Examrace

Competitive Exams: Minerals

Geologists know about thousands of minerals locked in rocks, but when rocks are exposed at the surface and weather away, less than 10 minerals remain. They are the ingredients of sediment, which in turn becomes sedimentary rock. When the mountains crumble to the sea, all of their rocks, whether igneous, sedimentary or metamorphic, break down. Physical or mechanical weathering reduces the rocks to small particles. These break down further by chemical weathering in water and oxygen. A very small number of minerals can resist indefinitely: Zircon is one and native gold is another. Quartz resists for a very long time, which is why sand, being nearly pure quartz, is so persistent, but given enough time even quartz dissolves into silicic acid, H_4SiO_4.

But most of the silicate minerals produce solid residues after chemical weathering. Silicate residues are what make up the minerals of the Earth's land surface.

The olivine, pyroxenes and amphiboles of igneous or metamorphic rocks react with water and leave behind rusty iron hydroxides. These are an important ingredient in soils but uncommon as solid minerals. They also add brown and red colors to sedimentary rocks.

Feldspar, the most common silicate mineral group and the main home of aluminum in minerals, reacts with water too. Water pulls out silicon and other major cations (positive ions) except for aluminum. The feldspar minerals thus turn into hydrated aluminosilicates that is, clays.

Amazing Clays

Clay minerals are not much to look at, but life on Earth depends on them. At the microscopic level, clays are tiny flakes, like mica but infinitely smaller. At the molecular level, clay is a sandwich made of sheets of silica (SiO_4) tetrahedra and sheets of magnesium or aluminum hydroxide ($Mg(OH)_2$ and $Al(OH)_3$). Some clays are a proper three-layer sandwich, a Mg/Al layer between two silica layers, while others are open-face sandwiches of two layers.

What makes clays so valuable for life is that with their tiny particle size and open-faced construction, they have very large surface areas and can readily accept many substitute cations for their Si, Al and Mg atoms. Oxygen and hydrogen are available in abundance. From the viewpoint of microbes, clay minerals are like machine shops full of tools and power hookups. Indeed, even the building blocks of life amino acids and other organic molecules are enlivened by the energetic, catalytic environment of clays.

The Makings of Clastic Rocks

But back to sediments. With quartz and clay, the overwhelming majority of surface minerals, we have the ingredients of mud. Mud is what geologists call a sediment that is a mixture of particle sizes ranging from sand (visible) to clay (invisible), and the world's rivers steadily deliver mud to the sea and to large lakes and inland basins. That is where the clastic sedimentary rocks are born, sandstone and mudstone and shale in all their variety.

The Chemical Precipitates

When the mountains were crumbling, much of their mineral content dissolved. This material reenters the rock cycle in other ways than clay, precipitating out of solution to form other surface minerals.

Calcium is an important cation in igneous rock minerals, but it plays little part in the clay cycle. Instead calcium remains in water, where it affiliates with carbonate ion (CO_3). When it becomes concentrated enough in seawater, calcium carbonate comes out of solution as calcite. Living organisms can extract it to build their calcite shells, which also become sediment.

Where sulfur is abundant, calcium combines with it as the mineral gypsum. In other settings, sulfur captures dissolved iron and precipitates as pyrite.

There is also sodium left over from the breakdown of the silicate minerals. That lingers in the sea until circumstances dry up the brine to a high concentration, when sodium joins chloride to yield solid salt, or halite. And what of the dissolved silicic acid? That precipitates underground, from deeply buried fluids, as the silica mineral chalcedony. Thus every part of the mountains finds a new place in the Earth.

Minerals, Gemstones & Mineral Resources

What is a Mineral?

A mineral is any substance with all of four specific qualities.

1. Minerals Are Natural: Substances that form without any human help.
2. Minerals Are Solid: Substances that don't droop or melt or evaporate.
3. Minerals Are Inorganic: Substances that aren't carbon compounds like those found in living things.
4. Minerals Are Crystalline: Substances that have a distinct recipe and arrangement of atoms.

Unnatural Minerals

Until the 1990s, mineralogists could propose names for chemical compounds that formed during the breakdown of artificial substances, things found in places like industrial sludge pits and rusting cars (although iron rust is the same as the natural minerals hematite, magnetite and goethite). That loophole is now closed, but there are minerals on the books that aren't truly natural.

Soft Minerals

Traditionally, native mercury is considered a mineral, even though the metal is liquid at room temperature. At about 40 degrees below zero, mercury solidifies and forms crystals like other metals. So there are parts of Antarctica where mercury is unimpeachably a mineral.

For a less extreme example, consider the mineral ikaite, a hydrated calcium carbonate that forms only in cold water. It degrades into calcite and water above 8 degrees Celsius. It is significant in the polar regions, the ocean floor and other cold places, but you can't bring it into the lab except in a freezer.

Ice is a mineral, even though it isn't listed in the mineral field guide. But when ice collects in large enough bodies, it flows in its solid state, that's what glaciers are. And salt (halite) behaves similarly, rising underground in broad domes and sometimes spilling out in salt glaciers. Indeed, all minerals, and the rocks they are part of, slowly deform given enough heat and pressure. That's what makes plate tectonics possible. So in a sense, no mineral is really solid except maybe diamond.

