CHAPTER 2: MINERALS *Name: ______________*

Eight elements form 98% of the earth's crust. There are 92 naturally occurring elements. The rest are synthetically made and will not be discussed in this course.

Now a bit of a chemistry review. . .

An element cannot be broken down further chemically. An atom is the smallest unit of an element that keeps all chemical properties of the element.

Atoms are made of protons (positively charged particles in the nucleus), neutrons (neutral particles in the nucleus), and electrons (negatively charged particles outside of the nucleus).

The number of protons in the element determines what the element would be. The number of protons is called the atomic number. For example, if an element has 6 protons, it is always carbon and has an atomic number of 6.

If atoms have different numbers of neutrons but have the same number of protons, they are isotopes of each other. For example, carbon can have 6 neutrons, 7 neutrons, or 8 neutrons but it always has 6 protons.

The sum of the protons and the neutrons is called the atomic mass number.

Example: 6 protons in carbon + 6 neutrons = atomic mass of 12

When an atom loses or gains electrons, the atom becomes charged and is called an ion. If the atom loses electrons (less negative) and becomes positively charged, the ion is a cation. If the atom gains electrons (more negative) and becomes negatively charged, the ion is an anion.

Example: Na^+ has lost an electron an is a cation. Cl^- has gained an electron and is an anion.

Atoms on the left hand side of the periodic table tend to lose electrons (and become cations) while atoms on the right hand side of the periodic table gain electrons (and become anions). They want to be like noble gases so atoms alter their electronic configuration to be the same as a noble gas.

Metals are on the left side of the periodic table and non-metals are on the right side of the periodic table. Metals form cations and non-metals form anions. When 2 or more elements combine, a compound forms. (Like NaCl, H_2O, $C_6H_{12}O_6$, etc.)

- When a cation and an anion combine, an ionic bond forms. *Example: NaCl*
- When 2 non-metals share electrons, a covalent bond forms. *Example: CO_2*

Review:

1. Write isotope names for the following:
   ${}^{63}_{29}Cu$____________ ${}^{11}_{5}B$____________ ${}^{35}_{17}Cl$ ___________
2. Identify the isotope names for the following:
   ${}^{24}_{12}?$ ____________ ${}^{32}_{16}?$ ____________ ${}^{7}_{4}?$ ____________
3. Write isotope symbols for the following:

   Phosphorus-32 _____ Gold-198______ Iodine-127_____
4. Identify the number and type of atoms in each of the following molecules, and if the compound is ionic or covalent.

   a) NH_3

   b) $Fe(SCN)_3$

   c) $CaSO_4{\cdot}2H_20$

   d) water

   e) carbon dioxide

5. Complete the following table:

Isotope	Symbol	Mass Number	Atomic Number	Number of Protons	Number of Neutrons
Lithium-7					
Carbon-14					
	$^{196}_{78}Pt$				
		238	92		
				87	136

Questions:

1. Explain how, by using the periodic table, you can determine the number of:

    a. Protons in an atom.

    b. Neutrons in an atom.

    c. Electrons in an atom.

2. Explain the differences between an atom, an ion, a cation, an anion, a molecule and an isotope.

3. Explain the differences between pure metals, ionic compounds and covalent compounds in terms of their fundamental particles and the arrangements of these particles.

What is a Mineral?

A mineral is "an inorganic solid element or compound with a definite composition and a regular internal crystal structure".

There are over 2000 different minerals (compared to millions of compounds), but only a few dozen are found very commonly in/on the Earth. We call these the **rock-forming minerals**.

There are **5 key characteristics** which all minerals exhibit:

1) Naturally occurring – not invented by humans
2) Inorganic – not made *solely* by living organisms or biological processes
3) Solid – not liquid or gas
4) Definite composition – specific ratio of elements chemically combined (example is quartz: SiO_2)**
5) Crystalline structure – repeating patterns of the definite composition (example is quartz: repeating patterns of SiO_2)

Note: The definite chemical composition can be very complicated because various cations can substitute for each other but not change the basic composition or structural type. For example, iron and magnesium cations (Fe^{+2} and Mg^{+2}) can switch for each other because they are the same size and both have a charge of +2. Therefore, olivine, which has the formula $(Fe,Mg)_2SiO_4$, may contain either iron or magnesium (or both!) in its mineral structure.

