Quadrant II – Notes

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Module Name: **Isomorphism, polymorphism and pseudomorphism**

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Notes:

Isomorphism:

- Calcite, rhodochrosite and siderite all look similar.
- Each is a carbonate, the only difference is that calcite contains calcium in addition to the carbonate radical, rhodochrosite contains manganese and siderite contains iron and all of them crystallize in the same pattern as that of calcite.
- It is possible to have similar atomic structures with differing atoms in similar positions. Hence, those minerals having differing chemical compositions but same atomic framework are called isomorphs.
- This can happen due to the similarity in atomic size and electrical properties, and this substitution is called isomorphous substitution.

Polymorphism

- Polymorphism means "many forms".
- **In mineralogy it means that a single chemical composition can exist with two or more different crystal structures.**

- If a crystal is subjected to different pressures and temperatures, the arrangement of atoms depends on the sizes of the atoms, and the sizes change with temperature and pressure.
- In general, as pressure increases the volume of a crystal will decrease and a point may be reached where a more compact crystal structure is more stable.
- The crystal structure will then change to that of the more stable structure, and a different mineral will be in existence.
- Similarly, if the temperature is increased, the atoms on the crystal structure will tend to vibrate more and increase their effective size.
- In this case, a point may be reached where a less compact crystal structure is more stable.
- When the crystal structure changes to the more stable structure a different mineral will form.
- **The change that takes place between crystal structures of the same chemical compound are called polymorphic transformations.**

Types of polymorphic transformations

- Al_2SiO_5 - has three polymorphs. The high pressure form is **kyanite** (Triclinic), the high temperature form is **sillimanite** (orthorhombic), and the low temperature, low pressure form is **andalusite** (orthorhombic). Transformations between all three polymorphs are reconstructive, thus all three forms can metastably exist at the Earth's surface. Transformation rates are somewhat faster, however, at higher temperatures in the Earth.
- SiO_2 - has 6 polymorphs. With decreasing temperature at low pressure, **cristobalite** (isometric) undergoes a reconstructive transformation to **tridymite** (hexagonal). Further lowering of temperature results in tridymite undergoing a reconstructive transformation to **high quartz** (also hexagonal). Lowering temperature further results in high quartz undergoing a displacive transformation to **low quartz**.
- Cristobalite and tridymite can exist metastably at the low temperatures near the Earth's surface, and thus are found in rocks. But high quartz

will also transform to low quartz before it reaches temperatures present at the Earth's surface, so it is never found in rocks.

- With increasing pressure, at low temperature low quartz undergoes a displace transformation to **coesite** (Monoclinic), and coesite undergoes a reconstructive transformation to **stishovite** (tetragonal) at even higher pressures. Thus, coesite and stishovite have metastable polymorphs that can be found in rocks.

Pseudomorphism

- Pseudomorphism is the existence of a mineral that has the appearance of another mineral. Pseudomorph means false form. Pseudomorphism occurs when a mineral is altered in such a way that its internal structure and chemical composition is changed but its external form is preserved. *Three mechanisms of pseudomorphism can be defined*:

- Substitution: In this mechanism chemical constituents are simultaneously removed and replaced by other chemical constituents during alteration. An example is the replacement of wood fibers by quartz to form petrified wood that has the outward appearance of the original wood, but is composed of quartz. Another example is the alteration of fluorite which forms isometric crystals and is sometimes replaced by quartz during alteration. The resulting quartz crystals look isometric, and are said to be pseudomorphed after fluorite.

- **Encrustation**: If during the alteration process a thin crust of a new mineral forms on the surface of a preexisting mineral, then the preexisting mineral is removed, leaving the crust behind, we say that pseudomorphism has resulted from encrustation. In this case the thin crust of the new mineral will have casts of the form of the original mineral.

- **Alteration**: If only partial removal of the original mineral and only partial replacement by the new mineral has taken place, then it is possible to have a the space once occupied entirely by the original mineral be partially composed of the new mineral. This results for example in serpentine pseudomorphed after olivine or pyroxene, anhydrite ($CaSO_4$) pseudomorphed after gypsum ($CaSO_4 \cdot 2H_2O$), limonite [$FeO \cdot (OH) \cdot nH_2O$] after pyrite ($FeS_2$), and anglesite ($PbSO_4$) after galena (PbS).