclinic syst.: one  $A_2$ , one  $m$ , or both
- ▶ Triclinic syst.:  $A_1$  or  $\overline{A}_1$

### CUBIC

$$a = b = c$$
$$\alpha = \beta = \gamma = 90^\circ$$

### TETRAGONAL

$$a = b \neq c$$
$$\alpha = \beta = \gamma = 90^\circ$$

### ORTHORHOMBIC

$$a \neq b \neq c$$
$$\alpha = \beta = \gamma = 90^\circ$$

### HEXAGONAL

$$a = b \neq c$$
$$\alpha = \beta = 90^\circ$$
$$\gamma = 120^\circ$$

### MONOCLINIC

$$a \neq b \neq c$$
$$\alpha = \gamma = 90^\circ$$
$$\beta \neq 120^\circ$$

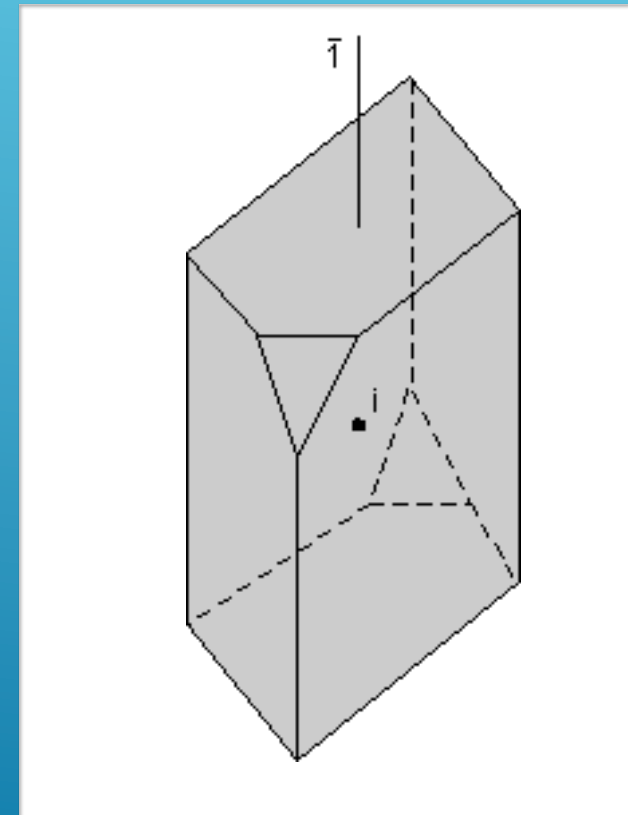
### TRICLINIC

$$a \neq b \neq c$$
$$\alpha \neq \beta \neq \gamma \neq 90^\circ$$

# TRICLINIC SYSTEM

$A_1$  or  $\bar{A}_1$

- ▶ **Pedial class: 1** (*54 minerals*)
  - ▶ No symmetry
  - ▶ Ex.: Kaolinite, Kristiansenite, Welshite
- ▶ **Pinacoidal class:  $\bar{1}$**  (*317 minerals*)
  - ▶ i
  - ▶ Ex.: microcline (K-feldspar), plagioclase, turquoise, wollastonite.



# MONOCLINIC SYSTEM

**m or  $A_2$**

## ▶ Sphenoidal class: 2

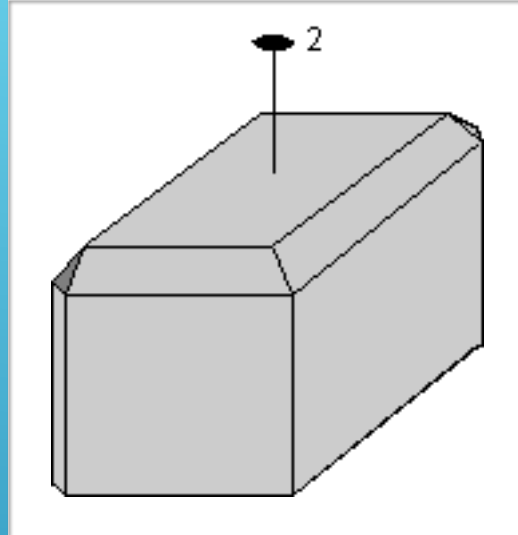
- ▶  $A_2$
- ▶ Ex.: Karpovite, Amicite

*(81 minerals)*

## ▶ Domatic class: m

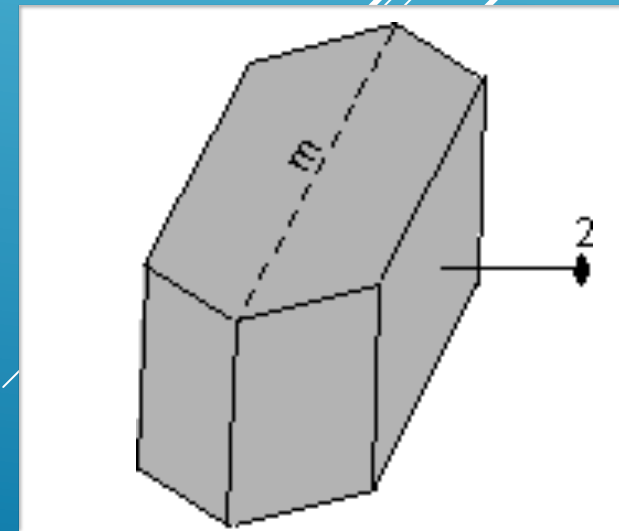
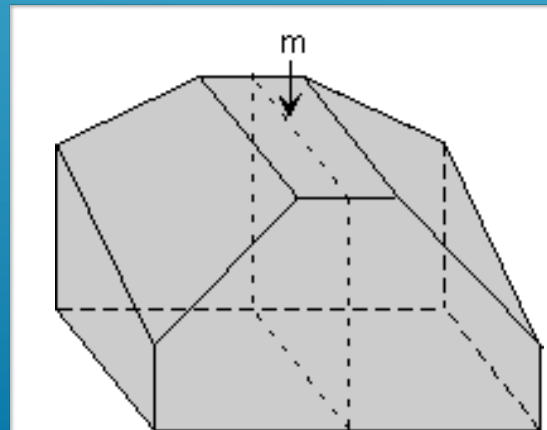
- ▶ m
- ▶ Ex.: Liberite, Neptunite, Dickite

*(86 minerals)*



## ▶ Prismatic class: 2/m *(1281 minerals)*

- ▶  $1A_2, m, i$
- ▶ Ex.: biotite, muscovite, azurite, chlorite, clinopyroxenes, epidote, gypsum, malachite, kaolinite, orthoclase, talc.



# ORTHORHOMBIC SYSTEM

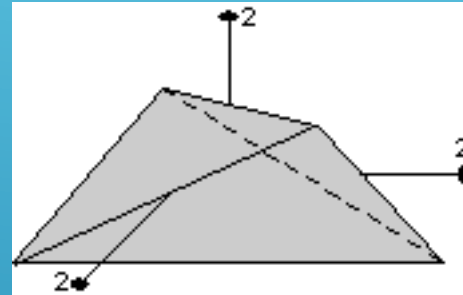
two fold axes or a 2-fold axis and 2 mirror planes

## ▶ Rhombic-disphenoidal class: $222$

▶  $3A_2$

▶ Ex.: Epsomite

*(88 minerals)*



## ▶ Dipyramidal class: $2/m2/m2/m$

▶  $3A_2, 3m, i$

▶ Ex.: andalusite, anthophyllite, aragonite, barite, cordierite, olivine, sillimanite, stibnite, sulfur, and topaz.

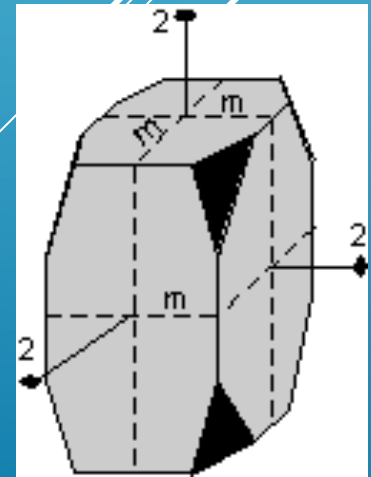
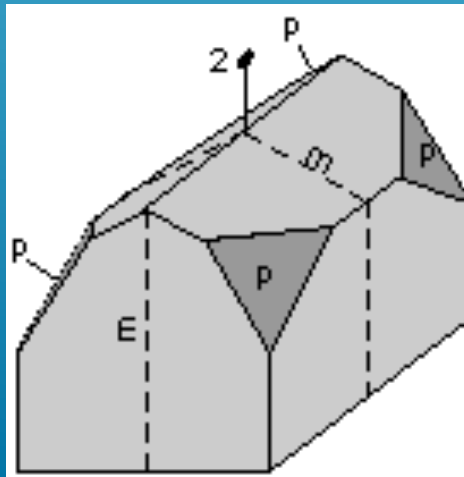
*(577 minerals)*

## ▶ Pyramidal class: $mm2$

▶  $1A_2, 2m$

▶ Ex.: Bismutite, pentagonite

*(133 minerals)*

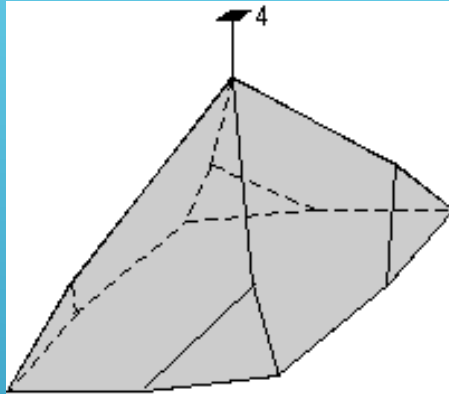


# TETRAGONAL SYSTEM (1)

$A_4$  or  $\overline{A_4}$

## ▶ Tetragonal-pyramidal class: 4

- ▶  $1A_4$
- ▶ Ex.: Wulfenite

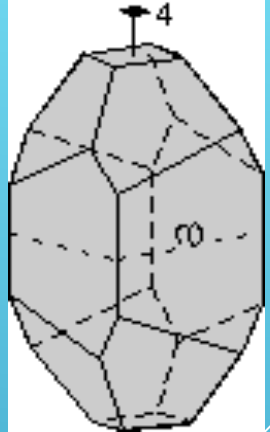


*(5 minerals)*

## ▶ Dipyramidal class: 4/m

- ▶  $1A_4, 1m, i$
- ▶ Scheelite and scapolite

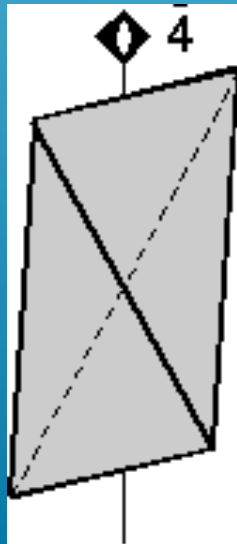
*(171 minerals)*



## ▶ Tetragonal-disphenoidal : $\overline{4}$

- ▶  $1\overline{A_4}$
- ▶ Ex.: Crookesite, Meliphanite

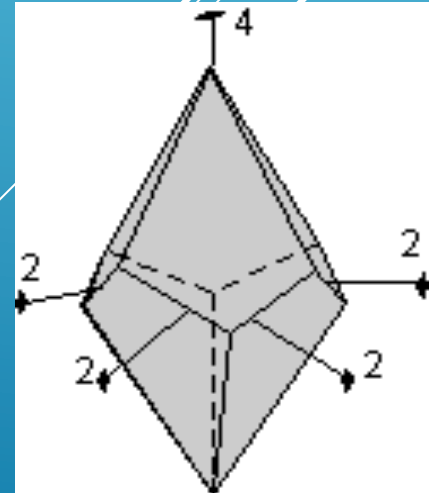
*(9 minerals)*



## ▶ Trapezohedral class: 422

- ▶  $1A_4, 4A_2$
- ▶ Ex. :Mellite, Cristobalite

*(23 minerals)*

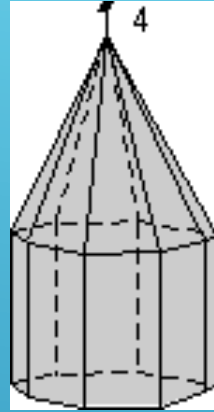


$A_4$  or  $\overline{A_4}$

## TETRAGONAL SYSTEM (2)

### ▶ Ditetragonal-pyramidal class: $4mm$

- ▶  $1A_4, 4m$
- ▶ Adranosite  
(15 minerals)



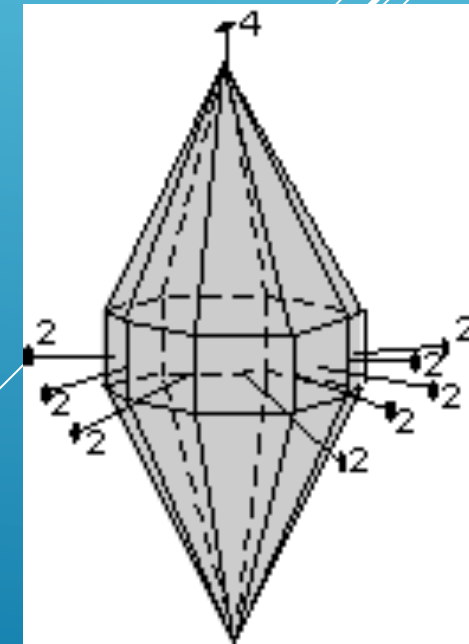
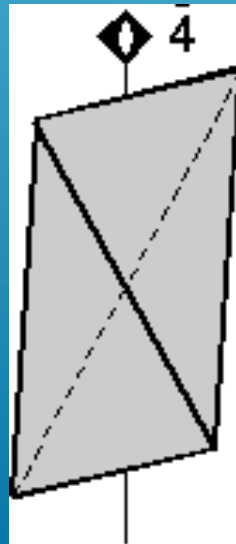
### ▶ Ditetragonal-dipyramidal class: $4/m2/m2/m$

- ▶  $1A_4, 4A_2, 5m, i$
- ▶ Ex.: anatase, cassiterite, apophyllite, zircon, and vesuvianite.

(171 minerals)

### ▶ Scalenohedral class: $\overline{4}2m$

- ▶  $1\overline{A_4}, 2A_2, 2m$
- ▶ Chalcopyrite, stannite  
(39 minerals)



# HEXAGONAL SYSTEM

$A_6$  or  $A_3$

- ▶ **Trigonal-pyramidal, 3:**  $1A_3$  (Simpsonite) (40)
- ▶ **Rhombohedral,  $\bar{3}$ :**  $1\bar{A}_3$  (Illmenite) (79)
- ▶ **Trigonal-trapezohedral, 32:**  $1A_3, 3A_2$  (Quartz) (36)
- ▶ **Ditrigonal-pyramidal, 3m:**  $1A_3, 3m$  (Feruvite) (112)
- ▶ **Hexagonal-scalenohedral,  $\bar{3}2/m$ :**  $1\bar{A}_3, 3A_2, 3m$  (Calcite) (208)
- ▶ **Hexagonal-pyramidal, 6:**  $1A_6$  (Nepheline) (28)
- ▶ **Trigonal-dipyramidal,  $\bar{6}$ :**  $1\bar{A}_6$  (Cesanite) (3)
- ▶ **Hexagonal-dipyramidal, 6/m:**  $1A_6, 1m, 1$  (Apatite) (62)
- ▶ **Hexagonal-trapezohedral, 622:**  $1A_6, 6A_2$  (Tristamite) (26)
- ▶ **Dihexagonal-pyramidal, 6mm:**  $1A_6, 6m$  (Demartinite) (34)
- ▶ **Ditrigonal-dipyramidal,  $\bar{6}m2$ :**  $1\bar{A}_6, 3A_2, 3m$  (Bazirite) (25)
- ▶ **Dihexagonal-dipyramidal, 6/m2/m2/m:**  $1A_6, 6A_2, 7m, i$  (Ice) (134)

# ISOMETRIC SYSTEM

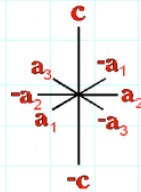
$4A_3$  or  $4\bar{A}_3$

- ▶ **Tetaroidal, 23:**  $3A_2$ ,  $4A_3$  (Melliniite) (25)
- ▶ **Diploidal,  $2/m\bar{3}$ :**  $3A_2$ ,  $3m$ ,  $4\bar{A}_3$  (Pyrite) (59)
- ▶ **Gyroidal, 432:**  $3A_4$ ,  $4A_3$ ,  $6A_2$  (Petzite) (4)
- ▶ **Hextetrahedral,  $\bar{4}3m$ :**  $3\bar{A}_4$ ,  $4A_3$ ,  $6m$  (Hauyne) (66)
- ▶ **Hexoctahedral,  $4/m\bar{3}2/m$ :**  $3A_4$ ,  $4\bar{A}_3$ ,  $6A_2$ ,  $9m$  (Diamond) (244)

### Trigonal Pyramidal Class

- Navigation**
- Home
  - Amorphous
  - Isometric
    - Diploidal
    - Gyroidal
    - Hexoctahedral
    - Hextetrahedral
    - Tetartoidal
  - Tetragonal
    - Dipyramidal
    - Disphenoidal
    - Ditetragonal Dipyramidal
    - Ditetragonal

**Axial Configuration**



**Paper Model**



Click on image to view or print the PDF file. Go to Help file for more information

**Trigonal - Pyramidal Class (3) [Mineral Species Listing](#)**

System	Class Name	AXES				Planes	Center	Hermann-Maugin Symbols
		2-Fold	3-Fold	4-Fold	6-Fold			
Trigonal	Pyramidal	-	1	-	-	-	-	3

