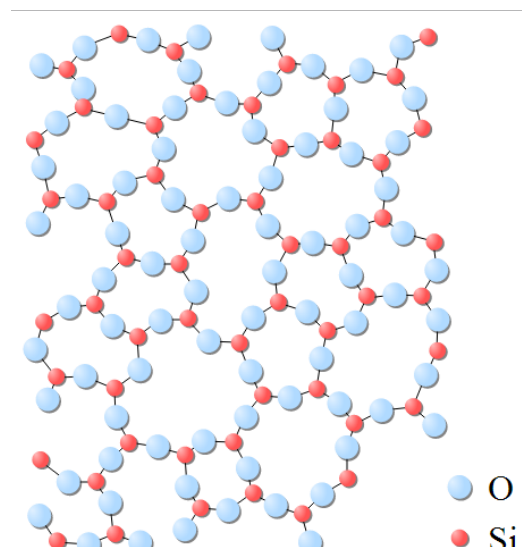
Minerals

- Naturally occurring, inorganic, solid.
- crystalline structure = an orderly array of atoms chemically bonded
- Chemical composition =a mineral can be written with a formula
  - Example in the pictures below Quartz crystals form, crystalline structure and chemical formula

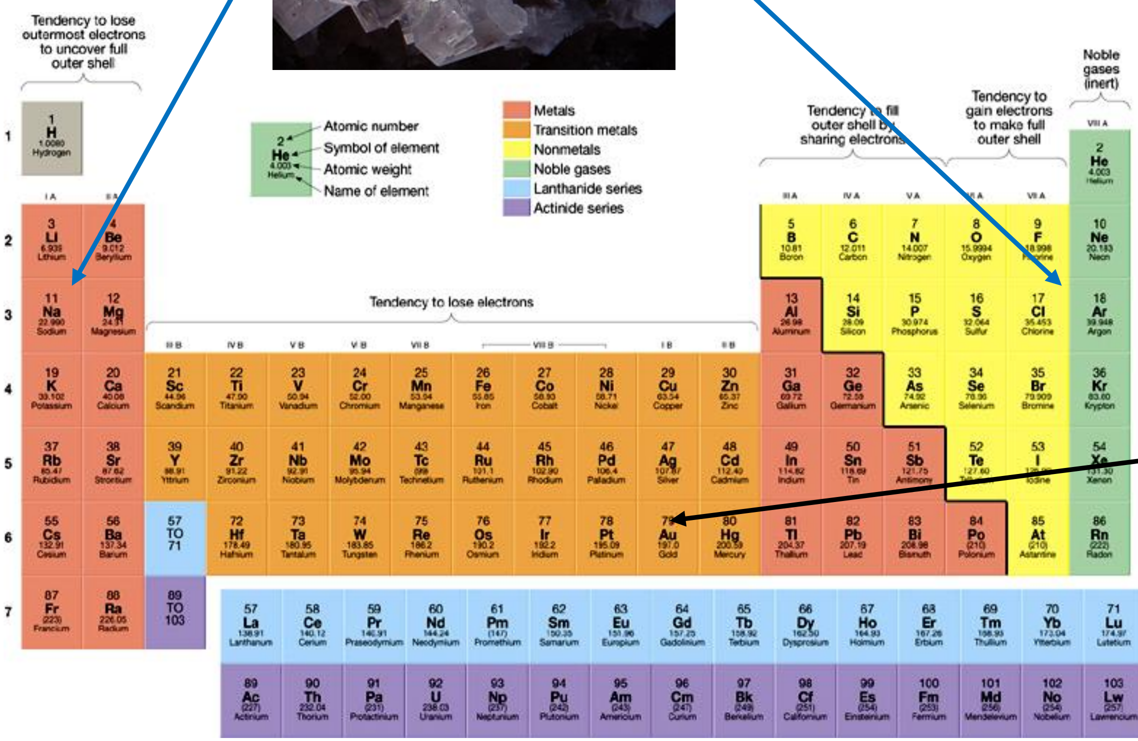


SiO_2

The building blocks of minerals: chemical elements

Minerals can be made by one or more chemical elements bound together:

