What parameters limit my choices of synthetic route and target composition?

The goal of the research project is to find new, environmentally friendly, inorganic pigments to replace traditional yellow, orange and red pigments. Each of these parameters places some limitations on your choice of a target stoichiometry. Let’s consider each in turn.

Yellow, Orange or Red Pigments

Your lab section has been divided into three color groups: yellow, orange and red. The yellow group is trying to find a replacement for CdS, Cadmium Yellow. The orange group is trying to find a replacement for CdS$_{1-x}$Se$_x$, Cadmium Orange. The red group is trying to find a replacement for HgS, vermillion.

New Pigments

Strictly speaking to be a new pigment your compound needs to be a compound that has not previously been made and reported. For our purposes we will consider the CRC Handbook of Chemistry and Physics to represent all known compounds (though in fact the CRC handbook does not list many known compounds, for example there is at least one commercial yellow pigment I know of that is not listed in the CRC Handbook). Therefore, you should come to lab on Monday/Tuesday with one or more target compositions that are not found in the CRC handbook.

Many of you might feel the prospect of finding a new compound to be a daunting assignment for a general chemistry student. In a sense it is, but there are several factors that make less formidable than it seems at first glance. One possible route is to study solid solutions. Unlike a molecule, an extended solid can have variable composition. For example, pigments ranging from yellow to orange through red can be obtained by preparing solid solutions of CdS and CdSe. These compounds are not heterogeneous mixtures of yellow CdS crystals and black CdSe crystals. Rather they are homogeneous mixtures where the sulfide ions are randomly replaced by selenide ions. Solid solutions are not reported in the CRC handbook so they clearly offer a wide range of possibilities for your target stoichiometry.

We are adopting a combinatorial approach to the search for new pigments. Combinatorial chemistry is based on the idea that using automated methods it is possible to prepare a large number of samples and then look at the properties of all of the compounds prepared, with the hope of finding a few compounds have promising properties. For this experiment we are using students in place of the robots that are normally employed in combinatorial chemistry. We are also deviating from the strict combinatorial approach by asking for your intellectual input as to what compositions might make a good pigment. Still I realize that you are relative newcomers to chemistry and I fully expect that (a) not all of the pigments will turn out to be close to the target color, (b) many of you may propose target compositions that I would never dream of, and (c) some of you may end up making different compounds from the ones that you are trying to make. However, it is these very uncertainties that make me hopeful that you might discover something new that I would never think of.

Environmentally Friendly Pigments

Given the fact that we are looking for pigments that are environmentally friendly, certain elements will not be allowed. Furthermore, some elements are either too expensive or radioactive to realistically consider. Therefore, the following elements are excluded:

Excluded due to Toxicity*
• Cadmium (Cd)
• Mercury (Hg)
• Thallium (Tl)
• Chromate (CrO$_4^{2-}$)

*Excluded due to Cost*
• The Platinum Group Metals: (Au, Pt, Pd, Rh, Ir, Ru, Os)
• The Lanthanides, except Cerium (Ce)

*Excluded due to Radioactivity*
• All elements with atomic numbers larger than 83 (Po to U)
• Technetium (Tc)

*Lead is not strictly forbidden because it is much less toxic than many of its neighbors, such as Cd, Hg and Tl. However, it does have negative environmental properties which make it less than ideal. It is almost certain that no company would actually produce new pigments based on lead.*

**Inorganic Pigments**

Inorganic pigments generally have much better stability to light and heat than do organic pigments and dyes. In this module we are specifically targeting inorganic pigments. Therefore, all compositions must contain a metal.

**Design Parameters**

Taking into account all of the above considerations each color subgroup (8-9 students) will be instructed to come up with pigment compositions that meet the following criteria:

1. No two students in the group may choose the same compositions
2. No more than 2 students in the group may prepare compounds that have either been prepared earlier in a general chemistry lab or are listed as pigments on the “Pigments through the Ages” website
3. No more than two students may prepare compounds that are found in the CRC Handbook of Chemistry and Physics (but are not limited by restriction #2).
4. No more than two compositions in each group may belong to the same solid solution series.

We are allowing some students in each group to prepare known compounds as a point of reference. It will be up to each group to decide which students, if any, will be allowed to make compounds that are limited by restrictions 2 and 3 above.