- Sphenoidal
- Triclinic
  - Pedial
  - Pinacoidal

**40 Minerals From the H-M Class Trigonal - Pyramidal (3)**

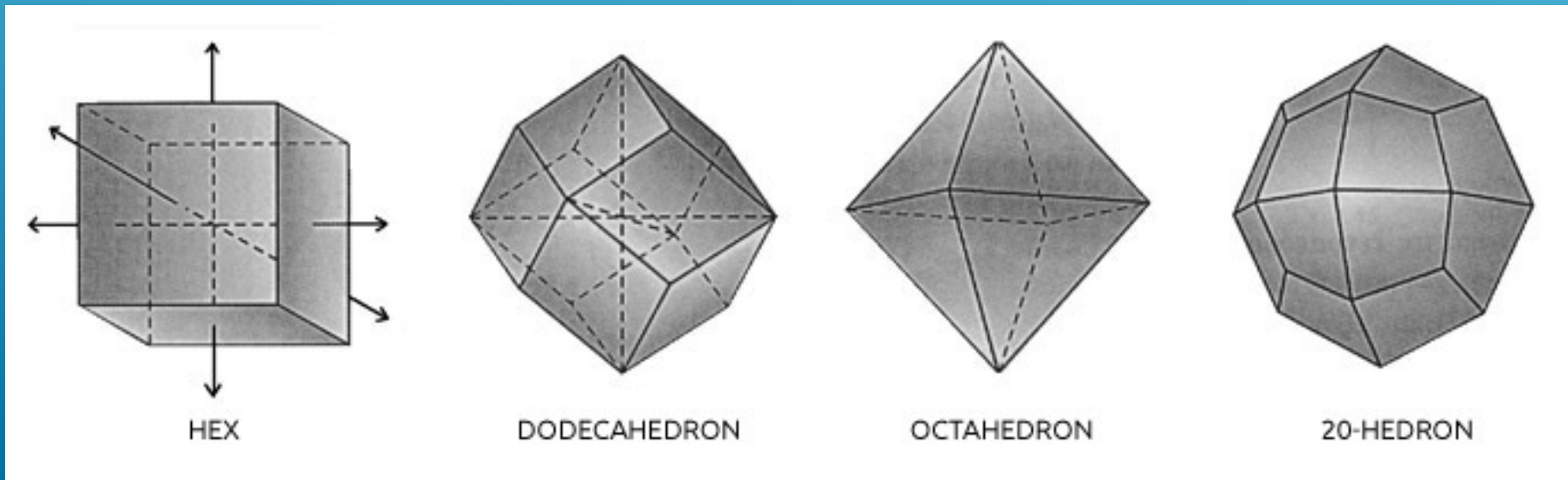
Mineral	Space Grp	a	c	Z	Vol (Ang3)	Calc Dens
<a href="#">Aktashite</a>	R 3	13.7200	9.3200	3	1519.3	5.47
<a href="#">Averievite</a>	P 3	6.3750	8.3990	1	295.6	4.01
<a href="#">Bechererite</a>	P 3	8.3220	7.3760	1	442.4	3.50
<a href="#">Belovite-(Ce)</a>	P 3	9.6920	7.2010	2	585.8	4.23
<a href="#">Benstonite</a>	R 3	18.2800	8.6700	3	2509.0	3.61
<a href="#">Biachellaite</a>	P 3	12.9130	79.6050	16	11495.4	2.71
<a href="#">Bottinoite</a>	P 3	16.0450	9.7840	6	2181.4	2.81
<a href="#">Brandholzite</a>	P 3	16.1140	9.8630	6	2217.9	4.62
<a href="#">Cappelenite-(Y)</a>	P 3	10.6700	4.6800	1	461.4	4.84
<a href="#">Carlinite</a>	R 3	12.1200	18.1750	27	2312.1	8.55
<a href="#">Deloneite-(Ce)</a>	P 3	9.5100	7.0100	2	549.1	3.84
<a href="#">Diversilite-(Ce)</a>	R 32	10.7080	60.0730	6	5965.2	3.80
<a href="#">Dixenite</a>	R 3	8.2330	37.4900	3	2200.7	4.36

# PART 2: CRYSTAL FORMS AND MILLER INDICES

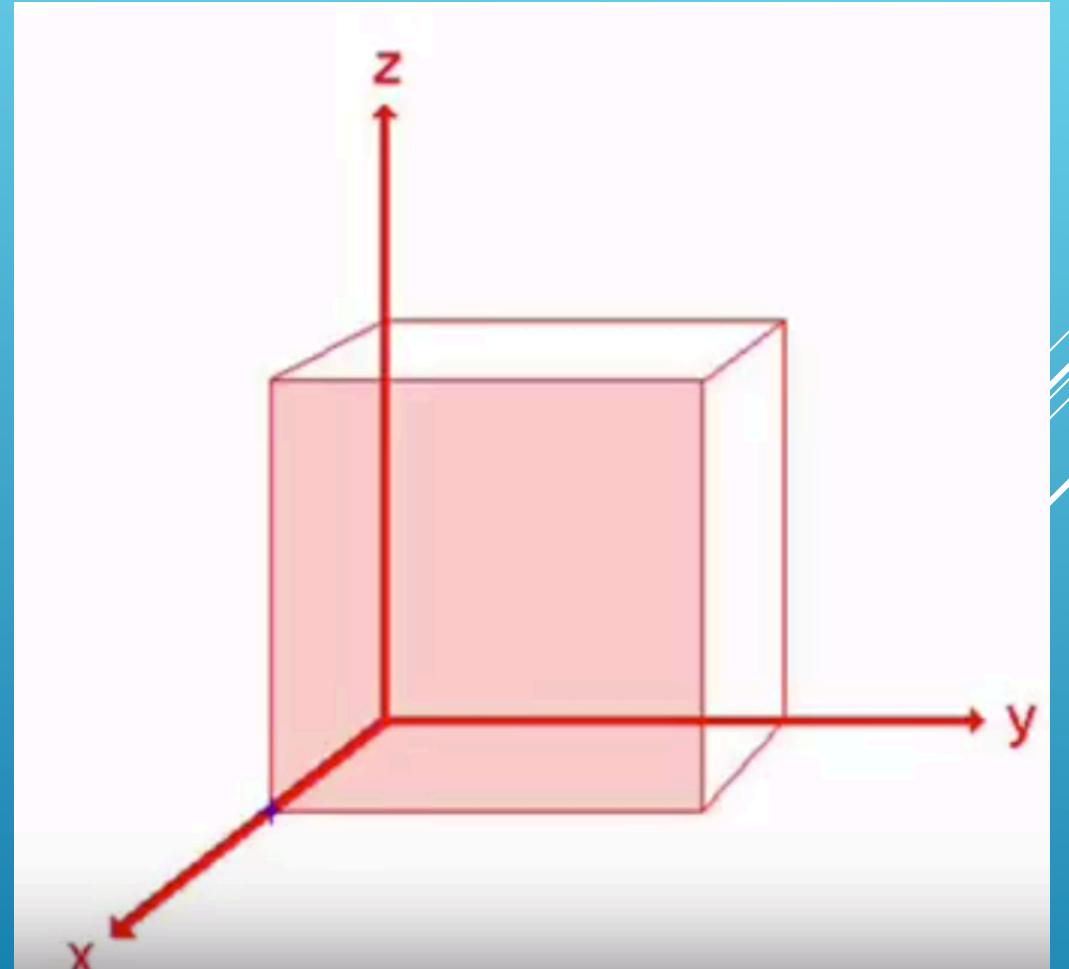
The background is a blue gradient, transitioning from a lighter blue at the top to a darker blue at the bottom. On the right side, there are several white, parallel lines that appear to be part of a larger graphic element, possibly representing crystal planes or a stylized arrow pointing towards the top right.

# MILLER INDICES

- ▶ Miller indices will allow us to label crystal faces via a **coordinate system** on each of those faces
- ▶ It's a fairly simple system once we understand how it works.
- ▶ You can actually identify symmetries of the crystals by looking at the label of each face of the crystal.

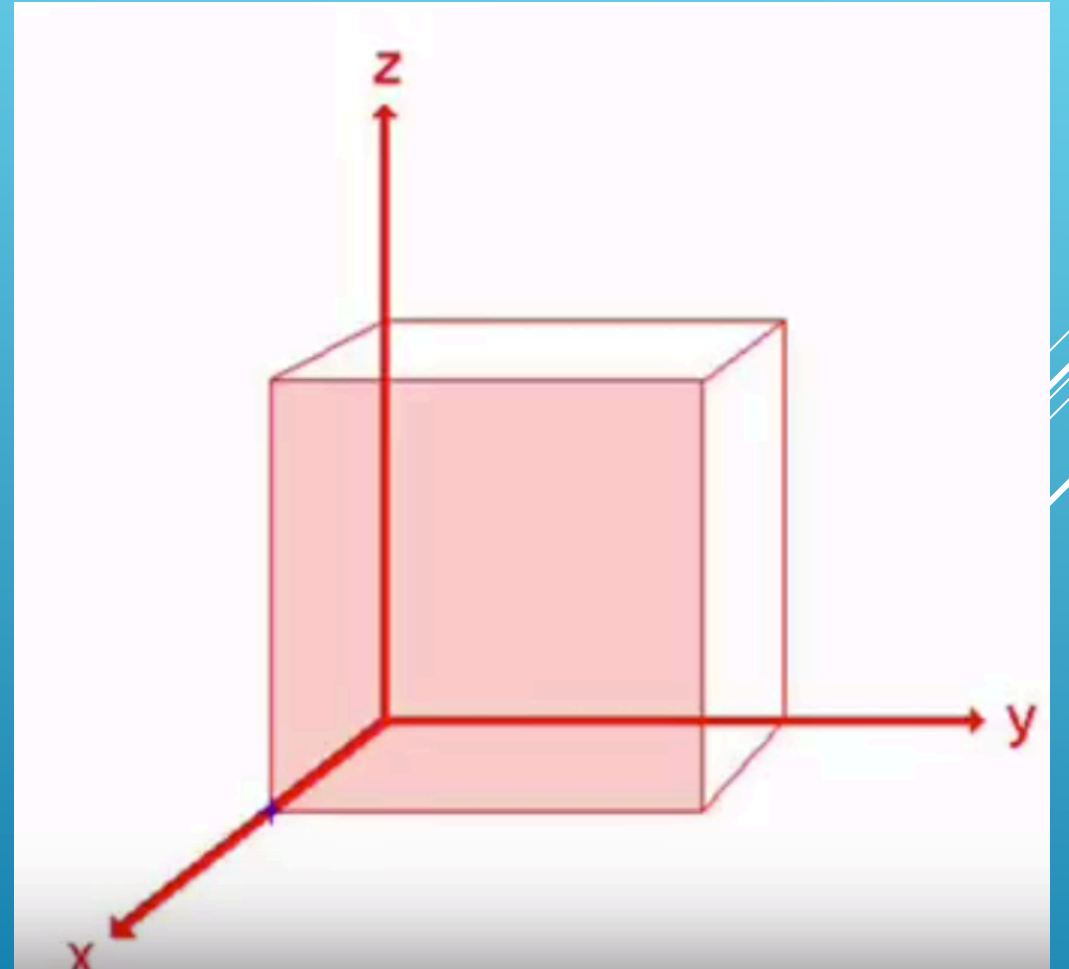


# MILLER INDICES



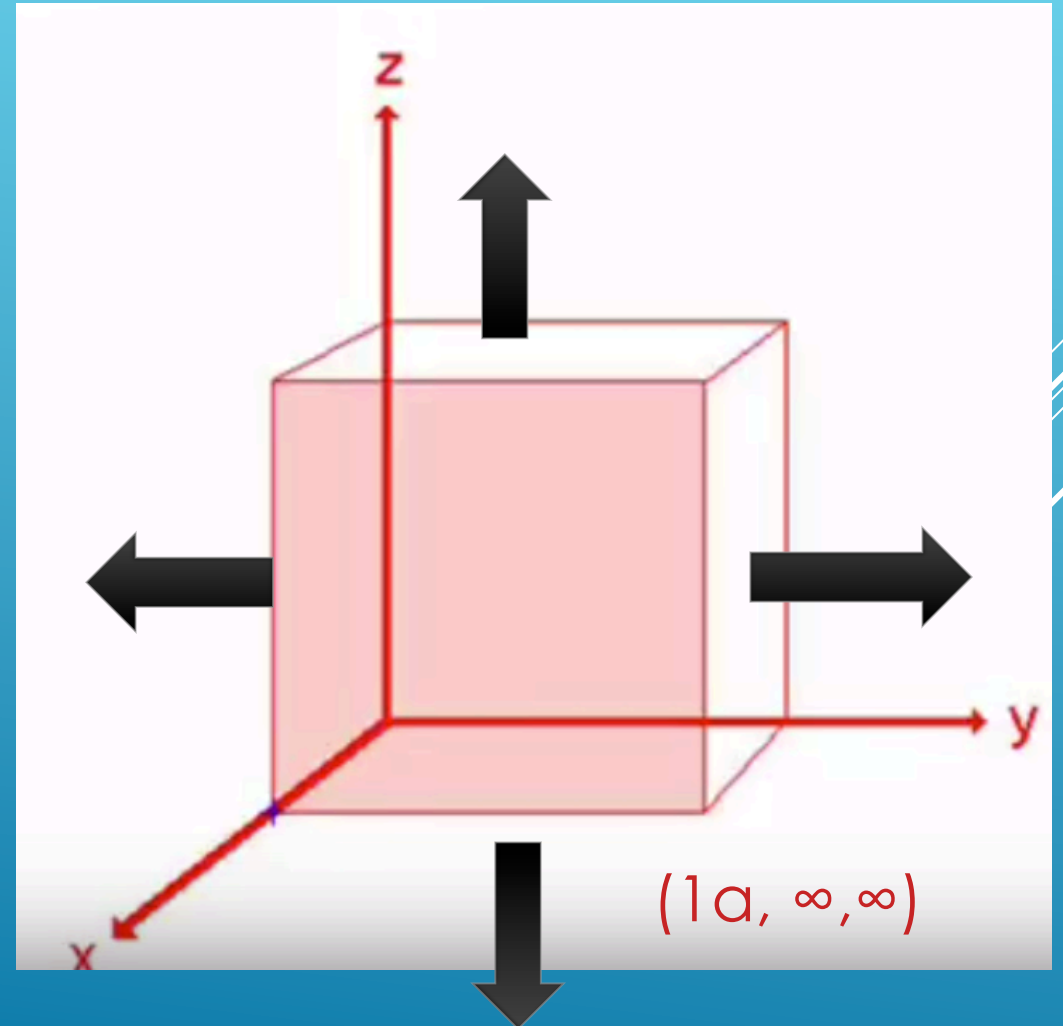
# MILLER INDICES

- ▶ Cube:  $a = b = c$ ,  $\alpha = \beta = \gamma = 90^\circ$
- ▶ Consider the red plan



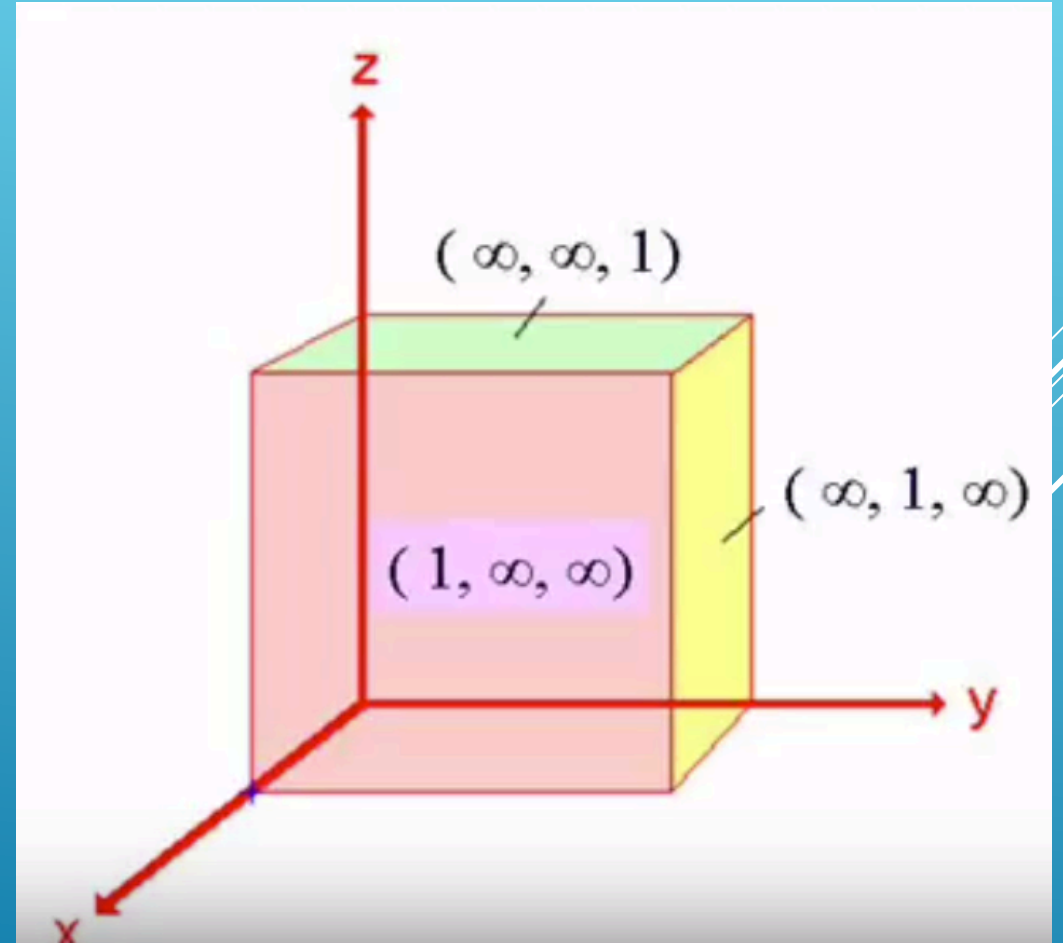
# MILLER INDICES

- ▶ In the x direction, the pink plan terminates at point  $1a$  and continues indefinitely in the y and z directions