Halite, table salt, is made of two elements, Sodium and Chlorine

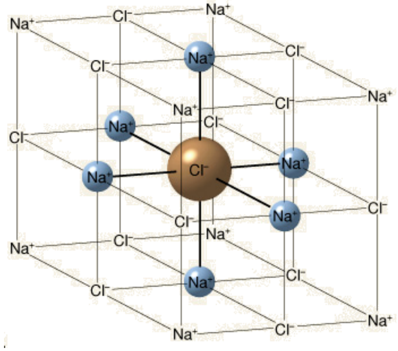


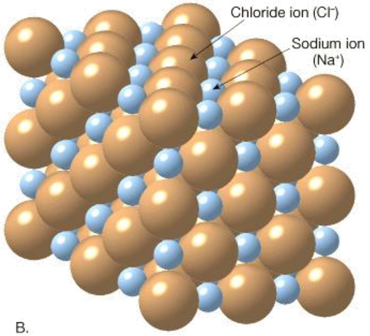
Gold is made on only one type of element, Au

Chemical bonds in minerals

- Minerals are held together by chemical bonds
- Minerals can have more than one type of bond to keep the crystalline structure together.
- The most common bonds found in minerals are:

Ionic bond: atoms gain or lose outermost (valence) electrons to form ions → weak!
Example: salt, made of Na and Cl, breaks down easily in water

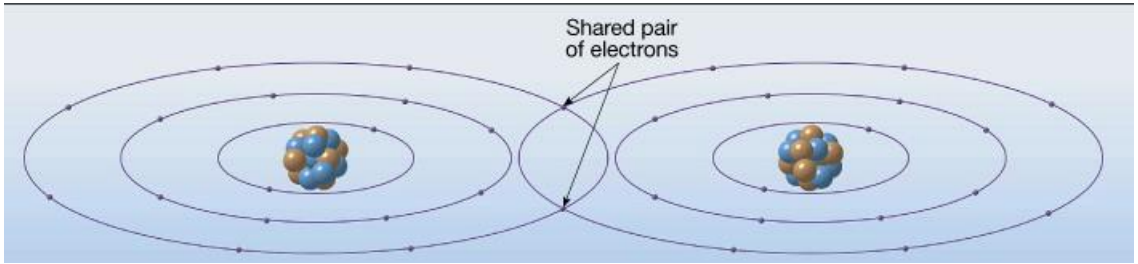




B.

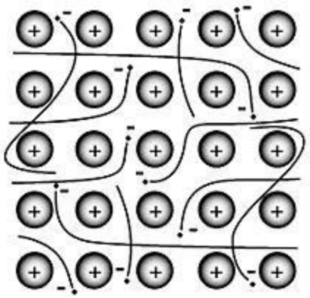
Covalent bond

- Atoms share electrons to achieve electrical neutrality
- Covalent compounds are generally stronger than those with ionic bonds



Metallic bond

- Electrons migrate freely among atoms, making the elements good conductor of electricity

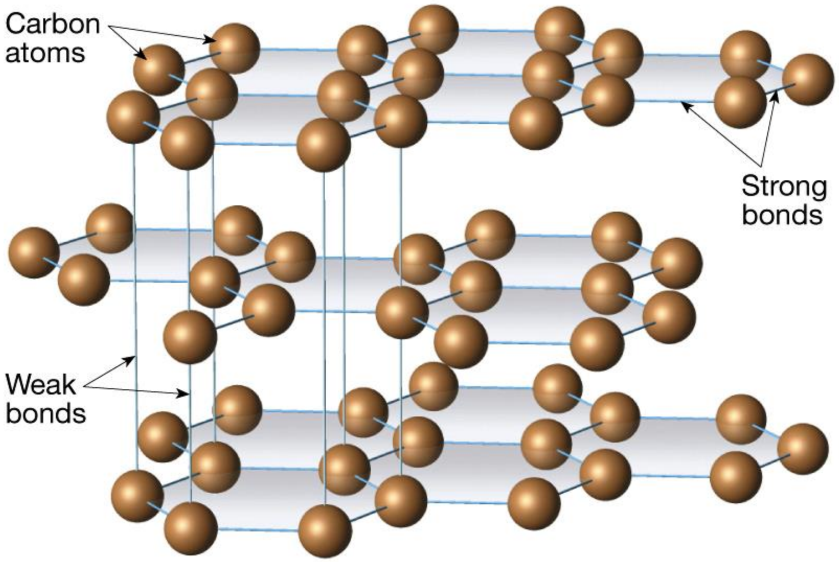


Mineral polymorphs

Importance of chemical bonding: Mineral polymorphs have same chemical composition, different crystalline structures

