Lesson Three: Minerals

Background Reading Part I: Basic Chemistry of Rock Forming Minerals

Minerals are defined as having a definable chemical composition. For example, the mineral quartz always has the composition of SiO_2. This means it is made of building blocks that include one silicon atom linked to two oxygen atoms. You can think of these as Lego blocks that are all the same. A single crystal may have millions of these blocks all stacked together to make the crystal that you hold in your hand. To understand minerals, we must understand what we mean by an element (such as silicon or oxygen), and how the presence of certain elements and their linking together (bonding) influences the mineral properties such as hardness, color, density, ability to cleave, and crystalline form.

In addition, it is important to recognize that although minerals have a definable chemistry, they can appear different due to a slight impurity added to the mineral chemistry. For example, amethyst (beautiful purple colored mineral) is really just quartz. However, a small amount of iron has been added to the SiO_2chemistry. It may help to think of these impurities as being like a drop of food coloring added to an ice cube. The ice is still basically H_2O, but adding food coloring can result in green ice, even though the coloring represents less than 1% of the composition of the ice cube. Likewise, Rose Quartz takes its color from impurities of titanium within the crystal.

Here are some basic aspects of chemistry we need to understand minerals:

Element: a substance that cannot be decomposed into simpler substances by ordinary processes. There are 92 naturally occurring elements. The atom is the smallest particle that exists as an element.

Common Elements in the crust: Oxygen (O), Silicon (Si), Aluminum (Al), Iron (Fe), Magnesium (Mg), Calcium (Ca), Potassium (K), Sodium (Na)

The table below lists the common elements found in the crust.

Negative Anion	Positive Cation
O^{2-}	Si^{4+} Al^{3+} Fe^{3+} Mg^{2+} Fe^{2+} Na^{1+} Ca^{2+} K^{1+}

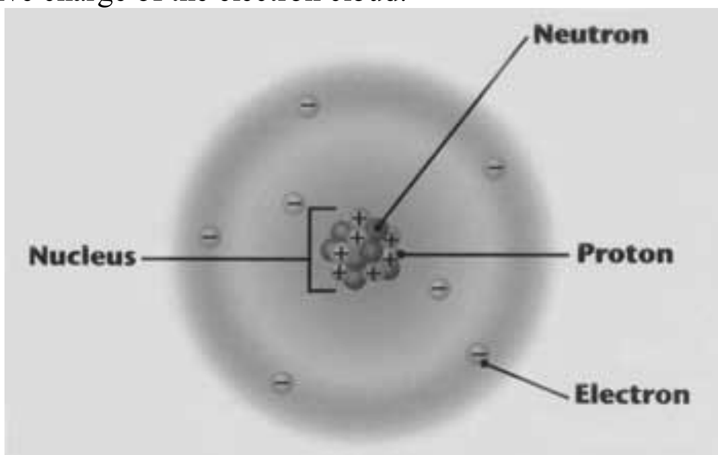
Note that the elements listed in the table above are listed as either negative or positive ions (Anion or Cations).

What is an ion?

Ions: An atom or molecule that possesses an electrical charge. This is due to an atom gaining or losing an electron.

Cations (positive charge, lost electrons), **Anions** (negative charge, gained electrons)

In order to understand why ions form, we need to understand the basic structure of an atom. Atoms are composed of a nucleus with neutrons and protons and a surrounding electron cloud. The neutrons have no charge, the protons have a positive charge, and the electrons have a negative charge. The positive and negative charges attract so the protons attract the negative charge of the electron cloud.



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The number of protons in the atom's nucleus defines the element. So, for example, Oxygen shows up on the periodic table as 8, because it has 8 protons in its nucleus. Silicon (Si) has 14 protons and it is listed as number 14 on the periodic table.