*** Chemical composition may not be exactly the same but the charges balance and the structure is the same.* ***

The extremely dense core of the Earth is predominantly composed of iron and nickel, while the dense mantle is made up of iron/magnesium/ silicon/oxygen-based minerals. The least dense crust is made of a variety of 'lighter' elements that form most of the known minerals:

Oxygen (O)	=	47%
Silicon (Si)	=	28%
Aluminum (Al)	=	8%
Iron (Fe)	=	5%
Calcium	=	<4%
Sodium (Na)	=	<3%
Potassium (K)	=	<3%
Magnesium (Mg)	=	<2%
All others	=	~1.5%

<u>How do we identify minerals?</u>

Some minerals can look/feel similar at first glance (eg: there are at least 50 minerals that are 'green'), but when all of the properties are tested, each one ends with a unique *set* of characteristics.

To identify minerals, we use the following 10 properties:

1) **Colour** – not very reliable as most minerals are not pure. Quartz should be clear; however, it can be found milky white, purple, or various other colours. Frequently, these impurities make a mineral more valuable.

2) **Streak –** This is the colour of the powder of the mineral. It is found by streaking the material on an unglazed porcelain tile. Since the tile has a hardness of 6, minerals with a hardness of more than 6 will just scratch the tile and a white powder will appear. Since many minerals have the same-coloured streak, this is not always reliable.

3) **Lustre –** This describes the way a mineral shines. ***Don't confuse with cleavage.*** The following are types of lustre:
   - Vitreous or glassy – example is quartz
   - Pearly – examples are mica and pearls
   - Greasy – example is talc
   - Resinous – example is wax
   - Dull (no shine at all) – example is clay
   - Metallic – examples are any metal

4) **Hardness** – Moh's hardness scale is a relative hardness scale of minerals. For example, a fingernail has a hardness of 2.5. This means that it can scratch anything with a hardness less than 2.5. However, all minerals with a hardness more than 2.5 can scratch a fingernail.

   Here is a Moh's Hardness Scale

1)	Talc	Talk is the softest and can be scratched by all other minerals.
2)	Gypsum	
3)	Calcite	
4)	Fluorite	
5)	Apatite	
6)	Feldspar	
7)	Quartz	
8)	Topaz	
9)	Corundum (ruby)	
10)	Diamond	Diamond is the hardest so it will scratch all other minerals.

Field Test	**Approximate Hardness**
Mineral can be scratched with a fingernail.	2.5 or less.
Minerals, too hard to be scratched by a fingernail and too soft to scratch a cent.	Between 2.5 and 3.5
Minerals which will scratch a penny but can be scratched by a hard steel nail.	Between 3.5 and 5.5
Minerals cannot be scratched by a hard steel nail but can be scratched by a quartz crystal.	Between 5.5 and 7

5) **Specific gravity (relative density) –** it tells you how heavy a mineral is compared to water for a given volume. If you have a value available, use it. If not estimate it by feeling it in your hand.

- Light – 1 to 3 (examples include calcite and quartz)
- Normal – 4 to 6 (examples include magnetite and pyrite)
- Heavy – over 6 (examples include galena and gold)

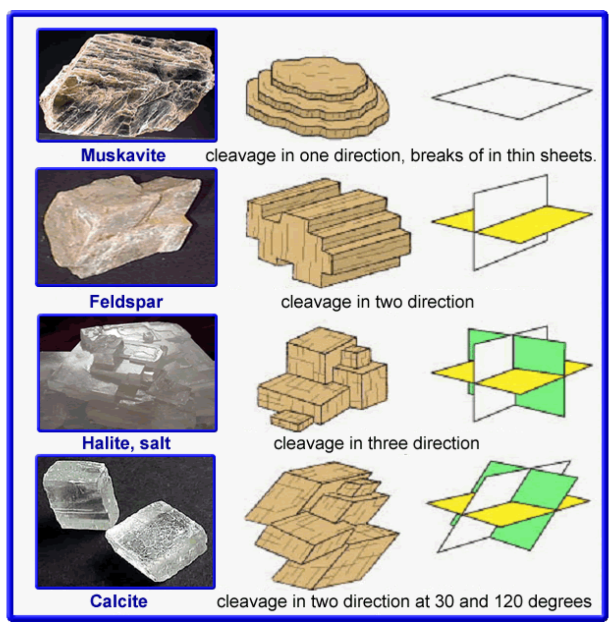
6) **Cleavage** – This tells how a mineral breaks or splits and can really help identify a given mineral

No cleavage means the mineral splits in any way (see fracture in #3).