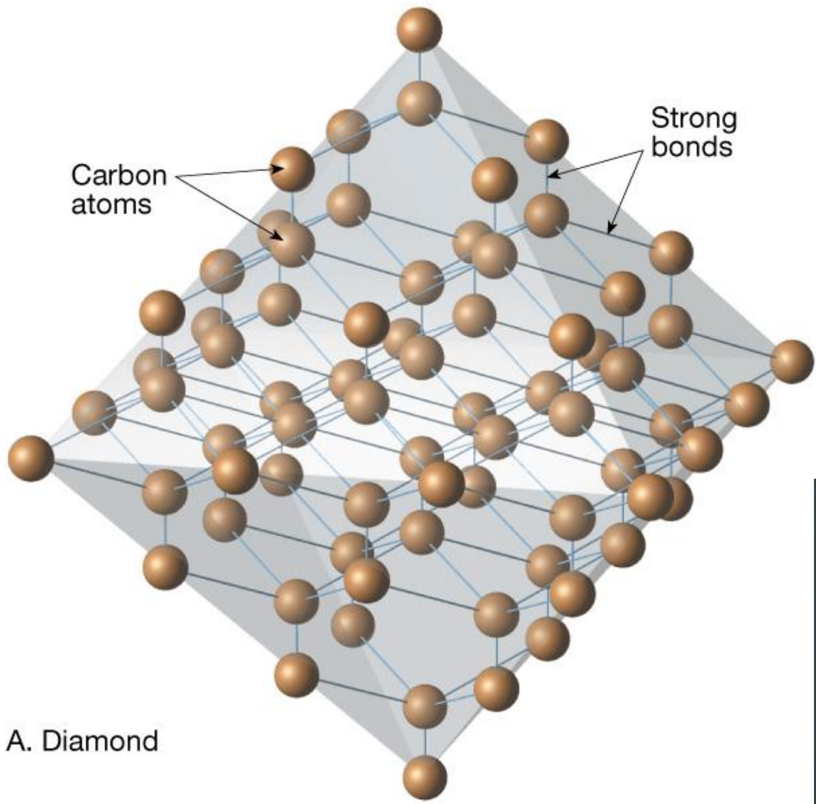
Graphite

"sheets" of carbon elements weakly bonded by ionic bonds



B. Graphite

Mineral polymorphs -2



Diamond

- covalent, strong bonds!

Uncut diamond cut diamond

Properties of minerals

- Mineral properties result from the mineral's chemical composition and crystalline structure

In lab, you will learn about properties useful for the identification of minerals

Mineral properties: Crystal form - *habit*

- The crystalline structure is the result of the orderly arrangement of atoms
- Minerals can crystallize in a set number of crystal shapes, depending on the type of chemical elements and chemical bonds that keep the structure together

Some examples of crystal habits

Physical properties: Color

- the presence and the amount of certain chemical elements in the mineral absorb specific wavelengths of incident light. The color we perceive is produced by the remaining wavelengths that were not absorbed.
- Colorless minerals mean that none of the incident light has been absorbed.
- Some minerals have distinctive colors – here are some examples:

Gold

Sulfur

Turquoise

Images from Cochise College http://skywalker.cochise.edu/wellerr/mineral/minlist.htm

Physical properties: Color variety

- Color can be the result of impurities and minor chemical elements trapped in the crystalline structure
- This way, the same mineral can take different colors
  - example quartz SiO_2

Various color of quartz crystals
Iron makes amethyst purple; iron, titanium and manganese make Rose quartz pink

Physical properties: Color – possibilities!