Ideally, there is a balance between the number of protons and electrons to make the total charge of the atom zero. Thus you might predict that Oxygen would have 8 protons and 8 electrons. This would be +8 and –8. Add these together and you get zero. However, there is a "tendency" of some atoms to gain or lose electrons. Oxygen has a tendency to gain two electrons. When this happens it then has +8 (protons) and –10 (electrons). This causes the total charge to be –2, (because +8 –10 = -2). This tendency is represented on the table of common elements presented above as O^{2-}. When an atom has a negative charge, like oxygen, we call it an **Anion**.

So, here's the tricky part – what made oxygen an anion? Was it the gaining of electrons or the loss of electrons? If you say gaining electrons, you are correct. This means that a gain of electrons makes an ion negative. Do you see why this can be confusing? It is a gain of something (negative electrons) that makes the atom negative, or an anion.

Following this same pattern, if an atom loses electrons (which are negative), the atom becomes more positive. If the atom has a positive charge it is called a **Cation.**

A way to remember that cations are positive (and anions are negative) is to remember that the word "cation" has the letter "t" and that the "t" looks like a plus sign. Also the prefix "a" or "an" means "not" or negative. If something is "atypical" it is not typical. Thus, an anion is negative.

Notice that most of the common elements in the earth's crust are cations (Silicon, Iron, Potassium, Calcium, Sodium, Aluminum, Magnesium). Oxygen is the only common anion in the table above.

Why do we care about ions?
Since positive and negative charges attract, anion and cations will attract and form compounds. These are building blocks of minerals. Look again at the table of common elements in the earth's crust. Notice that there is only one anion in this table. That means that this particular anion (oxygen) has to be involved in a lot of the "gluing together" of ions to form minerals. For this reason, Oxygen is the most common element in the Earth's crust. It seems strange, but when you are walking across a rocky field, beach, or mountain top, you are walking mostly on oxygen!

We call the process of ions "gluing together" – **Bonding.**
Two common types of atomic bonds are **ionic and covalent bonding.**

A bond that forms due to the ***exchange*** of electrons between a positive cation and a negative anion is called an **Ionic Bond**. The key word in this definition is ***exchange.*** **Ionic bonding is due to an exchange of electrons.** Common table salt (sodium chloride) is formed due to ionic bonding of Na^+ and Cl^-
An ionic bond tends to be weaker than a covalent bond. Thus, salt is not very hard.

Bounding that involves the ***sharing*** of electrons is called **Covalent Bond**. In this case one electron actually occupies the outer electron cloud of two atoms at once (yes, this is strange) and provides the added negative charge to pull the two atoms together. The key word in this definition is ***sharing***. **Covalent bonding is due to the sharing of electrons**. Diamonds are covalently bonded carbon atoms.
A covalent bond tends to be stronger than an ionic bond. Thus, diamond is very hard.

Why do we care about bonding?
Bonding determines mineral composition.
Bonding explains properties: hardness, cleavage, color, crystalline structure
Bonding explains tendency to change: oxidation, leaching of elements.

Worksheet 3.1: Basic Chemistry of Minerals

1. Silicon (Si) has a tendency to lose 4 electrons. This results is a charge of _____
2. Oxygen (O) has a tendency to gain 2 electrons. This results is a charge of _____
3. Which one of the two ions described above is considered a cation? ________

4. Use your answers from 1 and 2 to determine the charge of SiO_4. Assume the charges you listed as the answers as the charges for each atom in the molecule SiO_4. Remember SiO_4 consists of one silicon atom and four oxygen atoms, so you will need to add up the total charge for one silicon atom and four oxygen.

5. How many Magnesium ions does the SiO_4 ion need to bond with to provide a neutral charge? The charge for Magnesium results from losing two electrons. This is the formula for the mineral Olivine (gem quality olivine is called peridot)

6. A common way for minerals to form is through the cooling (or freezing) of magma. Do you think all minerals form from in this manner? If not, think of an example of another way a mineral could form.

7. Quartz (SiO_2) is a very common mineral but large well-formed crystals, like the one pictured at right are relatively rare. Describe a possible scenario in which a well-formed crystal like this one could form.