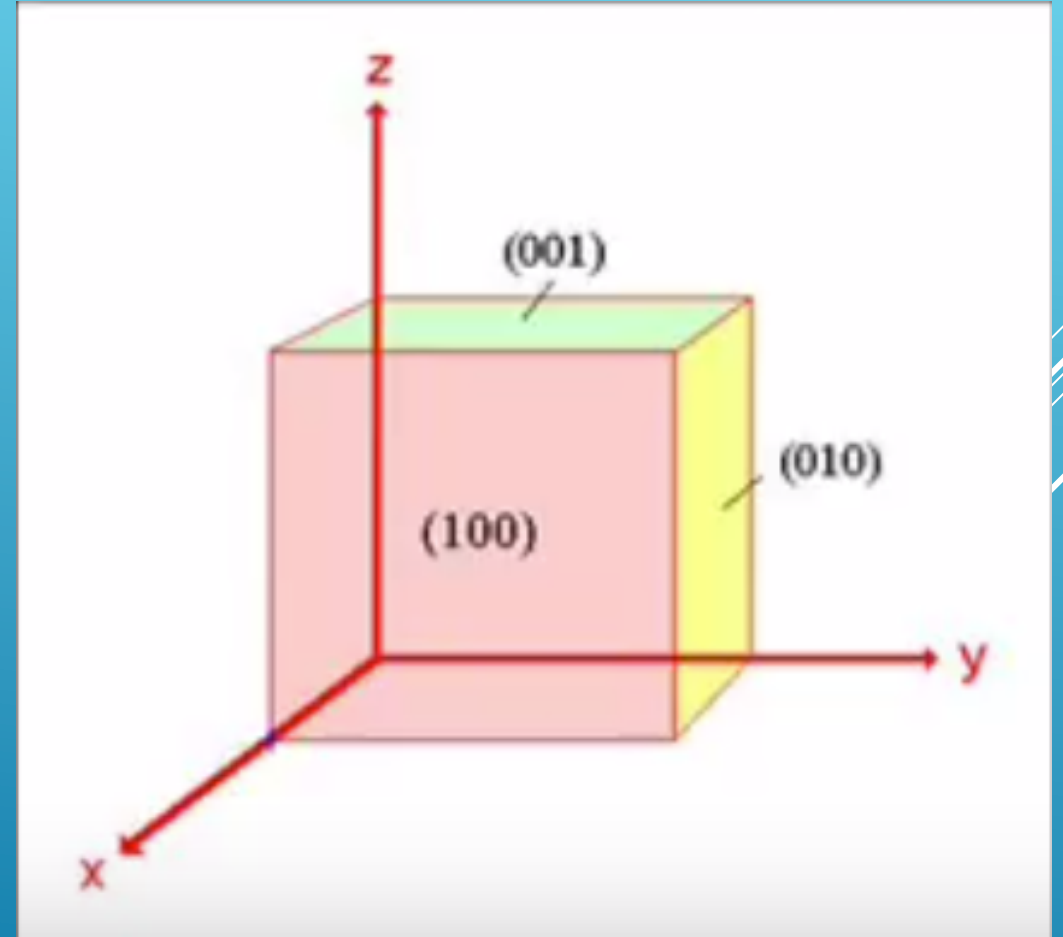
# MILLER INDICES

- ▶ In the x direction, the pink plan terminates at point 1a and continues indefinitely in the y and z directions



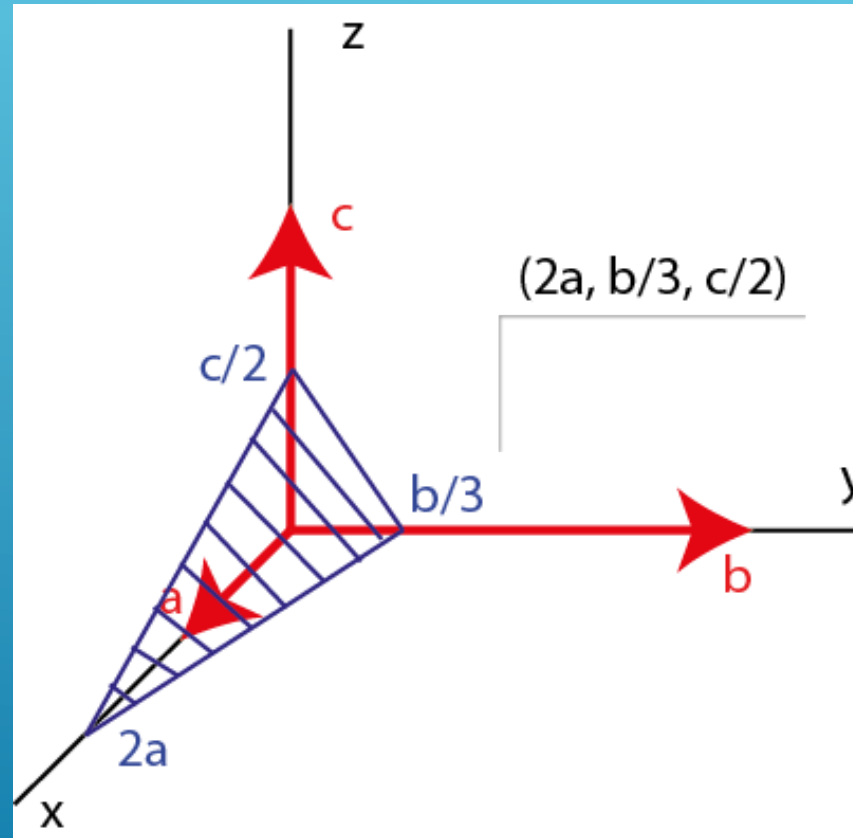
# MILLER INDICES

- ▶ By convention, Miller indices are reciprocal of the parameters of each crystal face.
- ▶ Pink face:  $(1/1, 1/\infty, 1/\infty) = (1\ 0\ 0)$
- ▶ Yellow face:  $(1/\infty, 1/1, 1/\infty) = (0\ 1\ 0)$
- ▶ Green face:  $(1/\infty, 1/\infty, 1/1) = (0\ 0\ 1)$
- ▶ Miller indices: in parentheses, no fractions



# MILLER INDICES

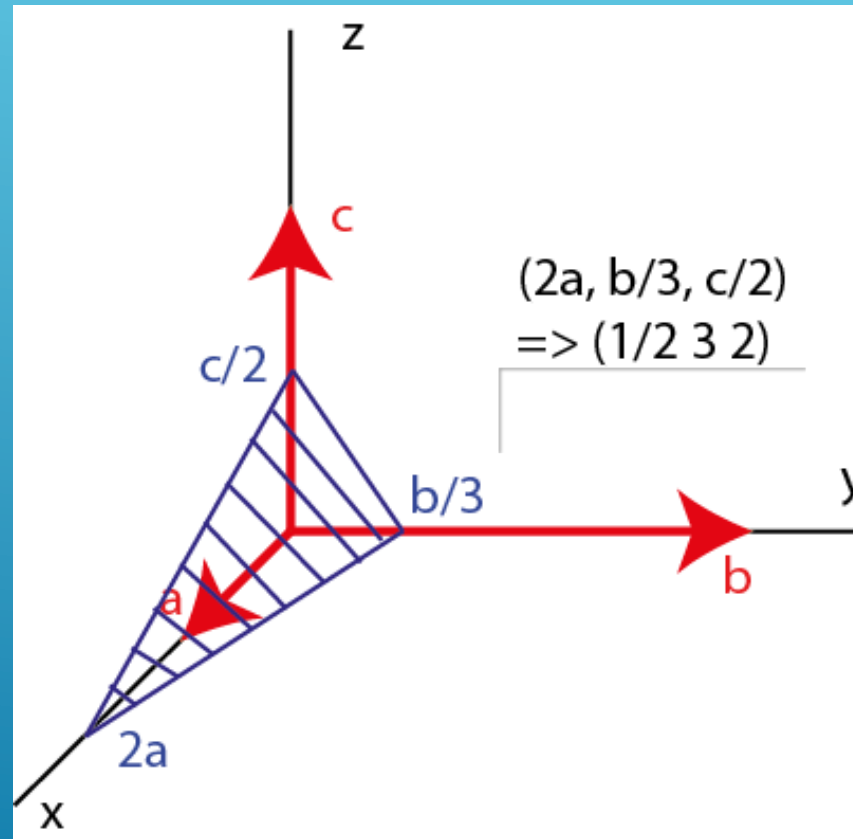
- ▶ By convention, Miller indices are reciprocal of the parameters of each crystal face.



- ▶ Miller indices: in parentheses, no fractions

# MILLER INDICES

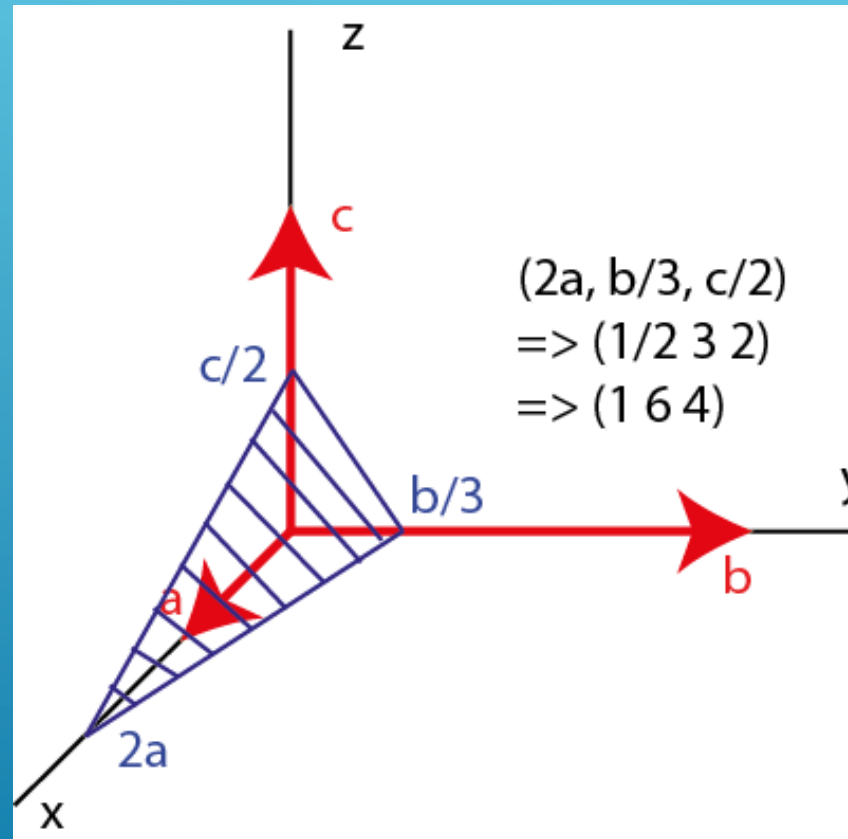
- ▶ By convention, Miller indices are reciprocal of the parameters of each crystal face.



- ▶ Miller indices: in parentheses, no fractions

# MILLER INDICES

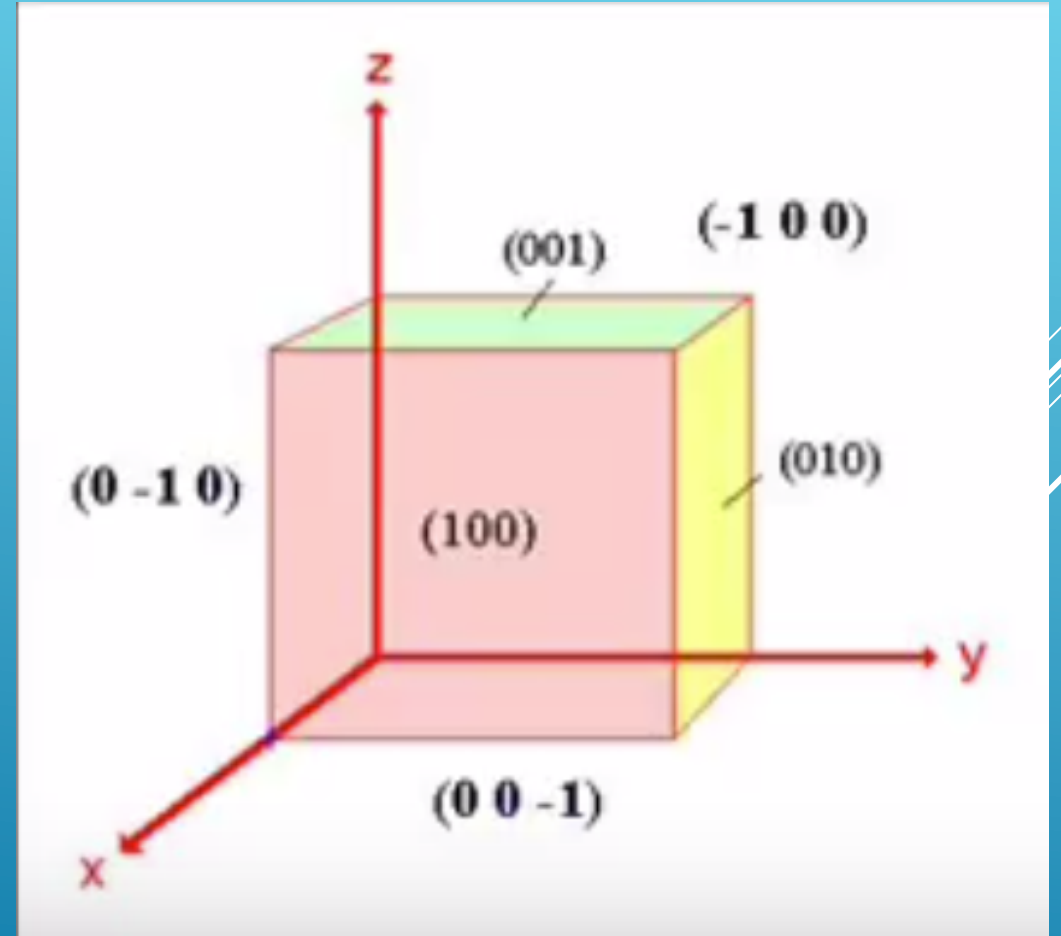
- ▶ By convention, Miller indices are reciprocal of the parameters of each crystal face.



- ▶ Miller indices: in parentheses, no fractions

# MILLER INDICES

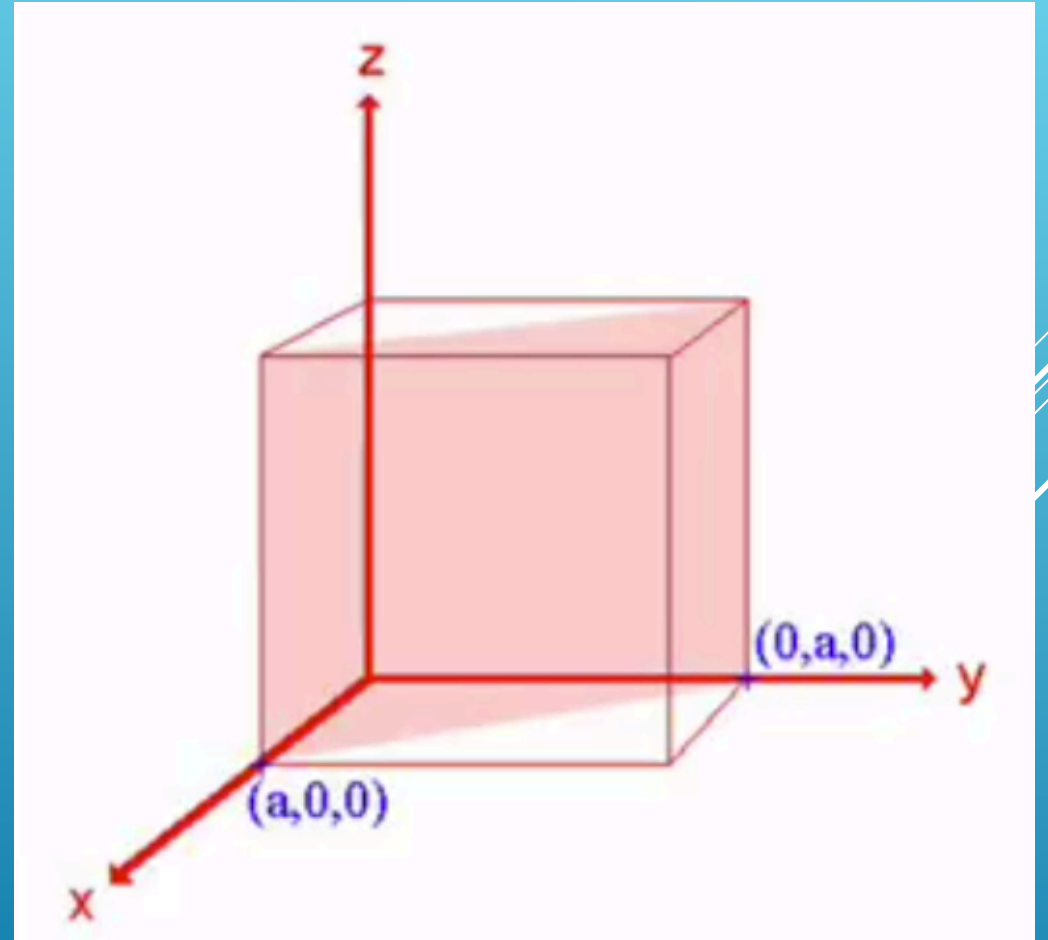
The opposite sides of each face are designed with negative signs



# MILLER INDICES

The plan of interest cuts two of the crystallographic axes.

Miller indices ?

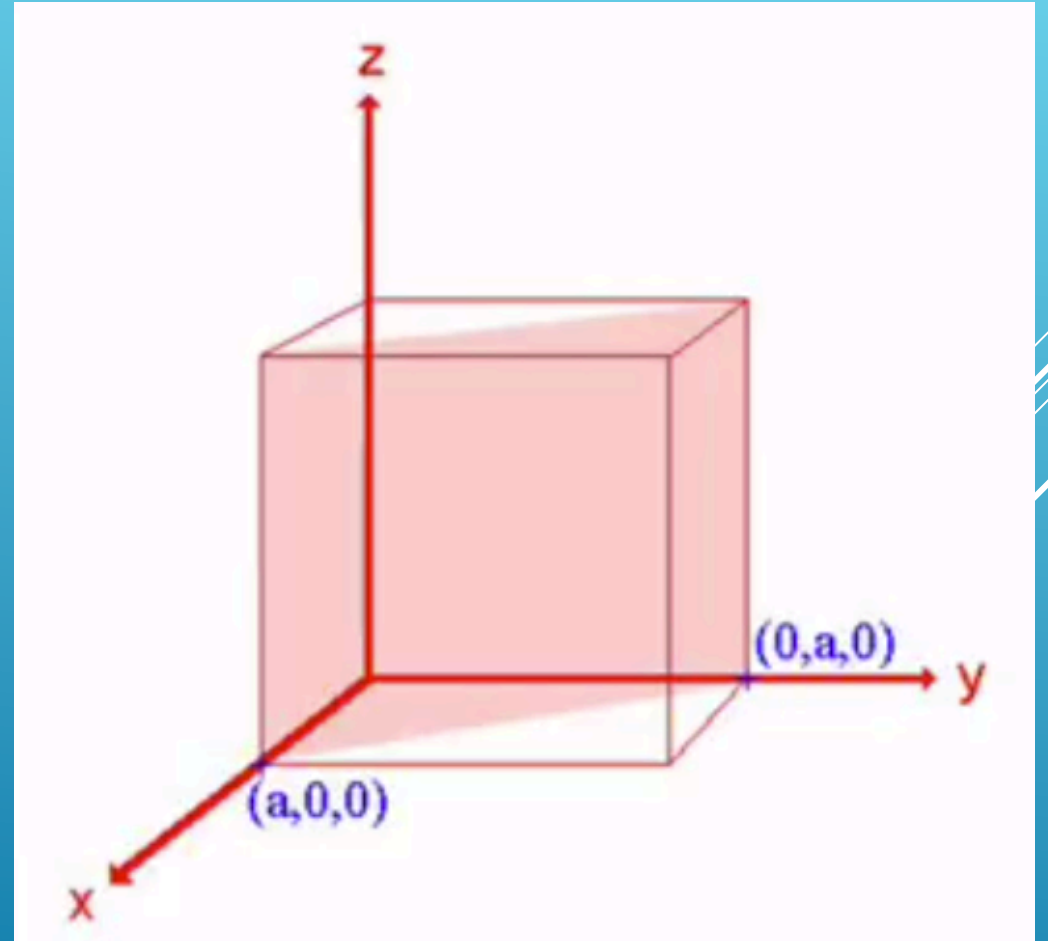


# MILLER INDICES

The plan of interest cuts two of the crystallographic axes.

