STRUCTURE OF MINERALS, CRYSTAL STRUCTURE, CRYSTAL SYSTEMS

Where indicated, refer to the diagrams A, B, C, D, E in the attachment.

1 Structure of Minerals and Crystal Structures

A mineral occurs naturally, has a specific chemical composition and a unique crystal structure. From Topic 2 you now know about compositions and how to read and speak them. Topic 3 is about the unique crystal structures.

You already know a little about the structure of a mineral. Most minerals form as a crystal which is an array of atoms with 3-dimensional order (A). Because of that order any part of the array is fully representative of the whole crystal. The smallest part that is fully representative is called the **unit cell** (B) and it holds at least one atom or molecule of the mineral (C), or at most, only a few atoms/molecules.

As the atoms or molecules in the array occur in straight lines and the lines are aligned in planes, the unit cell has a particular shape. It is a six-sided polygon, with each side being a parallelogram and opposite sides being identical. This shape is called a **parallelepiped** (D) and the size and shape are specified by the lengths of the three edges and the three angles between the edges. These six numbers are called **lattice parameters (E).**

It turns out that unit cells of crystals can have only **seven** different shapes and this restriction means that crystals can have only seven different forms. These forms are called the **crystal systems**. We could look at those seven shapes of the unit cell to see how to derive the seven crystal systems, but there is a better way,

2 Crystal Systems

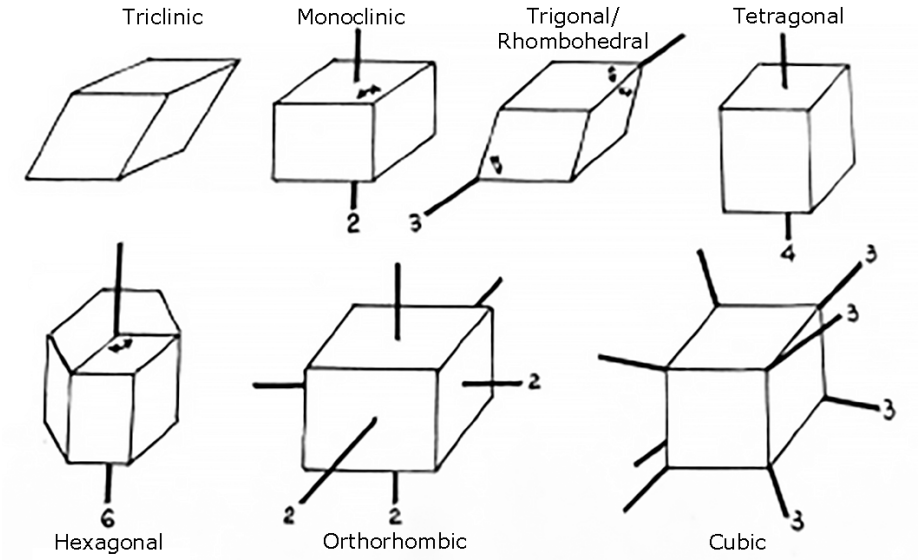
That way is concerned with one of the most important characteristics of three-dimensional bodies – and that is **symmetry**. The six kinds of symmetry are rotation, reflection, inversion, rotary inversion, glide and screw. It is **rotation** that will lead to the crystal systems.

We start by thinking about a straight line passing through an object of any kind. Let that object be a crystal. If that line serves any useful purpose, it is called an axis. Now, consider that object (a crystal) to be rotated through 360° that is, a full rotation, about that line, now called a **rotation axis**. During that rotation the crystal will pass through one or more positions of **self-coincidence**. Self-coincidence occurs when the position of the object (crystal) is indistinguishable from the starting position.

For crystals, the number of possible positions of self-coincidence in a full rotation can be only 1, 2, 3, 4 or 6. Each of these represents a form of rotation

symmetry. For these five kinds of rotation symmetry the rotation axes are named: a 1-fold axis, a 2-fold axis, a 3-fold axis, a 4-fold axis and a 6-fold axis, and these are the only rotation axes that can occur in crystals.
Each of these five different kinds of rotation symmetry is the distinguishing characteristic of one of the seven crystal systems.
A crystal that has only 1-fold rotation axes is called a **triclinic** crystal.
A crystal that has one 2-fold axis is called a **monoclinic** crystal.
A crystal that has one 3-fold axis is called a **rhombohedral** (or trigonal) crystal.
A crystal that has one 4-fold axis is called a **tetragonal** crystal.
A crystal that has one 6-fold axis is called a **hexagonal** crystal.

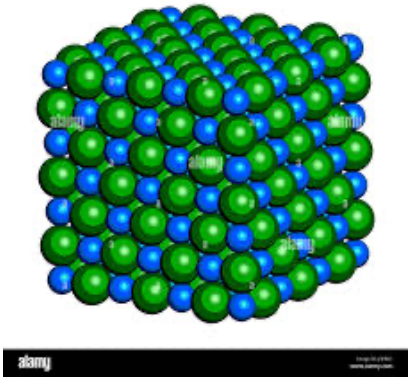
Additionally, some crystals can have three 2-fold axes that must be at 90° to each other. A crystal of this kind is called an **orthorhombic** crystal.
And, some crystals can have four 3-fold axes which can exist only if they are at at 70°32' to each other and so define the body diagonals of a cube. A crystal of this kind is called a **cubic** crystal and the unit cell is the defined cube.
Here are diagrams showing the unit cells for each of the seven crystal systems with the location of the rotation axis (or axes) of characteristic symmetry.