One plane means that the mineral breaks in pieces with flat bottom or top. Example: Mica has one good cleavage plane and splits in flakes.

Two planes means that a mineral splits with a flat top or bottom and with flat sides. If it breaks in these two directions easily, it has perfect cleavage in two directions (angle of 90°). The angle is very important in identification. Ex. pyroxene

Three planes means that a mineral splits with flat top and bottom, flat sides, and a flat front/back. If there is perfect cleavage in all three directions, the mineral splits into cubes (i.e., halite and galena). If not at 90°, it can form rhombohedral shapes (i.e., calcite).



7) **Fracture –** how minerals break when they don't have cleavage planes. Example: quartz fractures as it has no cleavage planes.

8) **Simple crystal shape** -- cubic (cube shape), rhombohedral (dog-tooth), hexagonal (six faces) and many more. Crystals are just repeating patterns of chemical formulas in a mineral.

For crystals to form, time is required. Molten rock must solidify slowly so that the atoms can align and form and grow orderly crystals. If the rock cool quickly, crystals don't have time to grow so a non-crystalline **glass** appears. A mineraloid has all the properties of a mineral except a regular crystal structure.

9) **Special Properties:**

a) **Reaction to dilute HCl –** carbonates fizz with HCl (calcite and dolomite)

b) **Smell –** limonite and malachite smell earthy

c) **Taste** – only for halite – tastes like salt

d) **Striations** – fine lines on cleavage planes

e) **Tenacity** – how well it will resist breaking (how brittle or malleable)

f) **Optical Properties** – calcite produces a double image of objects viewed through a crystal

g) **Radioactivity** – check with a Geiger counter

h) **Phosphorescence and Fluorescence** – check with UV light. Phosphorescent glows when the light is on and fluorescent glows when the light is off.

i) **Magnetism –** is it attracted to a magnet? (Examples are magnetite and pyrrhotite)

Common Rock Forming Minerals

As rocks are made of different minerals these minerals become important in the identification of rocks and an understanding of how the rocks are formed. Some of the more common minerals found in rocks are described below:

Quartz - a hard, shiny crystal that looks like milky or clear glass. It is a very common mineral that will scratch a hard knife. Often found in massive form – glassy or white interlocking crystals. Amethyst, rose quartz, smoky quartz and citrine are forms of quartz coloured by minute amount of different minerals.

Orthoclase Feldspar - pink, white, or grey crystals, slightly softer than quartz, two directional cleavage at 90°. Potassium feldspars, e.g. pink microcline - $K(AlSi_3O_8)$.

Plagioclase Feldspars are a continuum of sodium and calcium forms, e.g. white albite - $Na(AlSi_3O_8)$, is a common sodium plagioclase found in light coloured rocks while grey anorthite - $Ca(AlSi_3O_8)$, is a calcium plagioclase found in dark coloured rocks. Commonly have striations (grooves) on the crystals.

Muscovite Mica - a soft, light tan coloured mineral that forms thin translucent sheets, high aluminum.

Biotite Mica - a soft, black mineral that forms thin translucent sheets, high in iron, common in local plutonic rocks.

Amphibole (Hornblende**)** - Dull, dark green to black and slightly softer than feldspar, high in iron. 124° cleavage faces - distinguished from pyroxene by its cleavage. Calcium magnesium silicates.

Pyroxene (Augite**)** - Dull, dark green to black and slightly softer than feldspar, high in iron. 87° cleavage faces - distinguished from amphibole by its cleavage. Calcium magnesium silicates.

Olivine -hard greenish mineral, often found with hornblende/and or pyroxene.
Clays - very soft sub-microscopic flaky silicate minerals, white to grey.

Calcite - a very common soft white crystal, easily scratched with a knife, rhombohedral cleavage. Reacts with cold dilute hydrochloric acid (HCl).

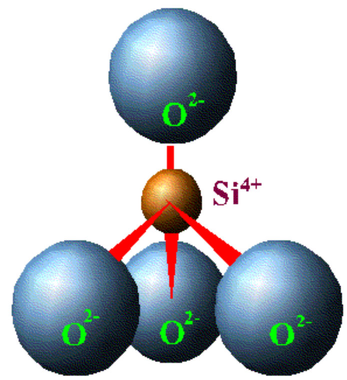
Dolomite - white to grey, harder than calcite, reacts with hot dilute hydrochloric acid.

