Script Unit 3.6

Welcome to Unit 3.6!

In this unit, we want to continue classifying crystals into crystal classes - and we will go through two more examples together!

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Look at this schematically drawn crystal shape in purple! The outer shape reminds me in a way of a handbag, apart from the fact that a crystal has usually not such a handle to carry it - but anyway… A handbag like this should also belong to the same symmetry class as this crystal!

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The recipe to classify is still the same: we examine this shape and search for symmetry elements and write down all symmetry elements we can find.

This time we want also to do it in a specific and systematic way, and this means the following in crystallography:

We look at the crystal in specific crystallographic directions, and by writing down the symmetry elements we find, we account for the order of these directions - these directions are in simple cases just the directions of the coordinate system, and here in the order a, b, and c.

These viewing directions are set by crystallographic rules, and we will specify this and come back to them, when we are talking about space groups.

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What symmetry elements do we find?

Well, along the a-direction we come across a mirror plane!

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What do we find, when we look along the b-direction? Right, another mirror plane! Finally, the c-direction is left. And there is a two-fold axis of rotation!

So, that’s it, these are all symmetry elements, a 2-fold axis of rotation and two mirror planes, being perpendicular to each other.

By convention, the rotational axis of highest order - which is in this case 2 - should run along the

c-axis, meaning that the crystal class is: *mm*2

The name for this crystal class is: rhombic-pyramidal or also orthorhombic-pyramidal - this name is also a hint that this class belongs to the orthorhombic crystal system. Struvite - this is Magnesium-Ammonium-Phosphate - crystallizes in this crystal class.

Here on the photo, there is one particular crystal sample, which shows this orthorhombic-pyramidal shape very clearly. At the webmineral.com-website you can find a 3D rotatable model of the shape, as in our previous example.

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Hemimorphite - a zinc containing silicate - is another mineral which crystallizes in this crystal class.

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Maybe let's look at one last example! Here, you can see another schematically drawn crystal shape - it looks like a hexagonal barrel.

Indeed it belongs to the hexagonal crystal system, and the viewing directions in the hexagonal crystal system are as follows: first, we have to look along the c-direction, then along a, and finally along a direction, which is not identical with one of the three axes of the coordinate system. This is the first time that we encounter this - so let me explain it a bit more in detail.

This direction is notated here in these square brackets, with the three numbers [2 1 0]. These are not Miller indices, but a way to describe lattice directions.

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Here you see our hexagonal lattice, with the lattice vectors a and b. And now we want to specify a certain direction within this lattice, so we use a vector, for instance this one here - you can always specify a direction with two points of the lattice -

The first point, the starting point should always be the origin of the system of coordinates (0 0 0). If the vector does not run through the origin, we carry out a respective parallel translation.

And then we go along this vector and look at which coordinates the vector will hit for the first time a lattice point. Here, this point has the coordinates 2, 1, and the third one is 0 - as we consider a 2-dimensional lattice only. So the point is given as the coordination triple 2 1 0 and is then embraced by these square brackets.

Regarding the hexagonal example there are two further symmetry related directions to [210],

which are only rotated by 120 degrees, namely [1-bar, 1, 0] and [1-bar, 2-bar, 0].

All symmetry-related directions can be denoted in such angled-brackets- <210> - and these comprises then all these three directions.

Now, it should be also clear that the lattice directions a and b can also be described as [100] for a, and [010] for the b-direction in this notation system.

Okey, but now let's switch back to our hexagonal barrel and let's have a look, which symmetry elements we can find in the different directions:

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Along the c-direction - clear - there is a 6-fold axis of rotation!

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And there is another SE along the same direction - can you see it? - Right, a mirror plane, perpendicular to the 6-fold axis of rotation. We write this again in this manner: 6/*m*.

The second direction is along a - and there is also a mirror plane present…and the last direction is along [210].

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Yes, there is also a mirror plane - there are no other unique symmetry elements present, so our crystal class is already complete.

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6/mmm - this crystal class is called according to the geometrical description dihexagonal-dipyramidal. Covellite, which is copper sulfide, for example, crystallizes in this crystal class. However, in nature you can find only very rarely such good developed shapes, more frequently there are such extensive bladed coverages on other minerals as shown here.

Other compounds, which belong to this crystal class are: the element Magnesium, Carbon in its graphite modification and Nickeline.

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While preparing this unit we had an idea: As most of you will know in 2014 the football world cup in Brazil took place - congratulations to the German football team - and maybe some of you have collected in your early life - as myself - such sticker albums from Panini with the portraits of the football players.

But in 2014 there was not only this soccer world championship - it was also the International Year of Crystallography. Therefore, Michael and I thought we can initiate a similar collectible - a poster of crystal classes!

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This is how it looks like! And you can download it from our website crystalsymmetry.wordpress.com. The idea is, that you print it out, pin it on a door or wall, and then take photos, whenever and wherever you see a crystal, classify them according to their crystal classes and stick them on the right place here onto your personal poster, in this way.

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Now, I'm afraid, there is one important thing still left in this unit, namely, the connection between the crystal systems and the crystal classes!

These 32 crystal classes, are, of course, not distributed over the crystal systems arbitrarily - this should have become already clear when looking at the poster of crystal classes. In detail it looks like that:

In this table, once more an overview of the crystal classes is given and how they distribute over the crystal systems. In the second column the characteristic symmetry elements of the crystal systems are given. Let's go through this table briefly!

In the triclinic crystal systems, there are only two crystal classes, one - and one-bar, which means either no symmetry element or just a centre of inversion. In the monoclinic crystal systems, there are three different crystal classes, either one two-fold axis of rotation, or one mirror plane or a two-fold-axis and a mirror plane, but in the same direction! And so on, and so on.

The characteristics of the trigonal crystal system is, that there is exactly one three-fold axis of rotation - and if you examine structures on your own, you should always check, if there is a mirror plane perpendicular to that three-fold axis - if so, then this constitutes a 6-bar! And then the structure belongs not to the trigonal crystal system, but to the hexagonal one!

And finally, the characteristics of the cubic crystal system is not a 4-fold rotational symmetry as one might think, but the existence of four 3-fold rotational axes!

Okey, now we will leave the external symmetry of crystals, and in the next unit we will explore translational symmetry in the plane - we will deal with plane groups or wallpaper groups as they are also called...