Miller indices ?

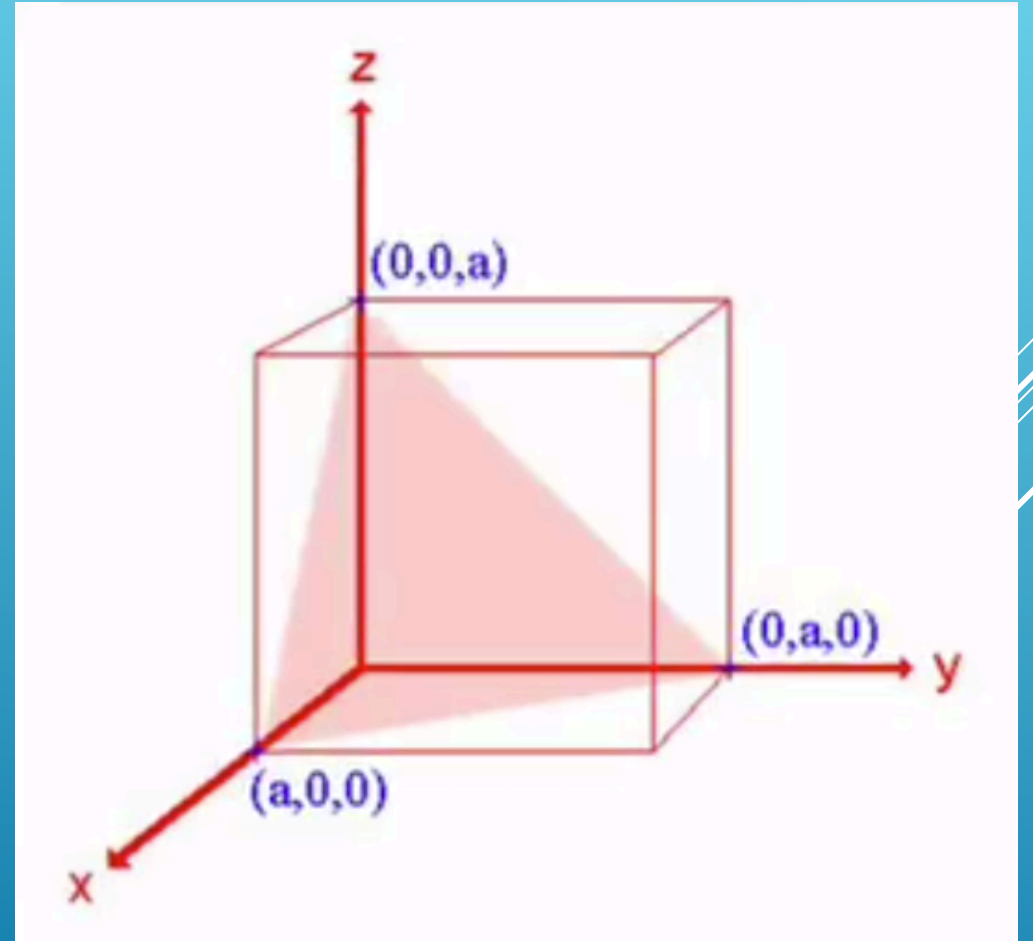
(110)



# MILLER INDICES

The plan of interest cuts the three crystallographic axes.

Miller indices ?

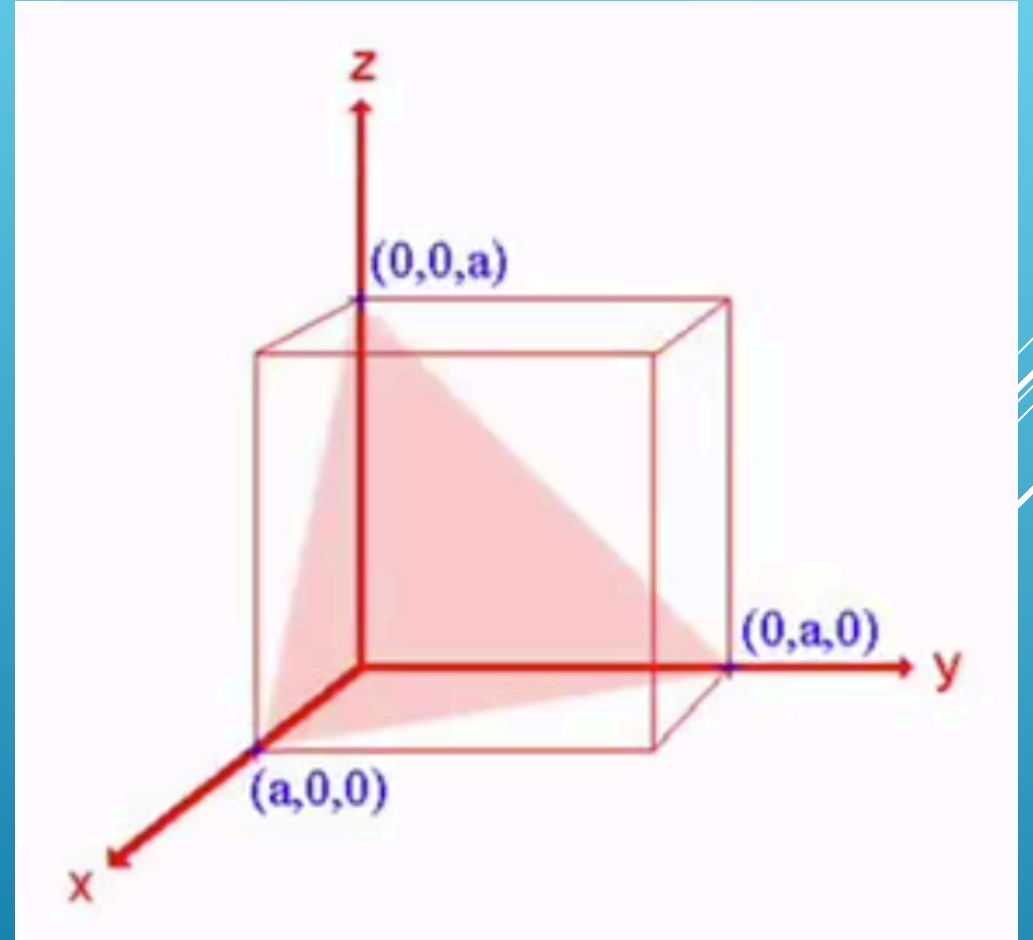


# MILLER INDICES

The plan of interest cuts the three crystallographic axes.

Miller indices ?

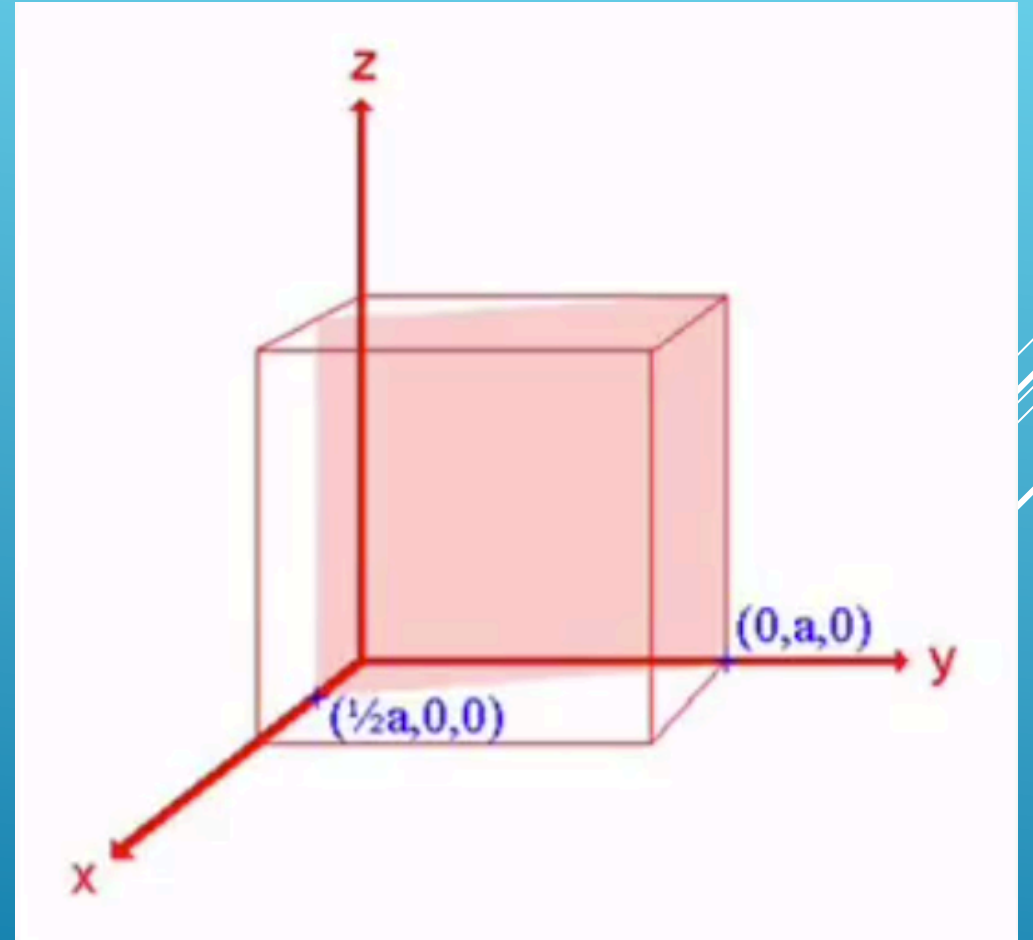
(111)



# MILLER INDICES

The plan of interest cuts two of the crystallographic axes but not equidimensionally

Miller indices ?

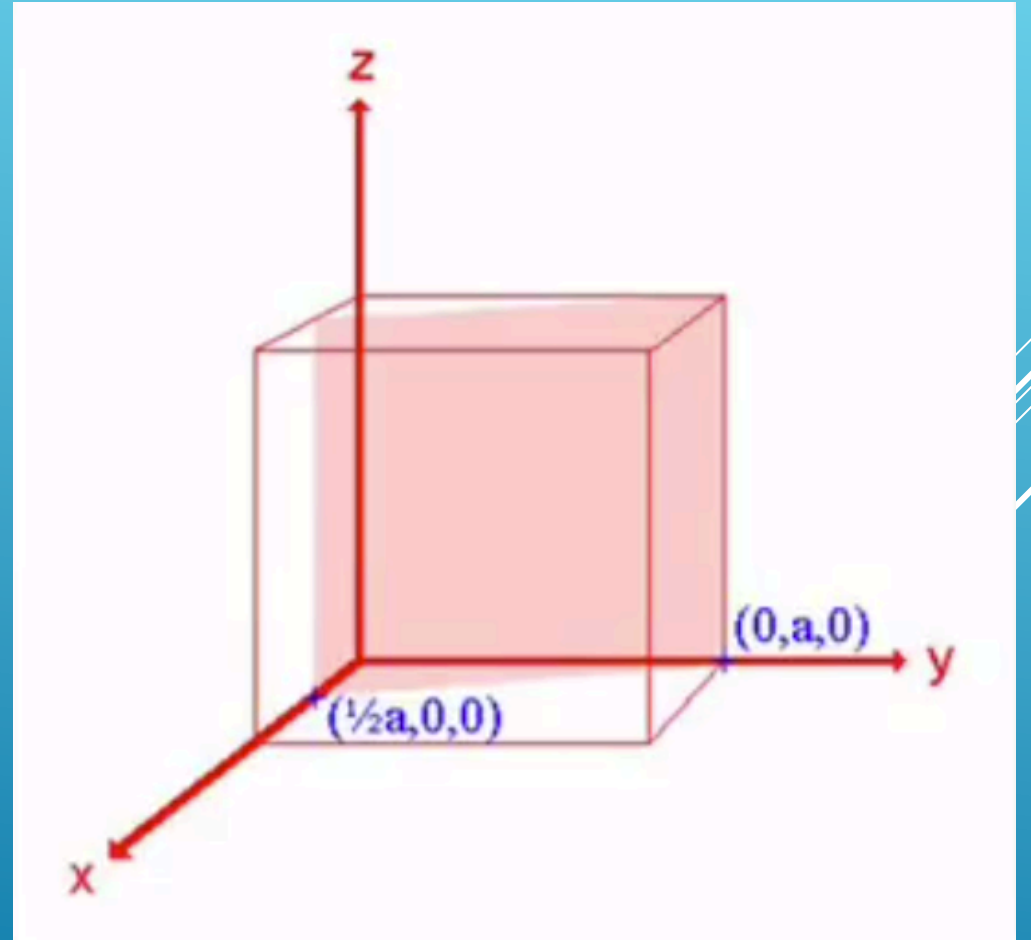


# MILLER INDICES

The plan of interest cuts two of the crystallographic axes but not equidimensionally

Miller indices ?

(2 1 0)



# MILLER INDICES

## Method:

- 1) Determining the axial ratio by dividing each unit cell dimension by the dimension  $b$ .

Ex. Augite:  $a=9.73\text{\AA}$ ,  $b=8.91\text{\AA}$  and  $c=5.25\text{\AA}$

Axial ratio: 1.09:1:0.59

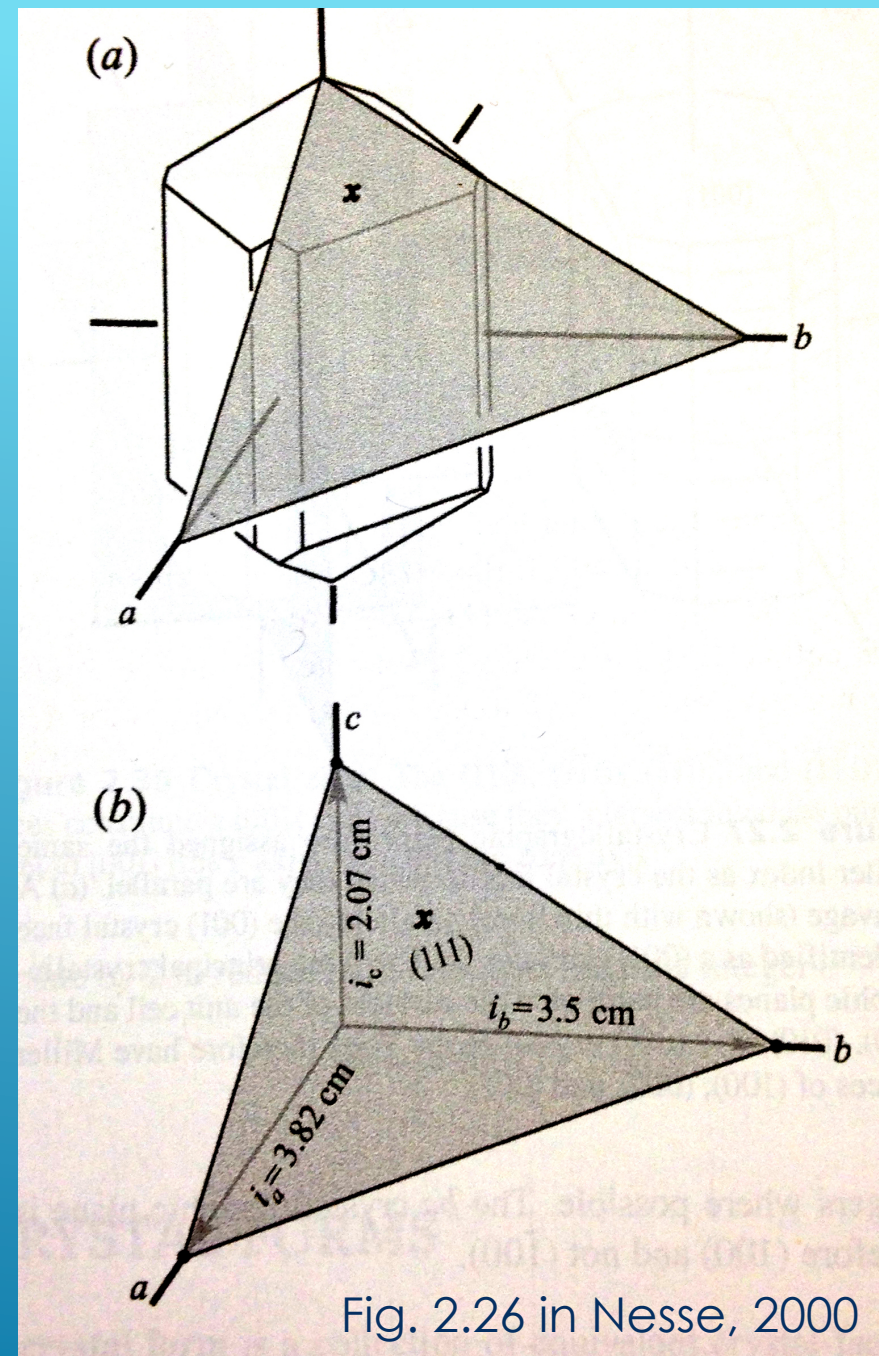


Fig. 2.26 in Nesse, 2000

# MILLER INDICES

## Method:

1) Axial ratio: Ex. 1.09:1:0.59

2) Determining the axial intercepts from the origin ( $i_a$ ,  $i_b$ ,  $i_c$ ) for the considered face:

Ex.:  $i_a=3.82$  cm,  $i_b=3.5$  cm,  $i_c=2.07$  cm

3) Miller index obtained by dividing the axial ratio by intercepts:

Ex.:  $(hkl) \propto (a/i_a, b/i_b, c/i_c) = (1.09/3.82, 1/3.5, 0.59/2.07)$

$(hkl) \propto (0.29 \ 0.29 \ 0.29) \Rightarrow (hkl) = (111)$

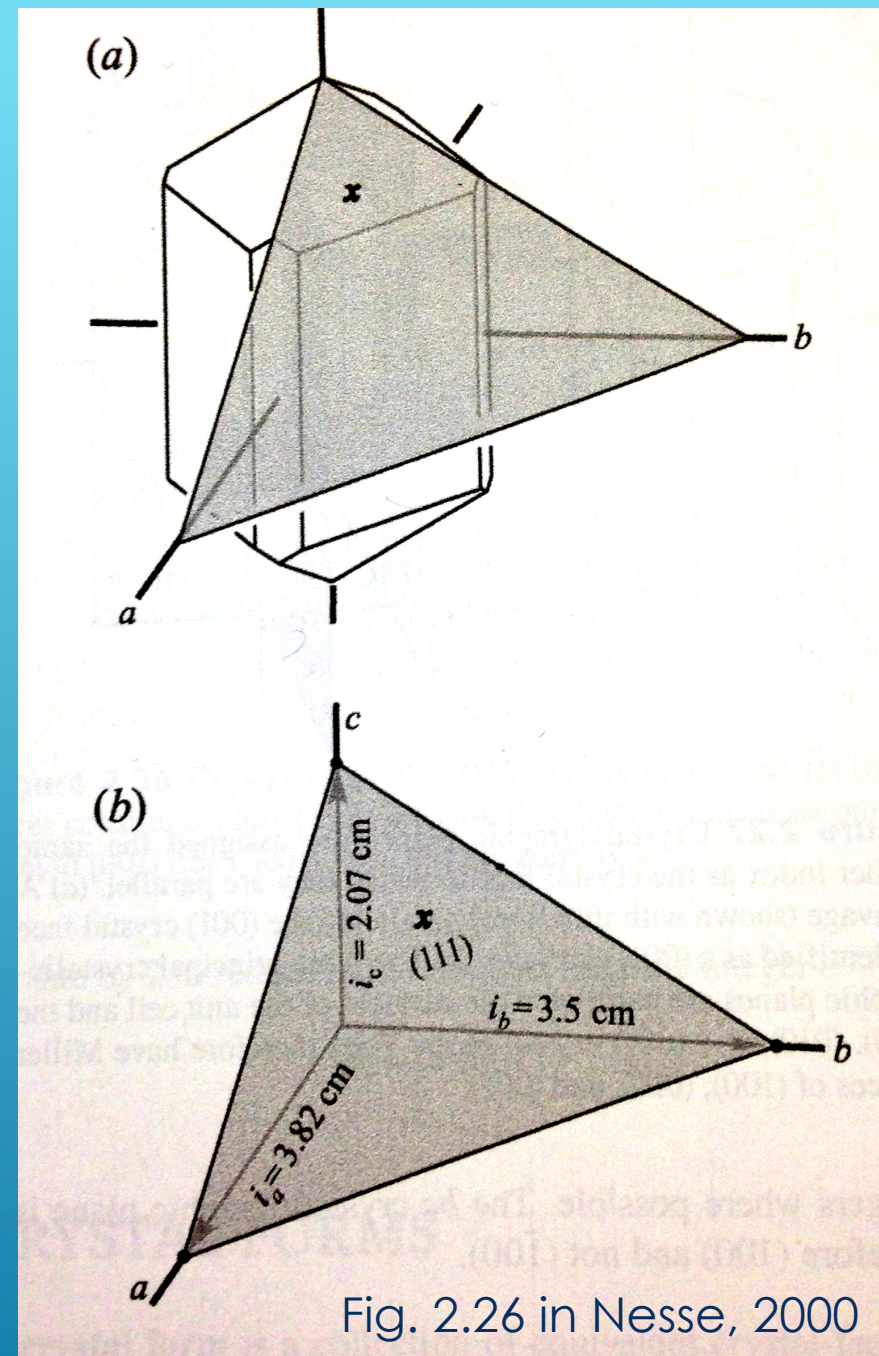
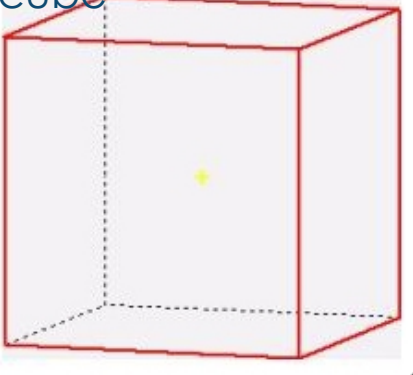


Fig. 2.26 in Nesse, 2000

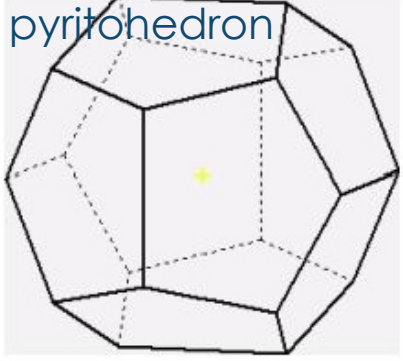
# CRYSTAL FORMS

## ► Isometric system

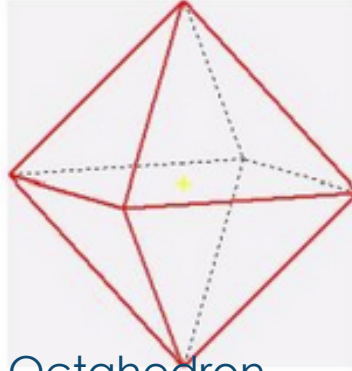
cube



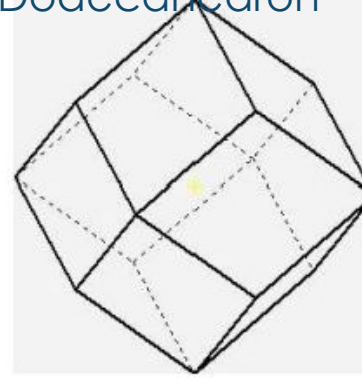
pyritohedron



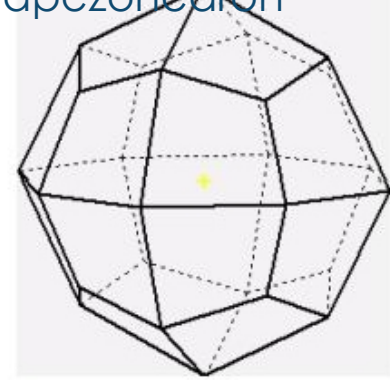
Octahedron



Dodecahedron



Trapezohedron



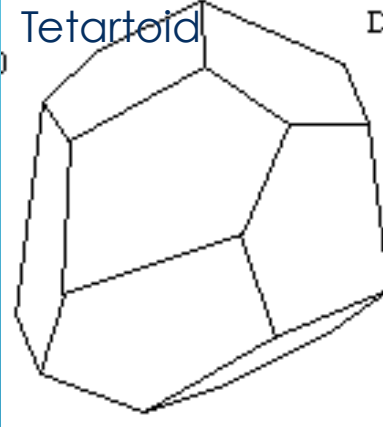
Hexoctahedron



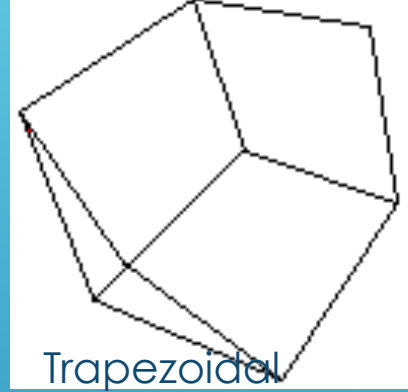
Trisoctahedron



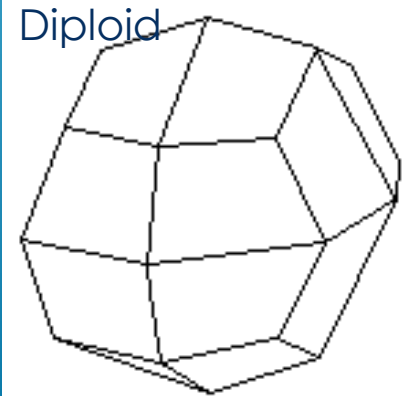
Tetartoid



Trapezoidal  
tristetrahedron



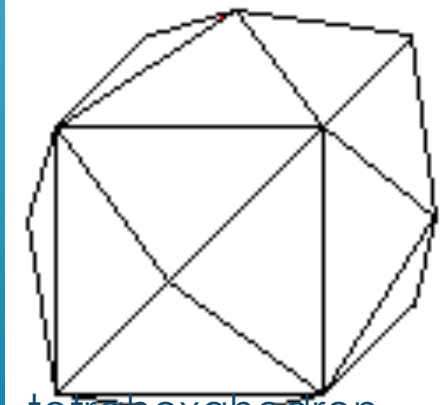
Diploid



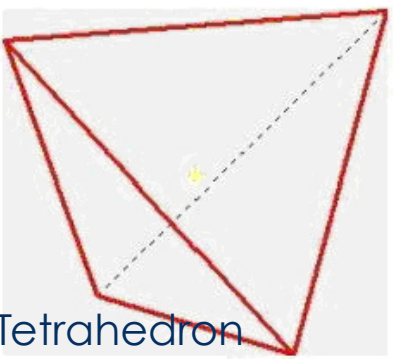
Gyroid



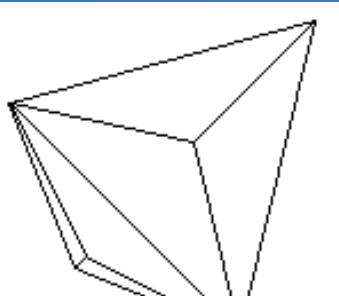
tetrahexahedron



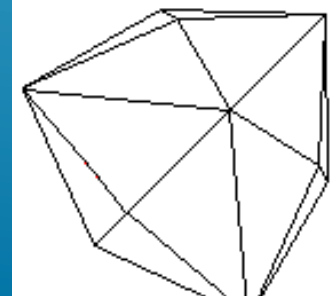
Tetrahedron



Tristetrahedron



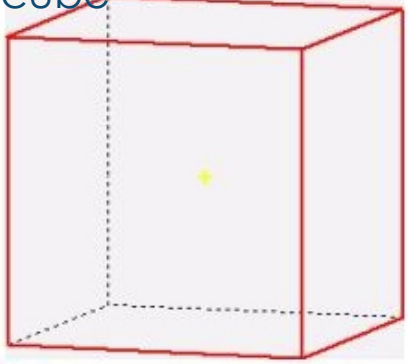
Hextetrahedron



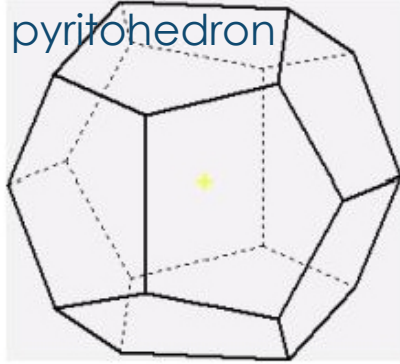
# CRYSTAL FORMS

## ► Isometric system

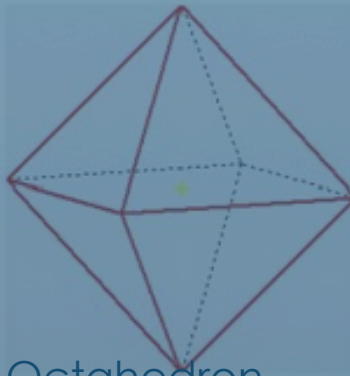
cube



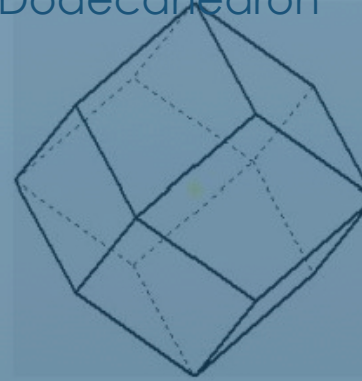
pyritohedron



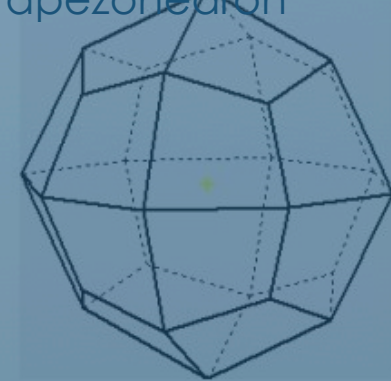
Octahedron



Dodecahedron



Trapezohedron



Hexoctahedron



Trisoctahedron



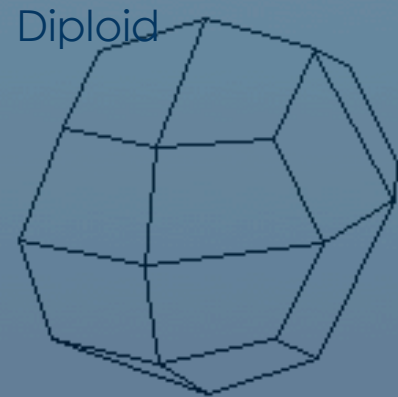
Tetartoid



Trapezoidal  
tristetrahedron



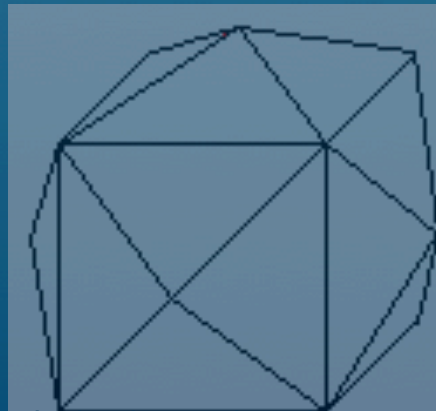
Diploid



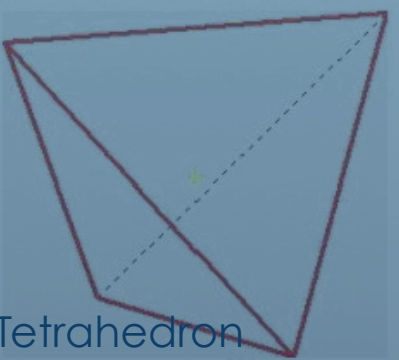
Gyroid



tetrahexahedron



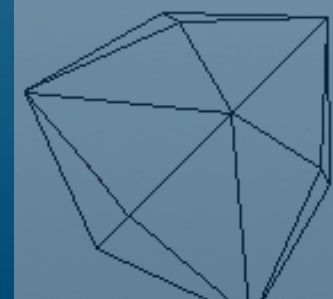
Tetrahedron



Tristetrahedron



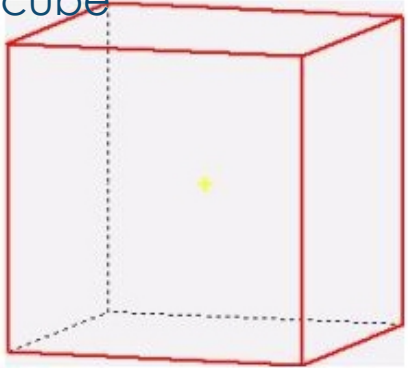
Hextetrahedron



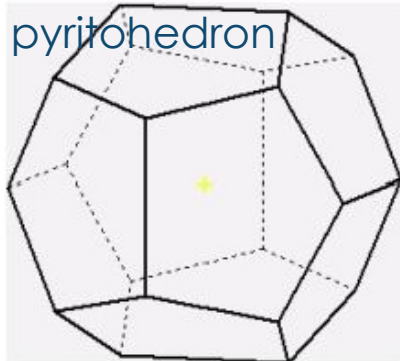
# CRYSTAL FORMS

## ► Isometric system

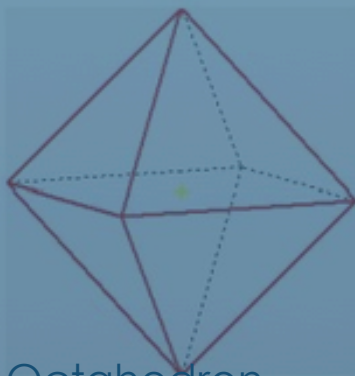
cube



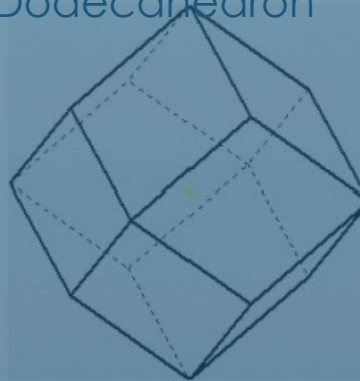
pyritohedron



Octahedron



Dodecahedron



Trapezohedron



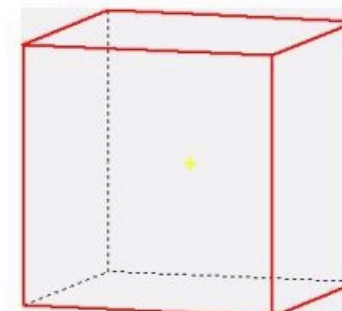
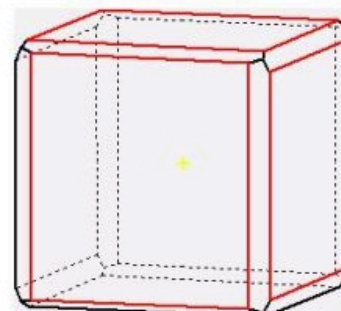
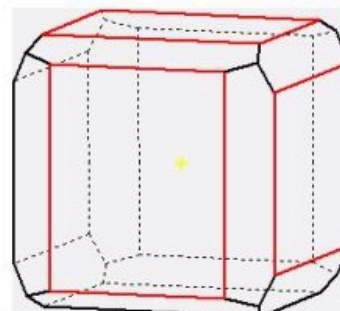
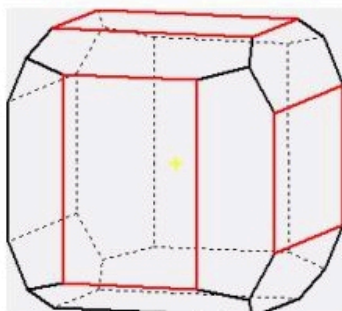
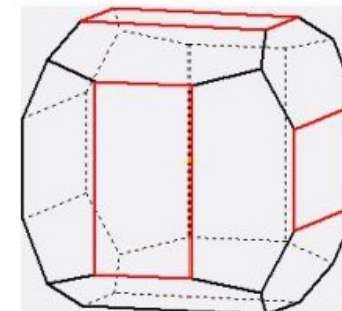
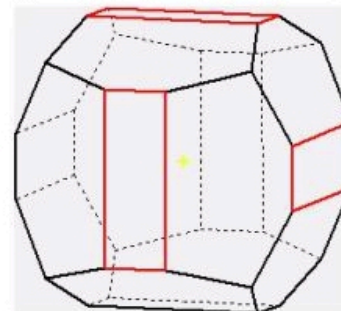
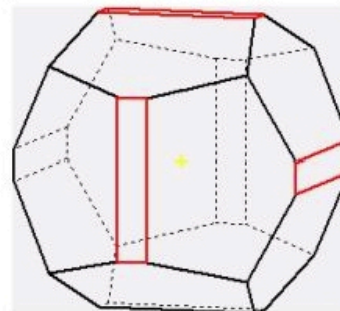
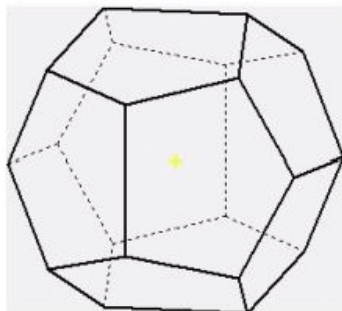
Tetartoid