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Background Reading Part II: Mineral Identification

Goals: Our goal in this lab is to become familiar with common physical properties of rock forming minerals and learn some basic techniques of mineral identification.

Background: Each mineral is characterized by a specific chemistry and internal structure. As a result, all specimens of a particular mineral will possess diagnostic physical properties. The physical properties of minerals we will investigate are: **Cleavage, Hardness, Color, Density, Luster, and Reaction to Hydrochloric Acid**. Other properties you might consider are Crystal Form, Taste, Magnetism, Streak, and Optical Properties.

You will only be responsible for the following common rock forming minerals on the lab exam: **Quartz, Potassium Feldspar, Plagioclase Feldspar (light and dark), Muscovite, Biotite, Amphibole (Hornblende), Pyroxene (Augite), Olivine, Calcite, Halite, Gypsum, Galena, and Pyrite.**

The following includes some additional information that will help with understanding the differences and similarities of these minerals. Remember we are focusing on some of the most common minerals found in the earth's crust (other than galena).

Quartz.

- Quartz can occur as either visible crystals or as aggregates of very small crystals.
- Quartz often endures the earth's erosive processes because it is hard and lacks cleavage. This hardness allows it to be polished (by nature or rock tumblers) and is one of the reason it is often used as a gemstone.
- Small impurities of other elements can give quartz different colors, bands, or patterns.
- Much of the cryptocrystalline quartz (agate, chert, etc.) forms when silicon dioxide crystallizes (precipitates) from groundwater.

Feldspar. Feldspars are a very common mineral in igneous rocks. However, their excellent cleavage and chemistry cause them to easily weather to clays. Therefore they are not as common away from their source areas (such as large granite outcrops) as quartz.

- Feldspar is a mineral group that includes Potassium Feldspar and Plagioclase Feldspars.
- The Plagioclase Feldspars are a subgroup of feldspars that range from light-colored Albite (sodium-rich) to dark-colored Anorthite (calcium-rich).
- Plagioclase can sometimes be distinguished from the Potassium Feldspars by the existence of striations (fine parallel grooves on the mineral surface).

Micas- This includes both **Muscovite and Biotite** that have similar hardness and cleavage

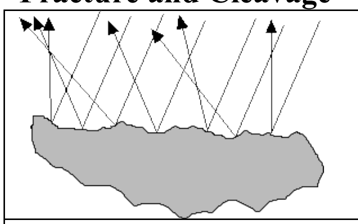
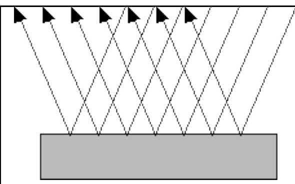
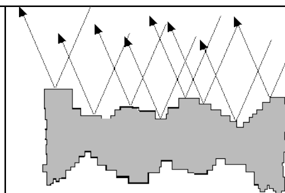
Amphibole and Pyroxene – These are both dark minerals with similar hardness. The cleavages on these minerals can be difficult to determine, but amphibole does not have 90 degree cleavages and Pyroxene does have 90 degree cleavages. This can be used to distinguish the two.

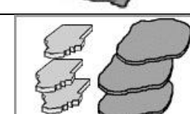
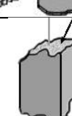
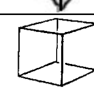
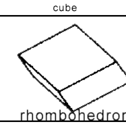
Aggregates – some of our specimens occur as aggregates of very small crystals (**olivine and pyrite**). Consequently it may be difficult to determine hardness and cleavage for these specimens.