Types of Minerals

Silicate Minerals

The most common element in the Earth's crust is oxygen. The second most common is silicon. Therefore, it makes sense that they form the largest group of minerals – the silicates. There are the most common rock forming minerals.

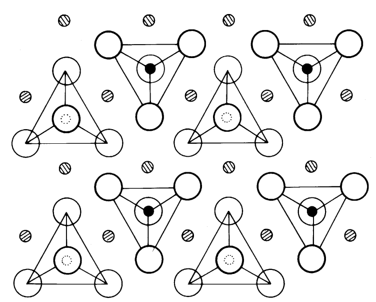
The silica tetrahedron is common to all silicates. The structure is based on an Si^{+4} surround by four O^{-2} anions . Electrons are shared and covalent bonds form. Each silica tetrahedron thus has a net charge of – 4.



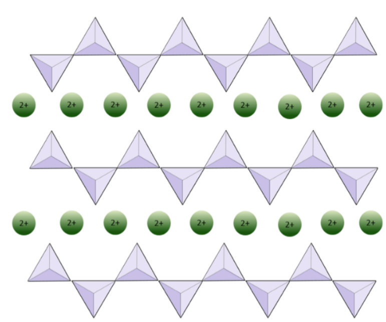
$Si + 4O \rightarrow SiO_4{}^{-4}$
$+4 + 4x\,(-2) = -4.$

a) Isolated Tetrahedra: Do not link to other silica tetrahedra

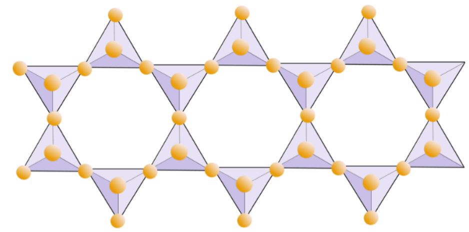
Olivine and garnet are composed of single silica tetrahedra. Cations with a charge of +2 balance out the $SiO_4{}^{-4}$ charge to create a neutral crystal.



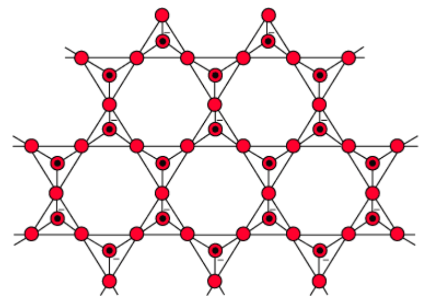
b) Single Chain Silicates: share one oxygen atom between adjacent tetrahedra, forming chains. Cations fit between the chains to balance the charges. Augite (pyroxenes) are single chain silicates.



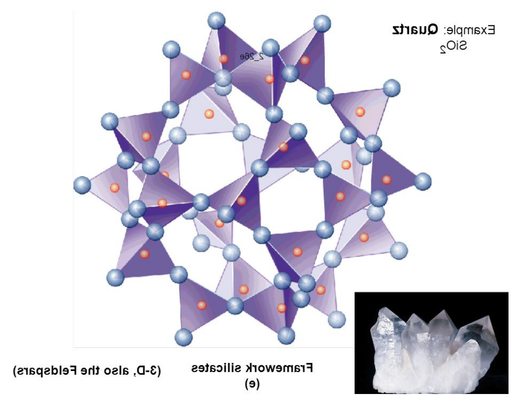
c) <u>Double-Chain Silicates</u>: form when two single chains of tetrahedral bond to each other . Hornblende (amphiboles) and asbestos are double chain silicates.



d) <u>Sheet silicates</u>: form when each tetrahedron shares three of its oxygen atoms with other tetrahedral. Produces sheets like pages in a book. An example is <u>mica</u> or <u>talc</u>.



e) <u>Framework silicates</u>: form when silica tetrahedra share oxygen in all 3 dimensions. Therefore, no balancing cations are needed and the complete chemical formula is just SiO_2. <u>Quartz</u> is a framework silicate. Due to its strong, tight structure, quartz has few cleavage planes and a hardness of 6. It is resistant to weathering. **<u>This is all due to its internal structure.</u>**



<u>Feldspars</u> are also <u>framework silicates.</u> However, some of the silicon atoms are replaced by Al^{+3}. Since Al^{+3} is not the same charge as Si^{+4}, the charges are not balanced. So, cations are needed to balance out the charge. Sodium (Na^{+}) and calcium (Ca^{+2}) cations interchange in <u>plagioclase feldspar</u> (white in colour)while potassium (K^{+}) and sodium (Na^{+}) cations interchange in <u>potassium feldspar</u> (pink in colour. (This is more difficult is potassium feldspar as K^{+} and Na^{+} are not the same size).