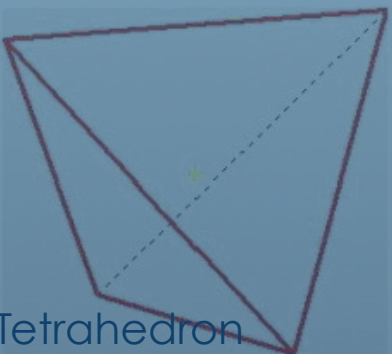
Di



Hexoctahedron



Tetrahedron



Tristetrahedron



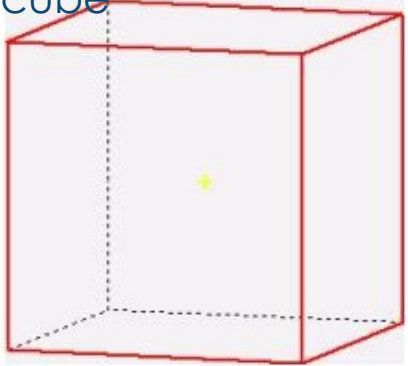
Hextetrahedron



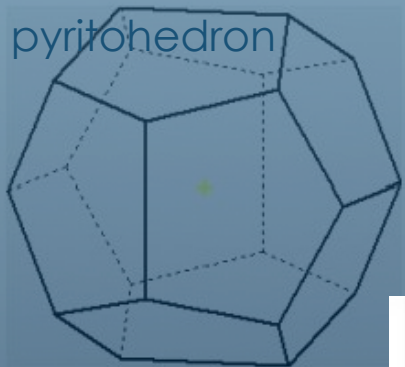
# CRYSTAL FORMS

## ► Isometric system

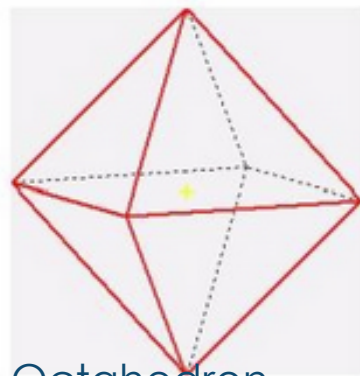
cube



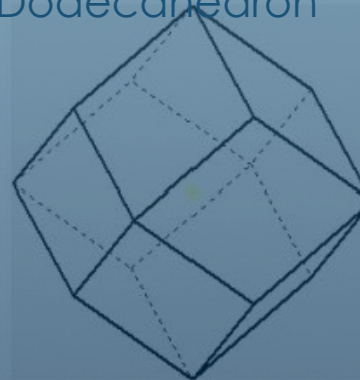
pyritohedron



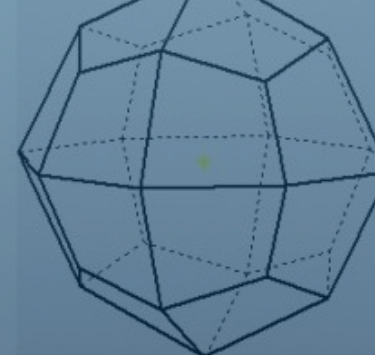
Octahedron



Dodecahedron

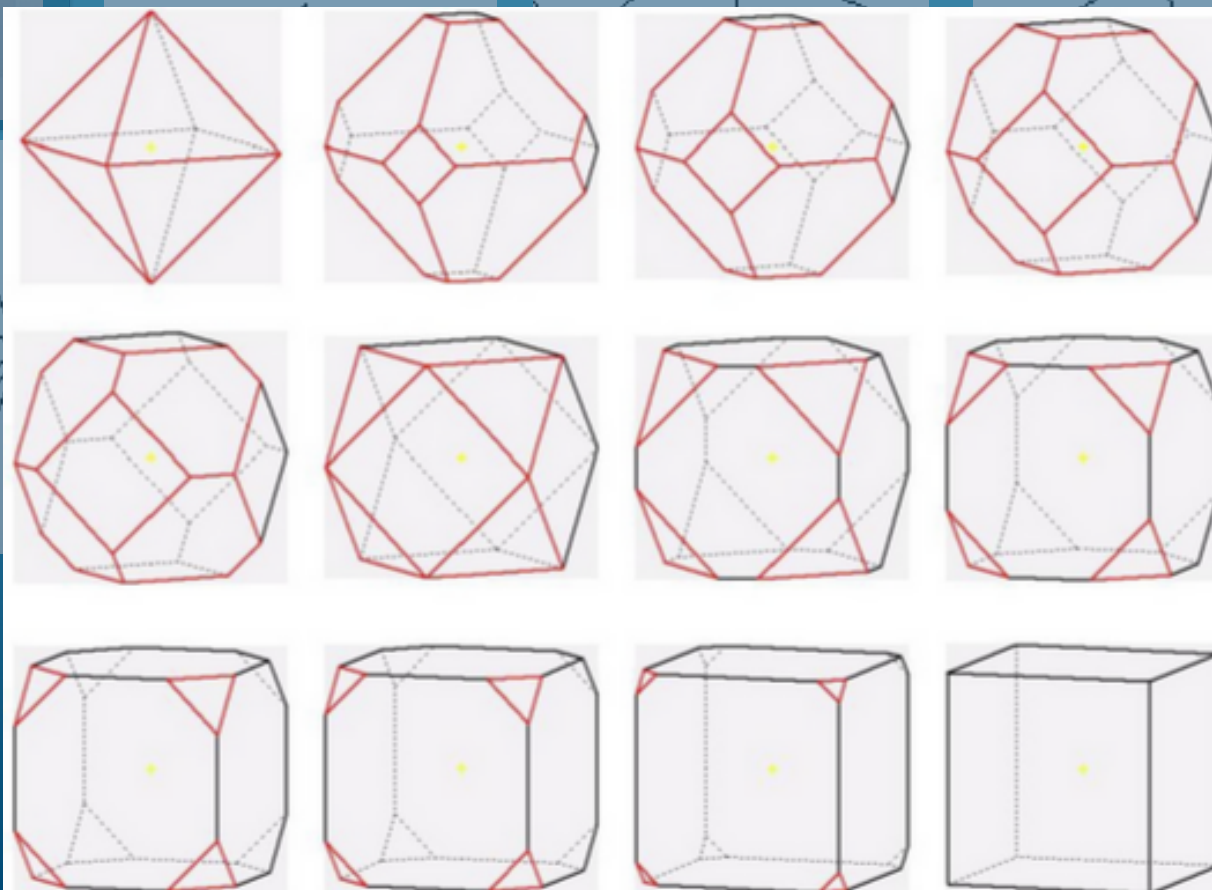


Trapezohedron



Tetartoid

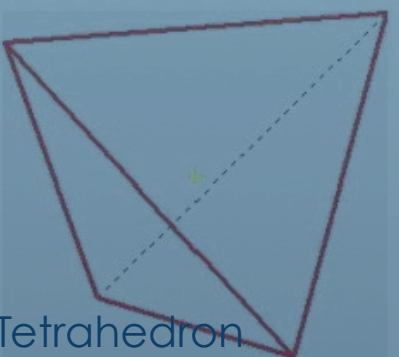
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Hexoctahedron



Tetrahedron



Tristetrahedron



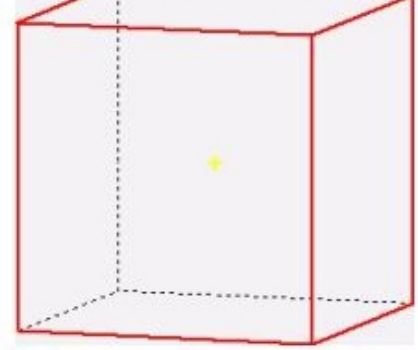
Hexitetrahedron



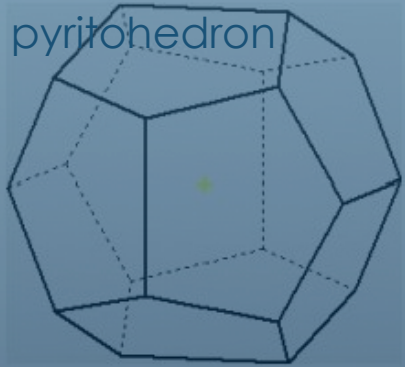
# CRYSTAL FORMS

## ► Isometric system

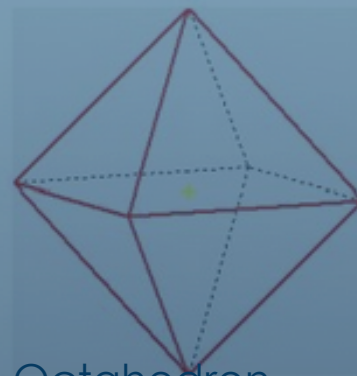
cube



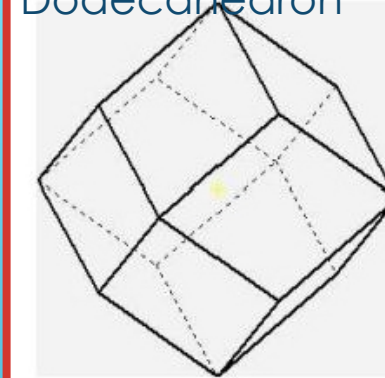
pyritohedron



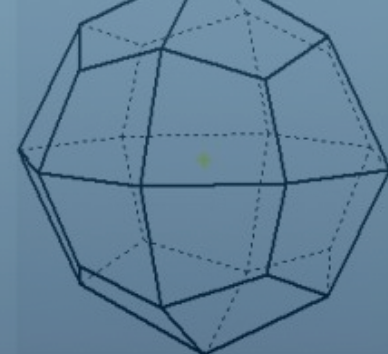
Octahedron



Dodecahedron



Trapezohedron



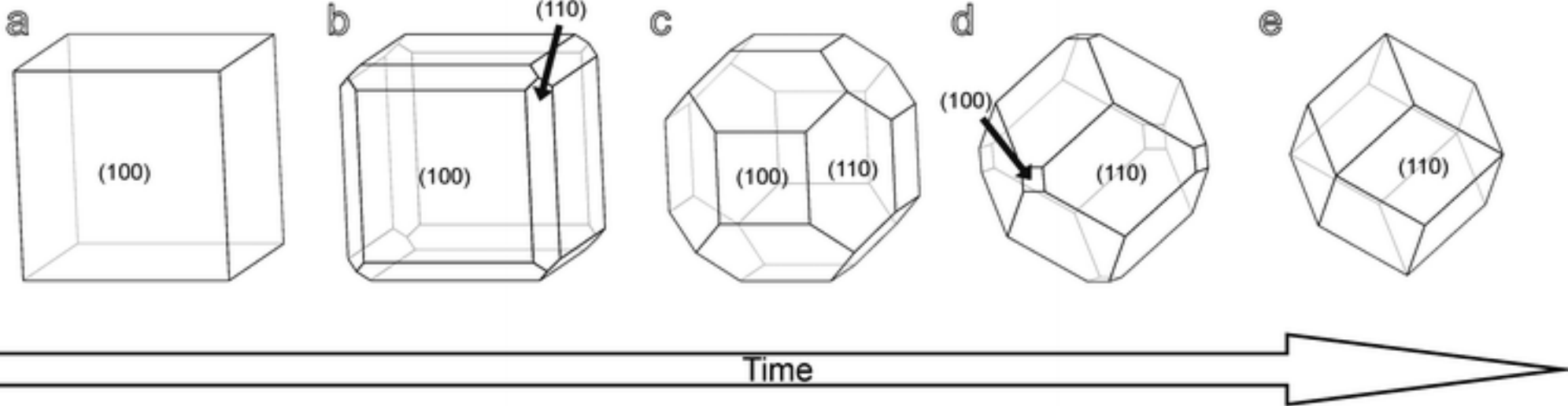
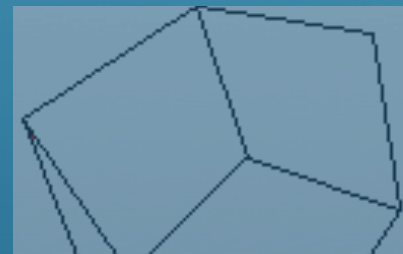
Hexoctahedron