Top row:
triclinic (every possible axis is 1-fold), monoclinic (marked angle not 90°), rhombohedral (marked angles are same and not 90°), tetragonal.
Bottom row:
Hexagonal (diagram showing hexagonal symmetry with 2 and 2 halves of unit cells, the marked angle is 120°), orthorhombic, cubic.
The crystal system names are sufficiently informative for them to be used to specify crystal structure. We finish this part of the study of minerals with the common practice for fully identifying a mineral with three terms as here.

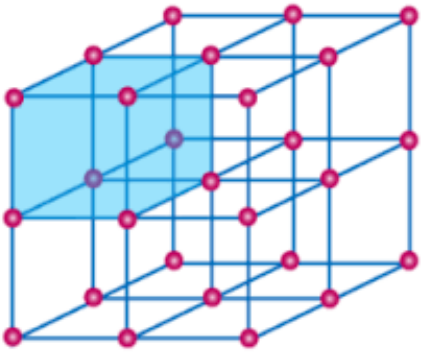
1 the mineral name	pyrite	gypsum	beryl	zircon
2 the composition	FeS_2	$CaSO_4.2H_2O$	$Be_3Al_2Si_6O_{18}$	$ZrSiO_4$
3 the crystal system	cubic	monoclinic	hexagonal	tetragonal

Crystal Structure Diagrams:



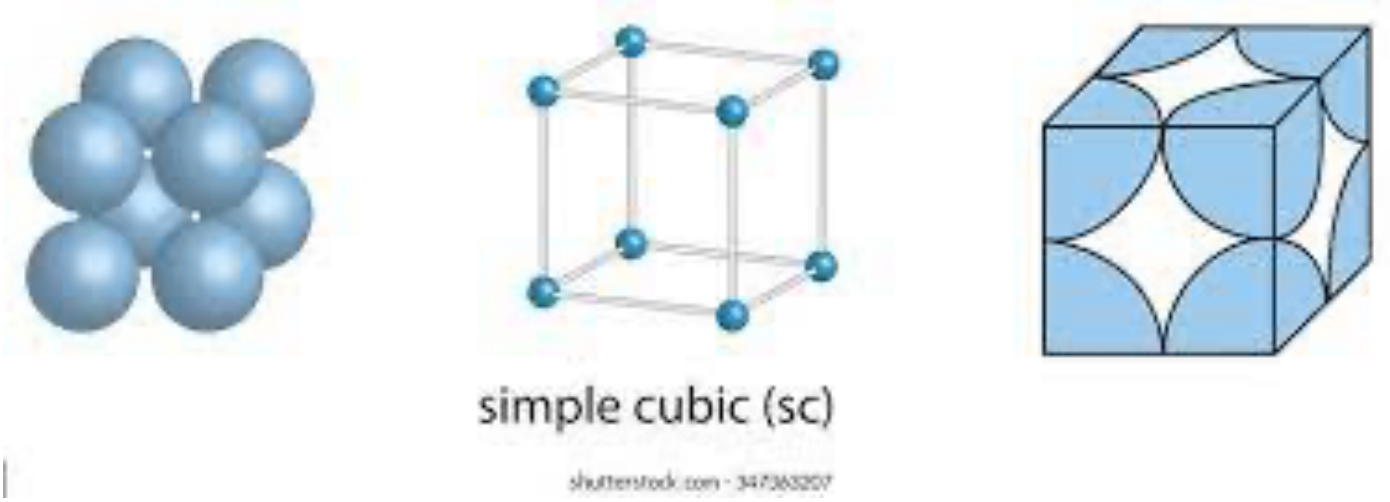
A

Model of crystal of NaCl



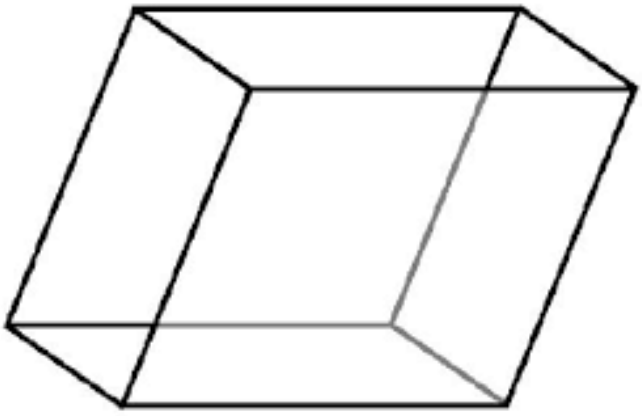
B

Model of atom sites and unit cell

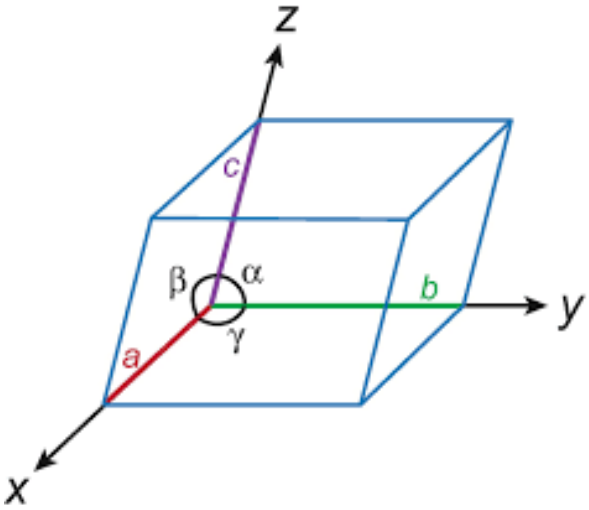


C

Models showing atoms in a unit cell, atom sites and the parts of the 8 atoms in the cell. Each part is 1/8 of an atom. So 8 atoms, each contributing 1/8 = 1 atom in cell.



D Parallelepiped shape of unit cell



E Lattice parameters