We will look at what cations are used where when we look at the Bowen Reaction Series in more detail later in the course.

Ferromagnesian vs. Nonferromagnesian Silicates

- Ferromagnesian silicates contain iron or magnesium, and are commonly dark coloured and relatively dense. Common examples are olivne, pyroxene, amphibole, and biotite.

- Nonferromagnesian silicates lack iron and magnesium, are generally light-coloured, and are less dense than ferromagnesian silicates. Examples include quartz, feldspars, and muscovite.

Non-Silicate Minerals

- **Native Elements**: a few (rare) elements occur by themselves in nature
  Includes gold, silver, copper, platinum, sulphur, graphite, diamond

- **Carbonates**: metals mixed with CO_3^{-2}.
  Of the other minerals, the carbonates are the most common. Calcite ($CaCO_3$) and dolomite (calcium-magnesium carbonate) are common minerals in this group. Azurite and malachite are also examples.

- **Sulphates**: metals mixed with SO_4^{-2}.
  Typical sulphates are barite (barium sulphate) and gypsum (calcium sulphate). These contain sulphur and oxygen (SO_4^{-2}).

- **Sulphides**: metals mixed with sulphur (but no oxygen).
  Include pyrite, chalcopyrite, sphalerite, molybdenite, and bornite.

- **Halides**: metals mixed with a halogen (F,Cl,Br,I).
  Include halite (sodium chloride) and fluorite (calcium fluoride).

- **Phosphates:** metals mixed with PO_4^{-3}. Includes apatite ($Ca_5(PO_4)_3F$)

- **Oxides**: metals mixed with oxygen. Includes hematite, limonite, and magnetite

Ore Minerals

When minerals are in a concentrated enough form that they can be economically mined and processed into metals they are known as ores. Canada has a rich history of mining that has been instrumental in opening up British Columbia, Ontario and Quebec in particular. The following chart lists the common ore minerals found in commercial quantities in Canada and specifically British Columbia, together with some of their properties. The chemical composition of the mineral has a significant impact on how it can be processed to extract the usable metal.

Metal	Mineral	Formula	Type	Colour
Copper	Chalcopyrite	$(Cu,Fe)S_2$	Sulphide	Yellow gold
	Chalcocite	Cu_2S	Sulphide	Grey
	Bornite	Cu_5FeS_4	Sulphide	Reddish purple
	Chrisocolla	$CuSiO_3 \cdot 2H_2O$	Silicate	Greenish blue
Iron	Hematite	Fe_2O_3	Oxide	Reddish brown
	Magnetite	FeO	Oxide	Black
	Limonite	$2Fe_2O_3 \cdot 3H_2O$	Oxide	Yellow to dark brown
Lead	Galena	PbS	Sulphide	Battleship grey
Molybdenum	Molybdenite	MoS_2	Sulphide	Silver grey
Nickel	Pentlandite	$(Fe,Ni)_9S_8$	Sulphide	Bronze yellow
Zinc	Sphalerite	ZnS	Sulphide	Greyish brown

Note: - Other minor ores such as pyrite, malachite and azurite are often mixed in with the major ores.

Review Questions:

1) What are the five characteristics of a mineral?

2) Explain the importance of time to the formation of crystals.

3) Describe 3 ways to distinguish calcite from halite.

4) What is the hardness of quartz on the Moh's scale? What is the hardness of calcite on the Moh's scale? How could you test the hardness?

5) Why do some minerals have good cleavage while other minerals only fracture?

6) Give several examples of native elements.

7) Name the first and second most abundant elements on Earth.

8) Put the following minerals under their correct family group: calcite, hematite, galena, limonite, sphalerite, magnetite, molybdenite, gypsum, bornite, chalcopyrite, malachite, azurite

Carbonates	**Sulphides**	**Oxides**

9) Classify these silicates and aluminosilicates into the correct class: quartz family, feldspars, muscovite, biotite, talc, augite, hornblende, garnet, asbestos, and olivine

Individual tetrahedron	**Single Chain**	**Double Chain**	**Sheet**	**Framework**

10) Which mineral(s) would you look for if you wanted to develop an iron mine?