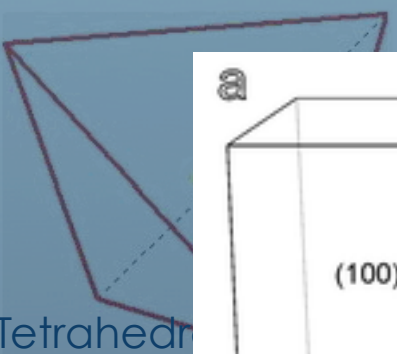
Tetartoid



Di



Tetrahedron



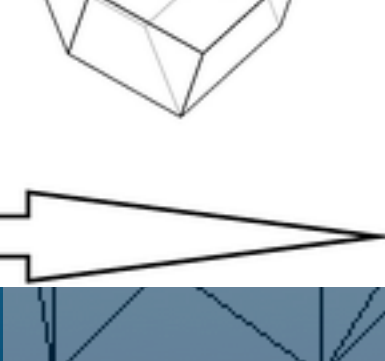
Tristetrahedron



Hextetrahedron



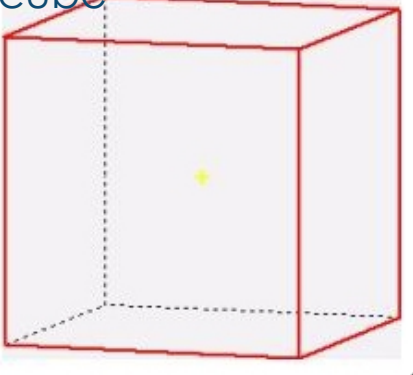
tetrahexahedron



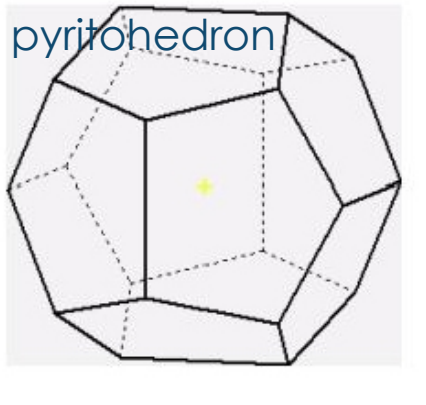
# CRYSTAL FORMS

## ► Isometric system

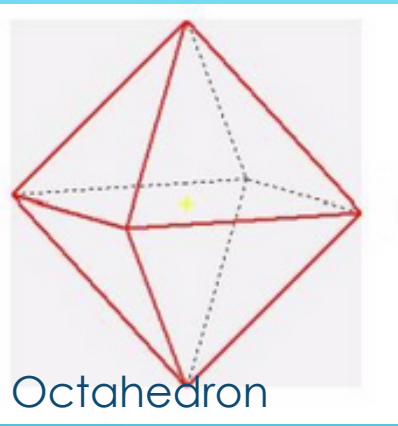
cube



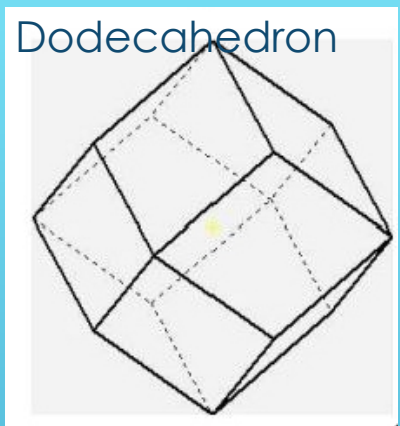
pyritohedron



Octahedron



Dodecahedron



Trapezohedron



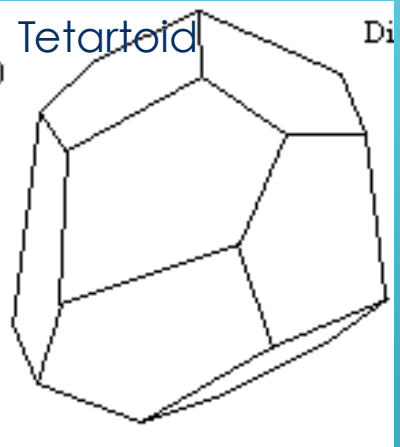
Hexoctahedron



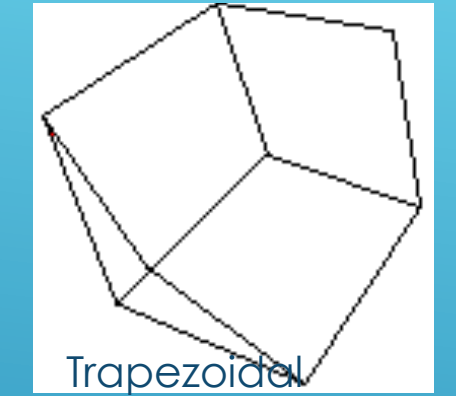
Trisoctahedron



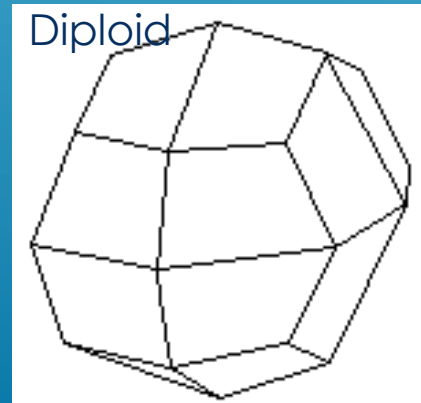
Tetartoid



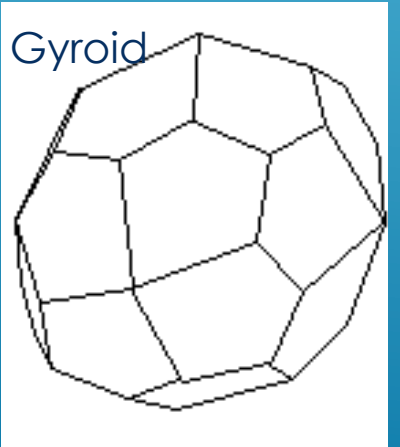
Trapezoidal  
tristetrahedron



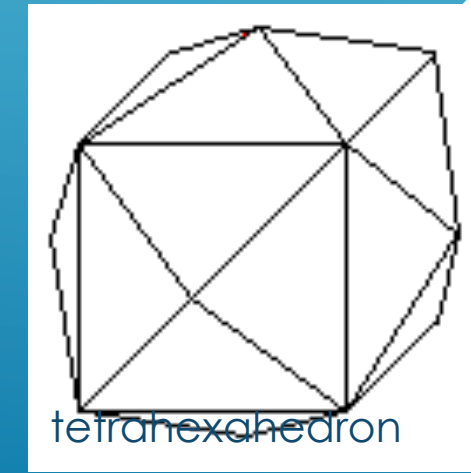
Diploid



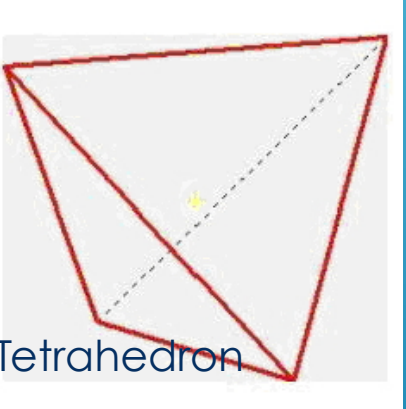
Gyroid



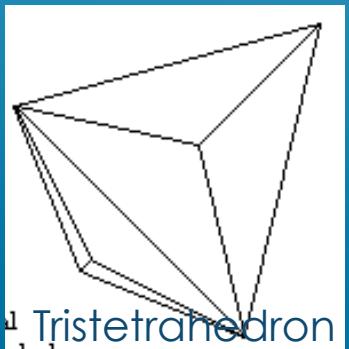
tetrahexahedron



Tetrahedron



Tristetrahedron



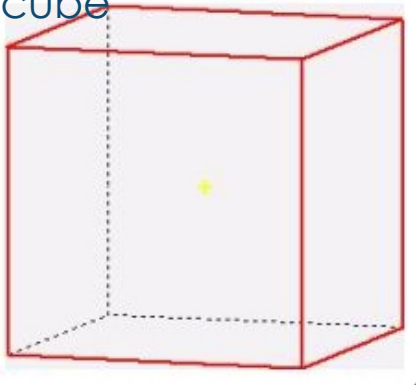
Hextetrahedron



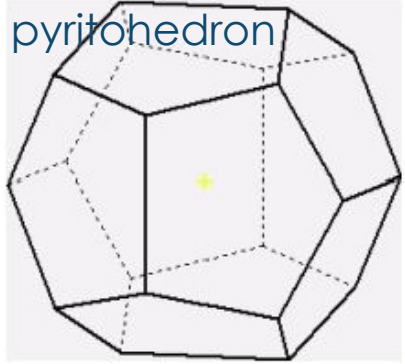
# CRYSTAL FORMS

## ► Isometric system

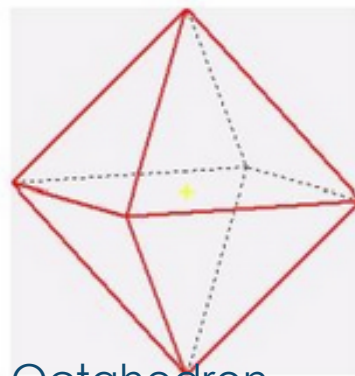
cube



pyritohedron



Octahedron

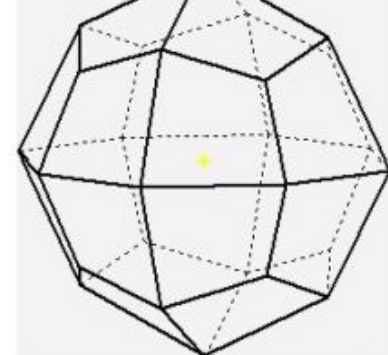


Dodecahedron



garnet

Trapezohedron



Hexoctahedron



Trisoctahedron



Tetartoid

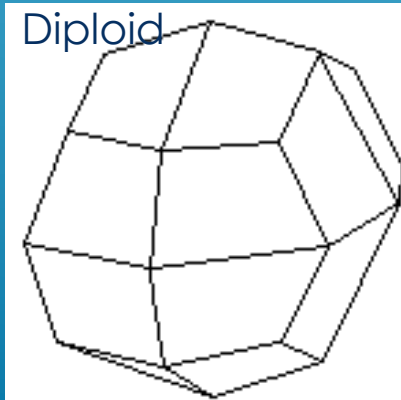


Di

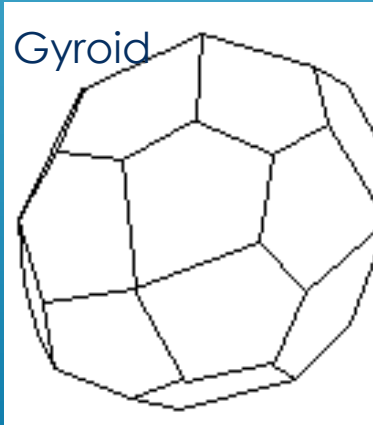


Trapezoidal tristetrahedron

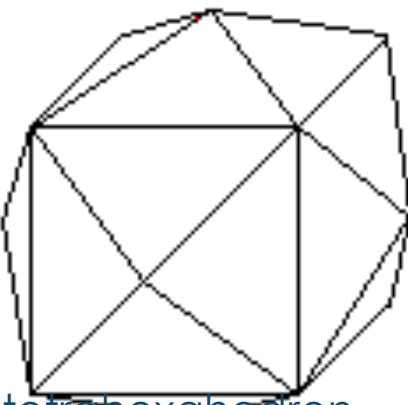
Diploid



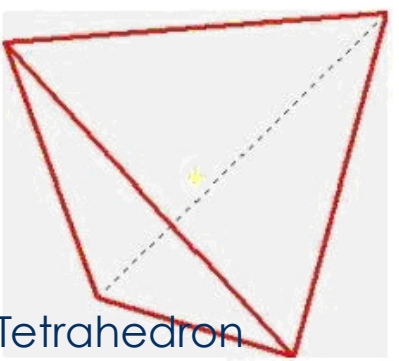
Gyroid



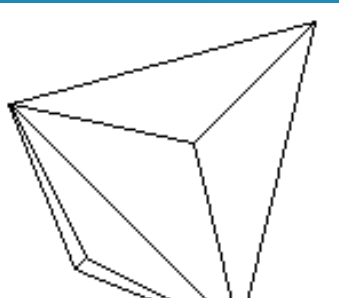
tetrahexahedron



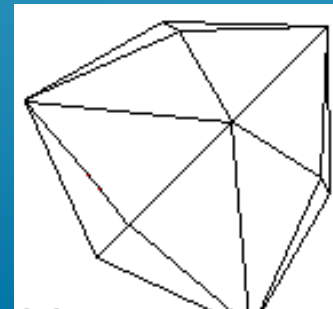
Tetrahedron



Tristetrahedron



Hexitetrahedron



# CRYSTAL FORMS

## ► Isometric system

cube



pyrite

pyritohedron



pyrite

magnetite



Octahedron

Dodecahedron



garnet

Trapezohedron



leucite

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diamond



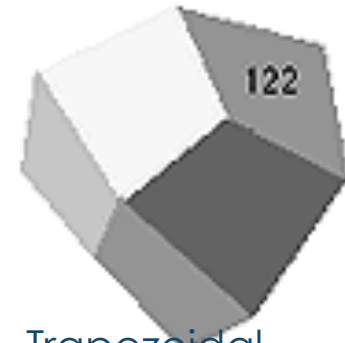
Trisoctahedron

Tetartoid



cobaltite

Di



Trapezoidal tristetrahedron

chalcocite



Tetrahedron

Hexoctahedron



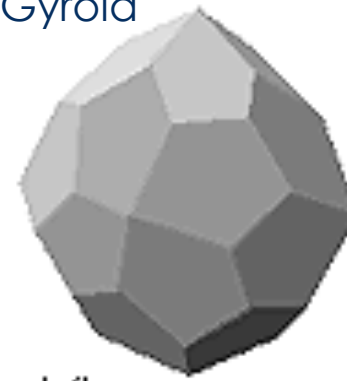
diamond

Diploid



pyrite

Gyroid



1-11

gold



tetrahexahedron

eulitine



Tristetrahedron

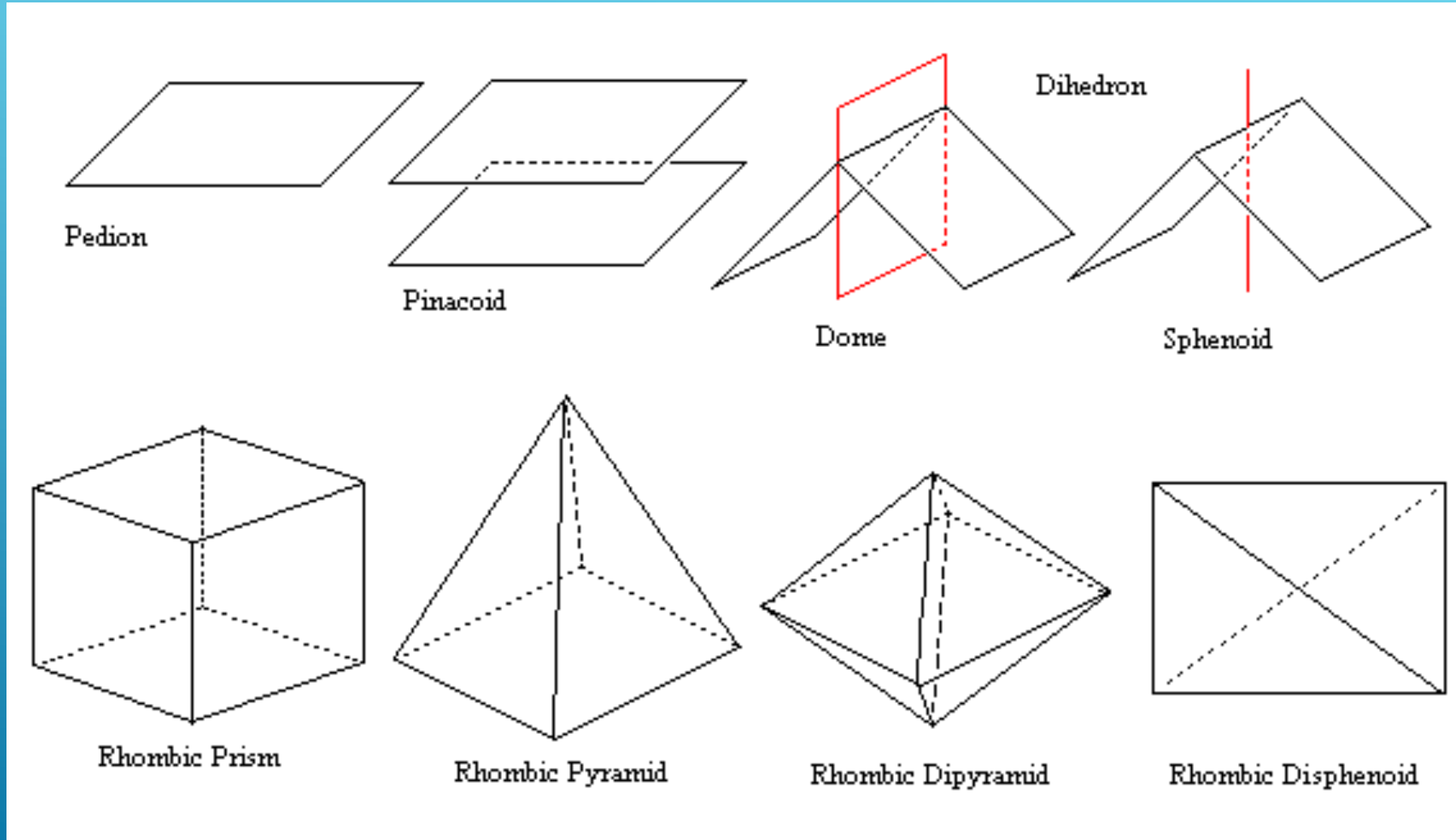
tetrahedrite



Hextetrahedron

# CRYSTAL FORMS

## ► Triclinic, Monoclinic and Orthorhombic Forms



Pedion

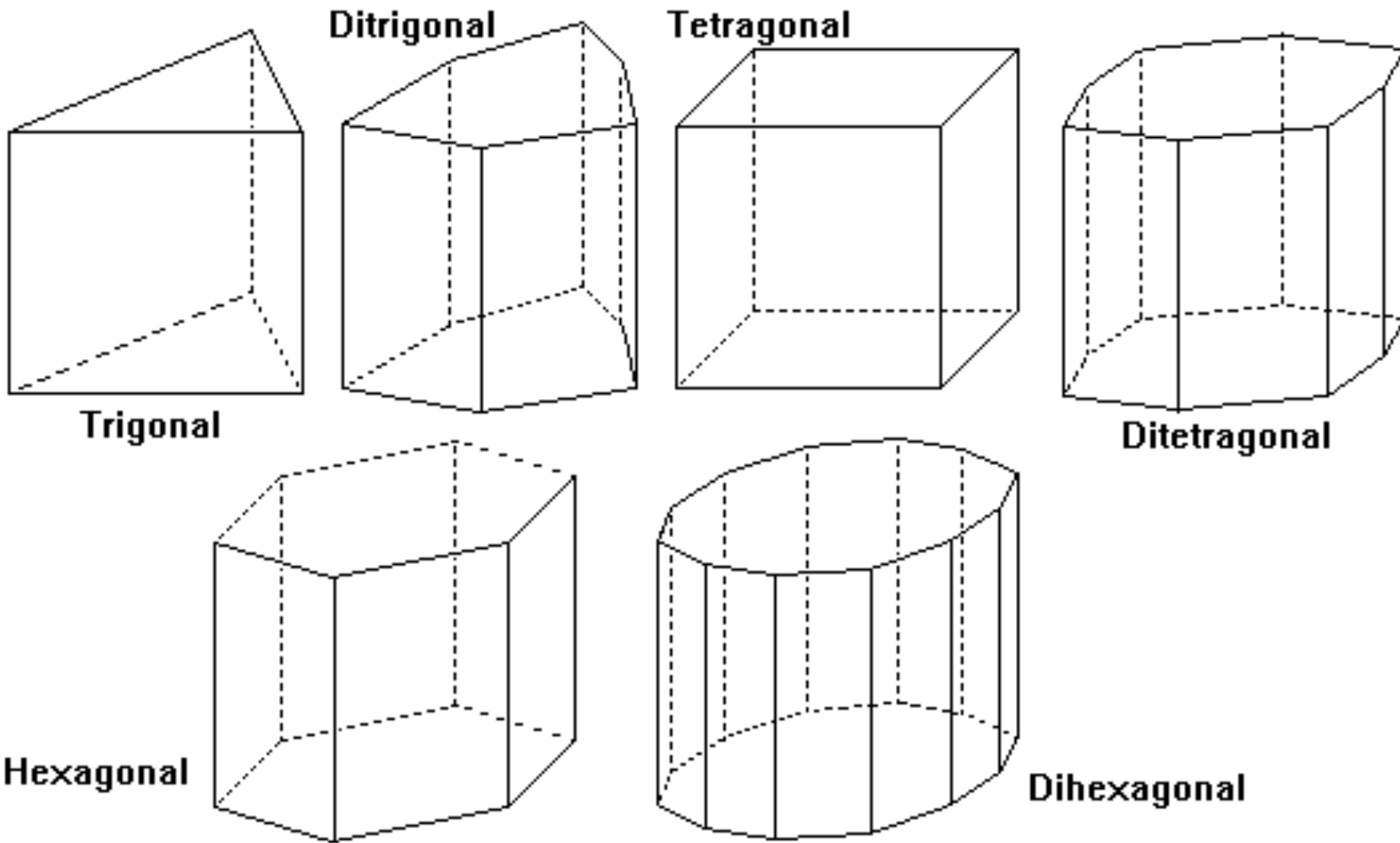
Pinacoid (m or  $A_2$ )

Dihedron (m or  $A_2$ ).