Other minerals that aren't quite solid are instead flexible. The mica minerals are the best-known example, but molybdenite is another. Its metallic flakes can be crumpled like aluminum foil. And of course the asbestos mineral chrysotile is stringy enough to weave into cloth.

Organic Minerals

The rule that minerals must be inorganic may be the strictest one. The substances that make up coal, for instance, are different kinds of hydrocarbon compounds derived from cell walls, wood, pollen and so on. These are called macerals instead of minerals (for more see Coal in a Nutshell). But if coal is squeezed hard enough for long enough, the carbon sheds all its other elements and becomes graphite. Even though it is of organic origin, graphite is a true mineral, carbon atoms arranged in sheets. Diamond, similarly, is carbon atoms arranged in a rigid framework. After some 4 billion years of life on Earth, it's safe to say that all the world's diamonds and graphite are of organic origin even if they aren't strictly speaking organic.

Amorphous Minerals

A few things fall short in crystallinity, hard as we try. Many minerals form crystals that are too small to see under the microscope. But even these can be shown to be crystalline at the nano-scale using the technique of X-ray powder diffraction, though, because X-rays are a super-short-wave type of light that can image extremely small things.

Having a crystal form means that the substance has a definite recipe, or chemical formula. It might be as simple as halite's (NaCl) or complex like, say, epidote (Ca2Al2 (Fe3 +, Al) (SiO4) (Si2O7) O (OH)), but if you were shrunk to an atom's size, you could tell what mineral you were seeing by its molecular makeup and arrangement.

But a few substances fail the X-ray test. They are truly glasses or colloids, with a fully random structure at the atomic scale. They are amorphous, scientific Latin for "formless." These get the honorary name mineraloid.

Mineraloids are a small club: Strictly speaking it includes only opal and lechatelierite. Opal is a nearly random combination of silica (SiO_2, the same as quartz) and water formed under near-surface conditions, while lechatelierite is a quartz glass formed by the shock of a meteorite impact or lightning striking the ground.

Other substances considered mineraloids include the gemstones jet and amber, which are respectively high-quality fossils of coal and tree resin. Pearl goes here too, although I disagree because by that logic, seashells should be included. The last mineraloid is rather like the rusty car I mentioned earlier: Limonite is a mixture of iron oxides that, while it may assume the shape of a proper iron-oxide mineral, has no structure or order whatever.

Examine Mineral

Steps to Mineral Identification: The first thing to do is to observe and test your mineral. Use the largest piece you can find, and if you have several pieces, make sure sure that they are all the same mineral. Examine your mineral for all of the following properties, writing down the answers. After that you'll be ready to take your information to the right place.

- Step 1: Pick Your Mineral
- Step 2: Luster. Luster is the way a mineral reflects light and the first key step in mineral identification. Look for luster on a fresh surface. The three major types of luster are metallic, glassy (vitreous) and dull. A luster between metallic and glassy is called adamantine, and a luster between glassy and dull is called resinous or waxy.
- Step 3: Hardness. Use the 10-point Mohs hardness scale. The important hardnesses are between 2 and 7. For this you'll need your fingernail (hardness about 2), a coin (hardness 3), a knife or nail (hardness 5.5) and a few key minerals.
- Step 4: Color. Color is important in mineral identification, but it can be a complicated subject. Experts use color all the time because they have learned the usual colors and the usual exceptions for common minerals. If you're a beginner, pay close attention to color but do not rely on it. First of all, be sure you aren't looking at a weathered or tarnished surface, and examine your specimen in good light. Color is a fairly reliable indicator in the opaque and metallic minerals for instance the blue of the opaque mineral lazurite or the brass-yellow of the metallic mineral pyrite. In the translucent or transparent minerals, color is usually the result of a chemical impurity and should not be the only thing you use. For instance, pure quartz is clear or white, but quartz can have many other colors.
- Step 5: Other Mineral Properties. Taste is definitive for halite (rock salt), of course, but a few other evaporite minerals also have distinctive tastes. Just touch your tongue to a fresh face of the mineral and be ready to spit after all it's called taste, not flavor. Don't worry about

taste if you don't live in an area with these minerals. Fizz means the effervescent reaction of certain carbonate minerals to the acid test. For this test, vinegar will do. Heft is how heavy a mineral feels in the hand, an informal sense of density. Most rocks are about three times as dense as water, that is, they have a specific gravity of about 3. Make note of a mineral that is noticeably light or heavy for its size.

- Step 6: Look It Up. Now you are ready for mineral identification. Once you have observed and noted these mineral properties, you can take your information to a book or to an online resource. Start with my table of the rock-forming minerals, because these are the most common and the ones you should learn first. Each mineral's name is linked to a good photograph and notes to help you confirm the identification. If your mineral has metallic luster, go to my Minerals with Metallic Luster gallery to see the most likely minerals in this group. If your mineral is not one of these, try the sources in the Mineral Identification Guides category.