Lecture Notes 12.001 Introduction into Minerals
O.Jagoutz

Why should we learn about minerals?
Mineral type, composition and shape define the rock type-> Geology
Mineral chemistry defines the chemical composition of a rocks-> Geochemistry
Mineral properties define the physical properties of rocks-> Geophysical/rheology
Fusibility of minerals control the composition of a melt derived from a rock->igneous petrology
Minerals react to changing P,T conditions-> metamorphic petrology
Ultimately minerals control e.g. the composition of seawater through weathering → input in the ocean, sequestering of elements in the altered oceanic crust
On the other hand, interaction between ocean and oceanic crust (clay minerals) → output (draw a simple diagram)

So essentially minerals control everything, and without a solid understanding of minerals it is impossible to understand earth processes.
The bad news is we know ~ 4000 different minerals, the good news is most rocks of the accessible earth are >95% made up by ~ two handfuls of minerals.

<u>Define: What is a mineral:</u> A solid with a highly ordered atomic arrangement and a definite (but not necessarily fixed) homogenous chemical composition.

<u>Highly ordered atomic arrangement:</u> internal structural framework of atoms/ions arranged in a regular repeating geometric pattern. -> crystalline (compared to amorphous)

Definite but not necessarily fixed composition: varies within limits. Implies the composition of a mineral can be expressed by a specific chemical formula.
e.g Quartz Si:O 1:2-> SiO_2
Most minerals however are solid solutions: composition can vary in certain limits:
e.g. Olivine (Fe,Mg):Si:O 2:1:4 → $(Mg,Fe)_2SiO_4$ but can be anything between the two end-members Forsterite Mg_2SiO_4 and Fayalite Fe_2SiO_4. In this case we have a complete solid solution between Fe and Mg.
On the other hand, other minerals show immiscibility (e.g. solvus) at certain conditions e. g. $CaMgSi_2O_6$ and $Mg_2Si_2O_6$ (draw the solvus diagram and explain its use as a thermometer.)

Sometimes we have a solid solution between two types but not the third one (explain the feldspar diagram and its temperature dependence as they have this texture in the K-feldspar).

Types of minerals:

There are many different ways to describe types of minerals. One common way is to describe them based on their anionic groups:

Oxides (O^{2-}), sulfides (S^{2-}), sulfates SO_4^{2-}, silicates (SiO_4^{4-}), halites (F^-,Br^-,Cl^-), carbonates (CO_3^{2-})etc…
By far the most important groups are silicates, carbonates, oxides

Silicates: the principal building blocks of silicates are SiO_4^{4-} tetrahedra. There are numerous different ways to arrange the tetrahedra (show diagram from the book)
I don't expect you to know all the different silicate types in detail. It is important to understand the arrangement of these tetrahedra as well the chemical composition of the silicates as they control certain properties. Depending on the way we arrange them we produce certain gaps between the tetrahedra that allow the mineral to incorporate different cations. The "gaps" are called sites and are named differently. The arrangements of the tetrahedra control certain physical properties of the minerals. I like to give two detailed examples of a chain silicate (pyroxene) and a double chain silicate (amphibole), draw a picture of them, explain the sites and explain the importance of the ring structure as it can incorporate OH groups-> water ->hydrous minerals. Certain common minerals can have up to 10 wt% H_2O in them. They are like a sponge. They suck up water and allow water to be transported into the deep earth, which as we will see later is very important for the most dangerous type of volcanism we have on earth that forms above subduction zones. And ultimately also in the production of the continental crust.

Explain the different cleavage pattern of the two minerals (90,120) and the shape of crystals)

So how can we identify minerals? There are laboratory methods like X-ray diffraction - when you walk along the endless corridor you see an x-ray diffraction lab which is used to measure the spacing between different atoms in minerals and this can be used to determine the mineral.

But here we use a combination of hands-on methods to identify minerals because once you have learned them they are fast and easy and we can use them when we are out in the field and don't have to bring every rock back into the lab. The most important aspect of identifying minerals and therefore the rock is…looking at them. And as minerals are often relatively small we use hand lenses to help. Explain how a hand lens is correctly used.

Mineral determination:
Important aggregate : mineral difference

Crystal shape: (if perfectly developed): prismatic/elongated, tabular, cubic (draw picture)
Crystal habit: the general shape of a crystal Euhedral, subhedral, anhedral

Mechanical properties:

-Cleavage: is the tendency of a mineral to break along regular parallel planes. Cleavage occurs because minerals have weaker bonds in one direction than in the other. Sequence of parallel steps along these directions; cleavage is described by the number of cleavage planes and their quality (perfect, good, fair, poor, absent)

-Parting: like cleavage but not smooth surfaces controlled by the crystal but induced by external forces or defects (e.g. corundum – no cleavages, but strong parting).

-Fracture: absence of a preferred orientation of weakness ->conchoidal fracture olivine, quartz, garnet - very diagnostic

Density: experience or lab measurements
Hardness: the resistance of a mineral to form microfractures (i.e. to be abraded). Relates to mineral type oxides, silicates= hard, most hydrous minerals soft, very diagnostic often identification tables are grouped based on hardness.
F Mohs in 1812 chose 10 common mineral to define what I snow called the Mohs relative hardness scale:
1 Talc, 2 Gypsum, 3Calcite, 4 Flourite, 5 Apatite, 6 Orthoclase, 7 Quartz, 8 Topaz, 9 Corundum, 10 Diamond in reality the Mohs hardness is near-exponential in terms of absolute hardness.
Additionally we have certain tools to help: fingernail: ~ 2.2; cooper penny 3.2; pocket knife ~5.1, glass plate 5.5

Color: relates to the chemistry of a mineral - can be very useful (olivine, clinopyroxene) or completely useless (Tourmaline)-> experience….
Diaphaneity - transparent, translucent, opaque
Luster: the general appearance of a mineral in reflected light: metallic/non-metallic
Streak: the color of the mineral in a finely powdered form - especially useful for oxides

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