Pyramid

# CRYSTAL FORMS

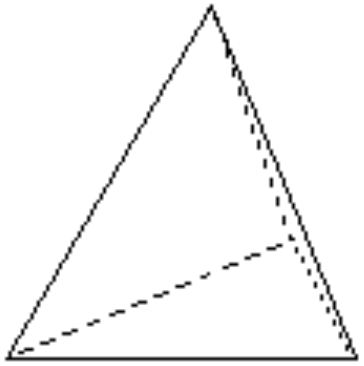
## ▶ 3-, 4- and 6-Fold Prisms



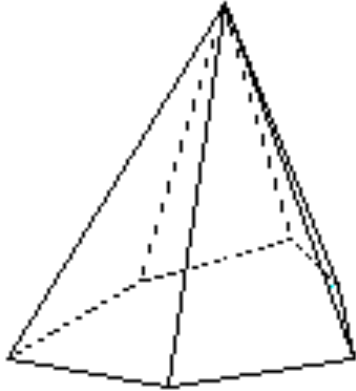
Set of faces all parallel to the Ax symmetry axis

# CRYSTAL FORMS

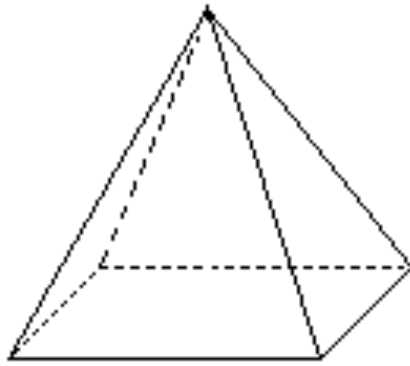
## ► 3-, 4- and 6-Fold Pyramids



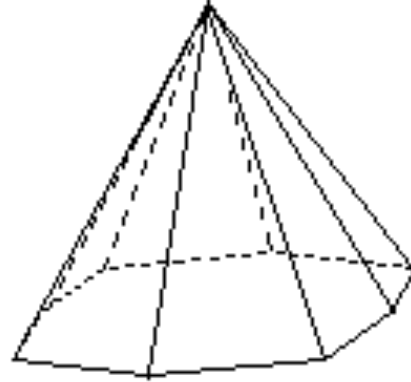
**Trigonal**



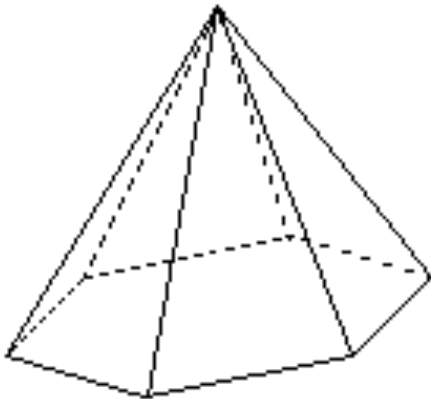
**Ditrigonal**



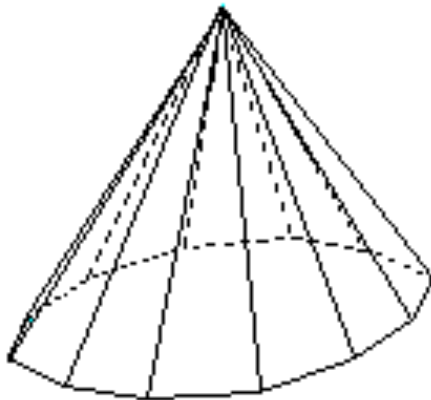
**Tetragonal**



**Ditetragonal**



**Hexagonal**

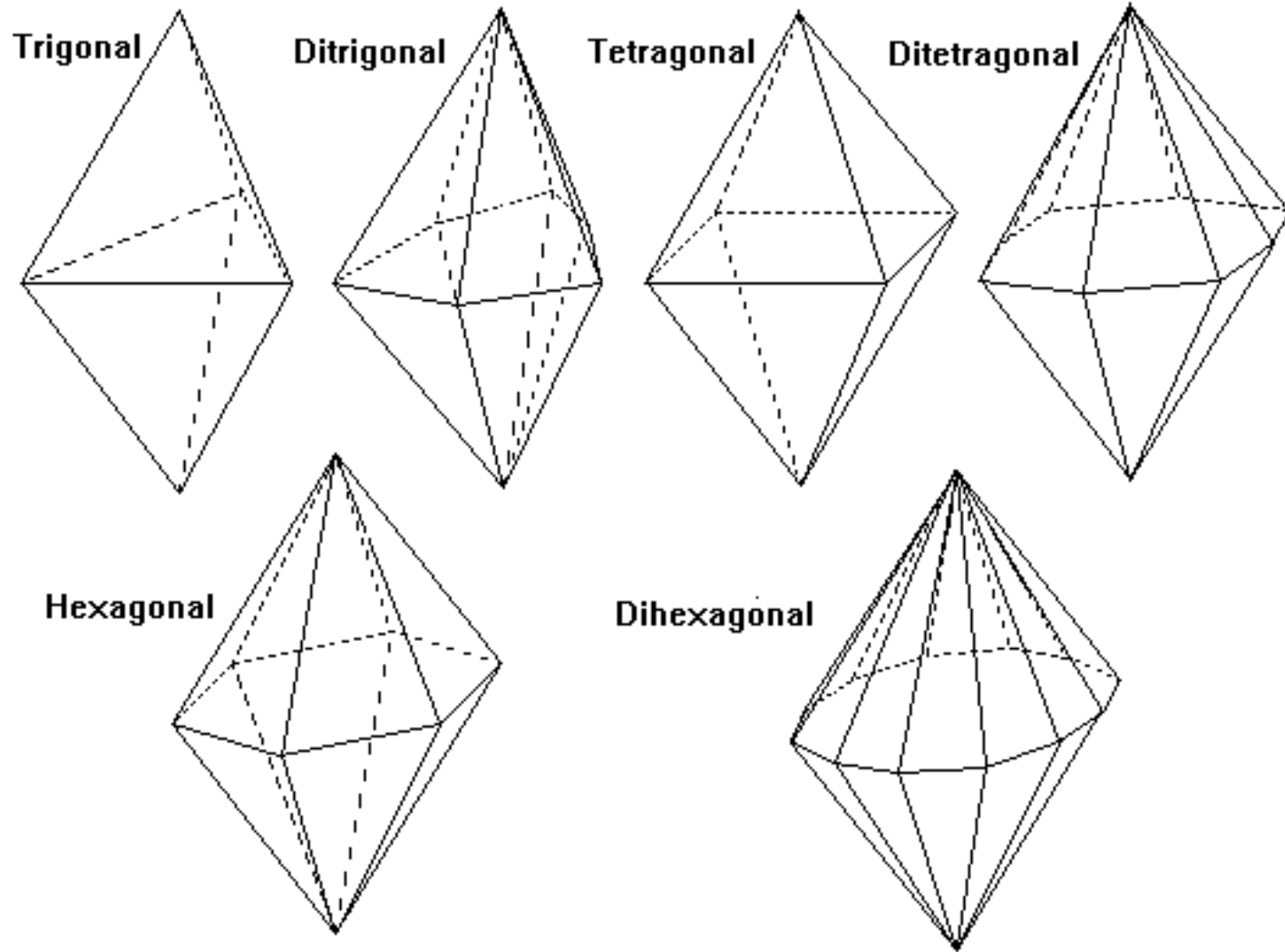


**Dihexagonal**

Set of faces intersecting at a symmetry axis

# CRYSTAL FORMS

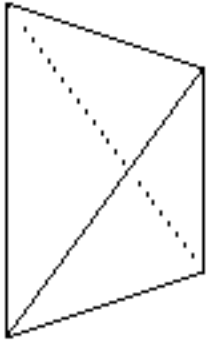
## ▶ 3-, 4- and 6-Fold Dipyramids



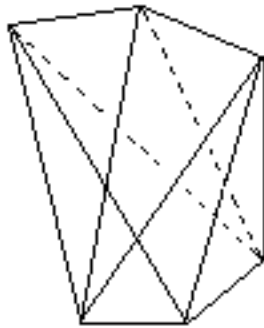
2 pyramids joined based to based along a mirror plane

# CRYSTAL FORMS

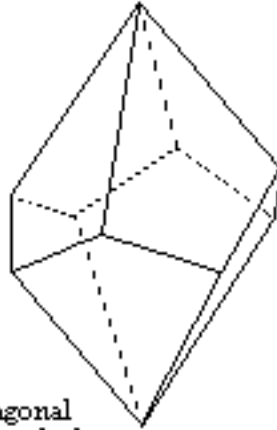
## ► Scalenohedra and Trapezohedra



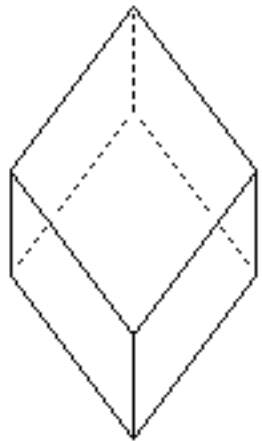
Tetragonal  
Disphenoid



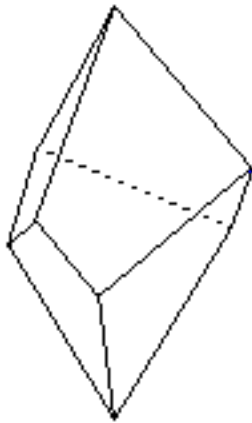
Ditetragonal  
Scalenohedron



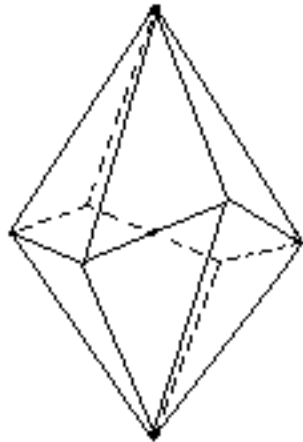
Tetragonal  
Trapezohedron



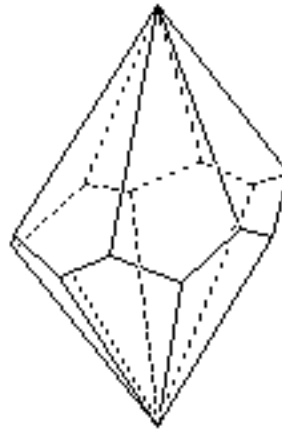
Rhombohedron



Trigonal  
Trapezohedron



Ditrigonal  
Scalenohedron



Hexagonal  
Trapezohedron

**Disphenoid:** “distorted” tetrahedron with isosceles triangles.

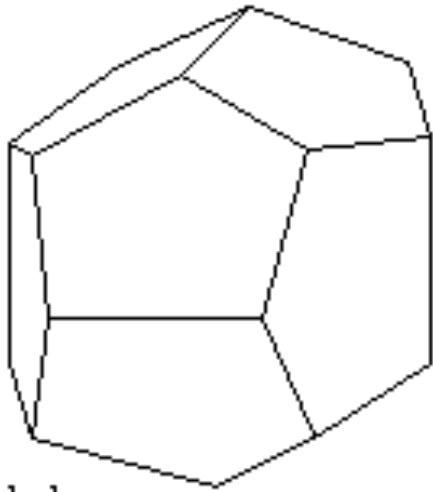
**Scalenohedron:** A solid made up of triangle faces (all sides unequal)

**Trapezohedron:** A solid made of trapezia

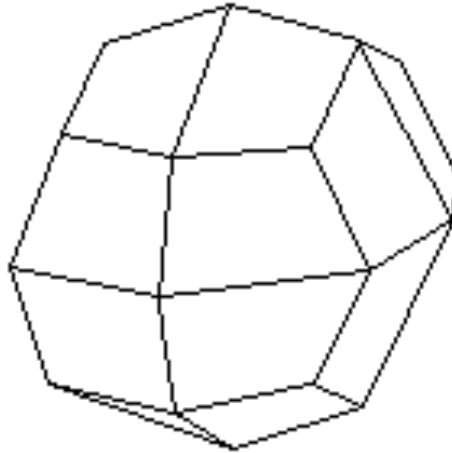
**Rhombohedron:** “distorted” cube along one of its diagonal three-fold symmetry axes.

# CRYSTAL FORMS

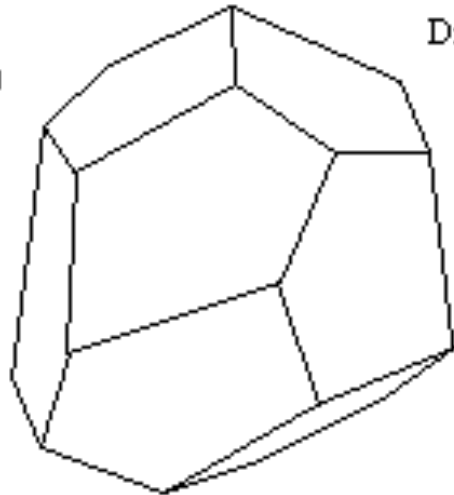
## ► Isometric forms (1): Tetartoidal, Gyroidal and Diploidal Forms



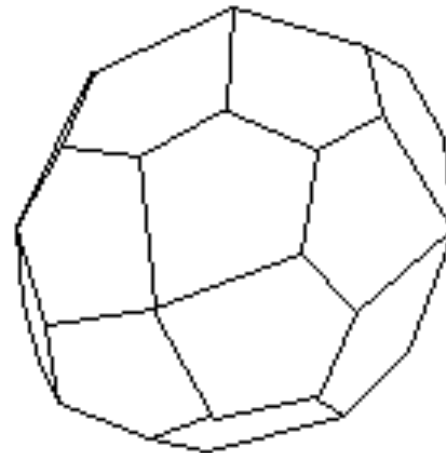
Pyritohedron  
(Pentagonal Dodecahedron)



Diploid



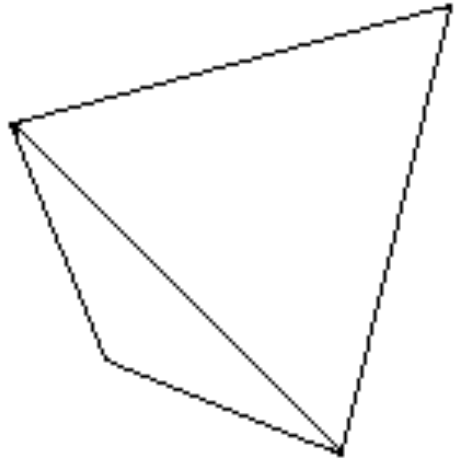
Tetartoid



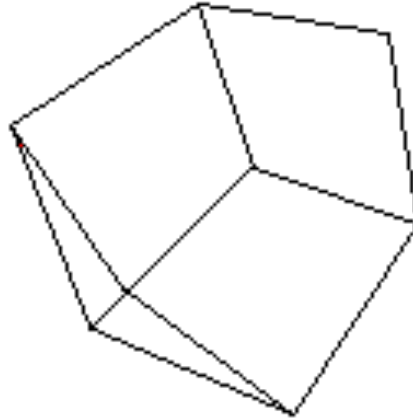
Gyroid

# CRYSTAL FORMS

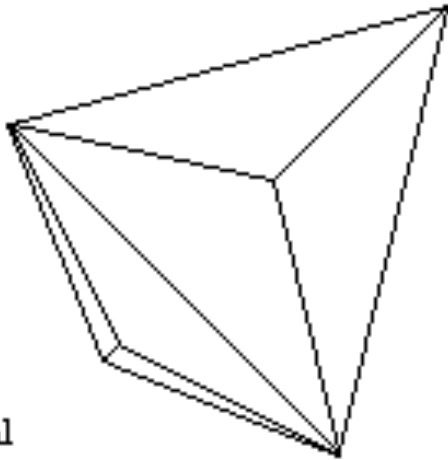
## ► Isometric forms (2): Hextetrahedral Forms



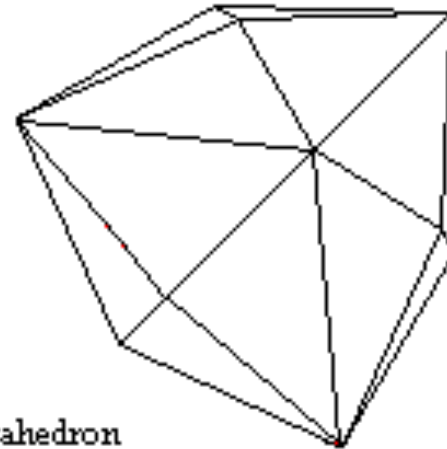
Tetrahedron



Trapezohedral  
Tristetrahedron



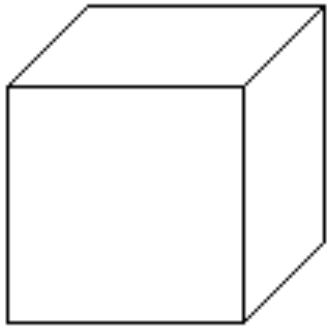
Trigonal  
Tristetrahedron



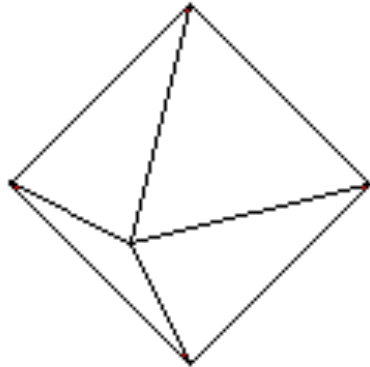
Hextetrahedron

# CRYSTAL FORMS

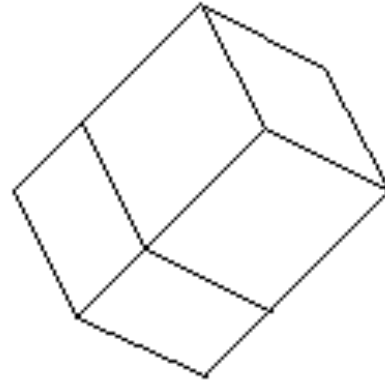
## ► Isometric forms (3): Hexoctahedral Forms



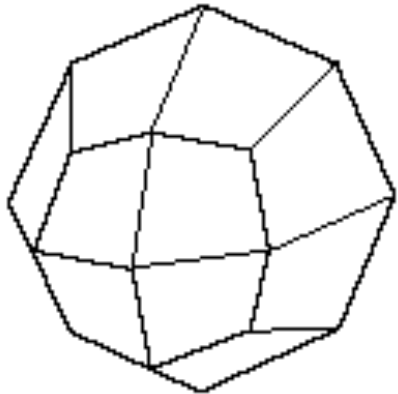
Cube



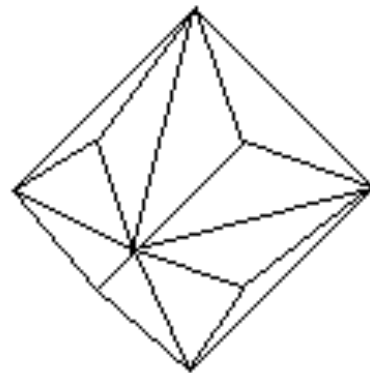
Octahedron



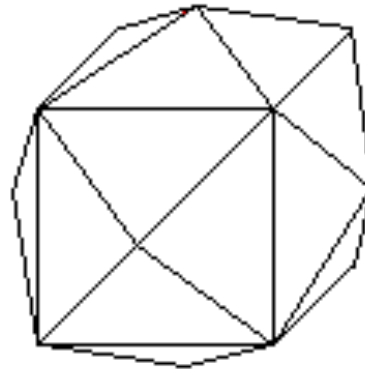
Rhombic  
Dodecahedron



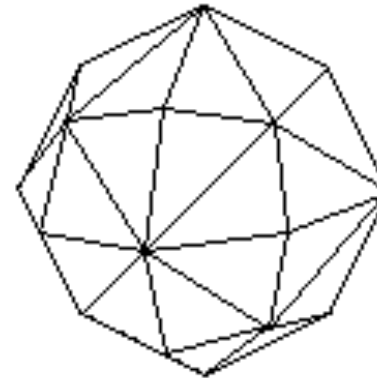
Trapezohedral  
Trisoctahedron



Trigonal  
Trisoctahedron



Tetrahexahedron



Hexoctahedron

# SUMMARY

- ▶ 7 crystal systems
  - ▶ 14 Bravais lattices
  - ▶ 32 crystal classes (or point groups)
  - ▶ 48 crystal forms (= set of crystal faces related by the same symmetry)
- 