Moh's Scale of Hardness

Moh's Scale and Minerals	**Hardness of Common Objects**
10 – Diamond	
9 – Corundum	
8 – Topaz	
7 – Quartz	**6.5- Streak Plate**
6 – K-Feldspar (orthoclase)	
5 – Apatite	**5. 5 – Glass, Knife Blade**
4 – Fluorite	**4.5 – wire, iron nail**
3 – Calcite	**3.5 – penny**
2 – Gypsum	**2.5 - fingernail**
1 - Talc	

Fracture and Cleavage – light reflection

		
Fracture – light is scattered by irregular surfaces	Perfect Cleavage – flat surface reflects all light in the same direction	Multiple Cleavage surfaces reflect light in the same direction to produce a "flash" when the specimen is turned in the light

Number of Cleavages	**Description**	**Diagram**
0	Irregular Masses without shiney surfaces	
1	Basal - "books" split apart along the base	
2 @90	Prisms – rectancular sections	
2 not @90	Prisms without right angles	
3 @ 90	Cubic	
3 not @ 90	Rhombic Cleavage – look like skewed cubes	

Name:____ Date:______

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Lab 3.2: Known Minerals

Task: Investigate the lab specimens to complete the mineral property chart below and indicate the most diagnostic properties for each mineral.

Mineral Properties

Name	Silicate or Nonsilicate	Hardness	Cleavage (number and angles); or Fracture	Color	Other: Unique Density, Streak, Acid Reaction, Metallic Luster
Quartz					
Muscovite					
Biotite					
K-Feldspar (Orthoclase)					
Na-Plagioclase Feldspar					
Ca-Plagioclase Feldspar					
Amphibole (variety Hornblende)					
Pyroxene (variety Augite)					
Olivine					
Calcite					
Gypsum					
Halite					
Pyrite					
Galena					

Lab 3.3: Unknowns

Identify the unknown mineral samples and state the distinguishing properties that were most helpful to you in identifying the mineral.

Specimen	**Mineral Name**	**Key Properties**
A		
B		
C		
D		
E		
F		
G		
H		
I		
J		
K		
L		
M		
N		
O		

Identify the minerals present in the provided rock samples:

Rock 1	**Rock 2**	**Rock 3**	**Rock 4**	**Rock 5**

Lab 3.4: Special Minerals

Investigate **at least two** of the "Additional Minerals" provided. DO NOT scratch these minerals or apply acid. Please treat them gently. You can use the reference material provided to answer the questions.

For each mineral indicate:

1. **Describe the mineral color and other visual appearances**
2. **Describe the mineral shape (e.g., bladed, cubic, columns, hexagonal, etc)**

Use the references to answer the following:

3. **Hardness and specific gravity (or density), distinguishing features**
4. **List the formula for the mineral**
5. **Indicate if the mineral is a silicate or a non-silicate.**
6. **If it is a non-silicate, indicate the specific mineral class (e.g., oxide, halide, etc.)**
7. **Briefly describe the environment of formation**

Mineral:	**Mineral:**
1	**1**
2	**2**
3	**3**
4	**4**
5	**5**
6	**6**
7	**7**

Minerals Quiz Review Sheet

Examples of Questions:

- Describe the distinguishing properties of the mineral in this aggregate
- List the mineral name
- Describe, as completely as possible, the cleavage of this mineral
- Describe the hardness of this mineral (this is **not** a mineral we saw in the lab)
- List a property that allows you to distinguish this mineral from others we have examined in the lab.
- List two of the minerals present in this rock
- List the hardness of this mineral

You are responsible for the following mineral properties:
Color
Streak
Hardness
Cleavage Planes and Angles (or fracture)
Acid Reaction
Density
Distinguishing Properties (how you tell this mineral from one that may be similar)

You are responsible for identifying the following minerals:
Quartz, Muscovite, Biotite, Potassium Feldspar, Sodium Plagioclase Feldspar, Calcium Plagioclase Feldspar, Amphibole (hornblende), Pyroxene (augite/hypersthene), Olivine
Calcite, Halite, Gypsum, Pyrite, Galena

Notes: You can use one side of 8.5x11 paper with your own notes – typed or hand written.
NOT ALLOWED:

- Any of the tables or charts in this lab book unless you type or write it onto a new sheet.
- Photocopies or scans of the lab, book, or another student's work]
- Photographs of minerals
- Consulting experts or other students during the exam

Photographs of our lab samples are available using the following link: http://tinyurl.com/g1mineral This link will also be available through Canvas. You will also have time to study the samples in the lab.