- The coloration of most gemstones is from impurities in the crystalline structure

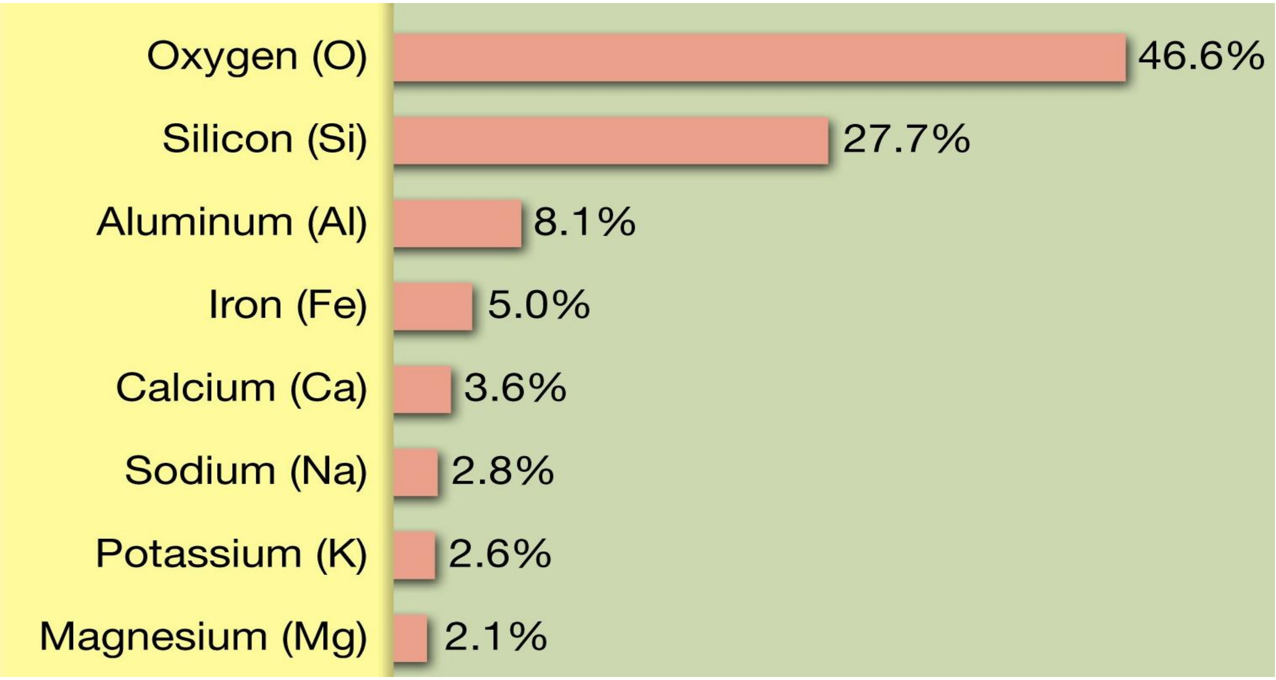
Boron impurities make the Hope Diamond blue
45.52-**carat** (9.10 g)

“watermelon” tourmaline, Smithsonian NMNH, reddish color from Manganese

Minerals of Earth's crust

- More than 4000 mineral species have been identified.
  - Minerals are classified based on their formula's anions (negative valence ionic group)

- Over 90% of the crust is made of minerals built with these 8 chemical elements



Native Elements mineral group

- Gold - Au

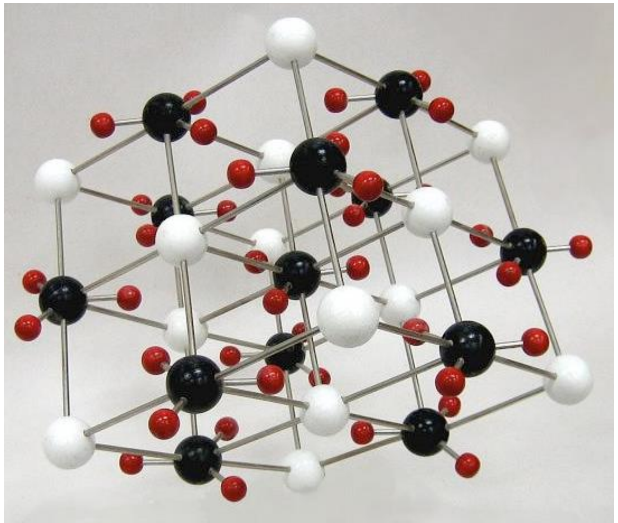
- Silver - Ag

- Copper - Cu

- Sulfur - S

Carbonate Group (CO_3^{2-})

Calcite $CaCO_3$



Calcite structure

Calcite from Rio Grande do Sul, Brazil

Calcite specimens from intro geology lab

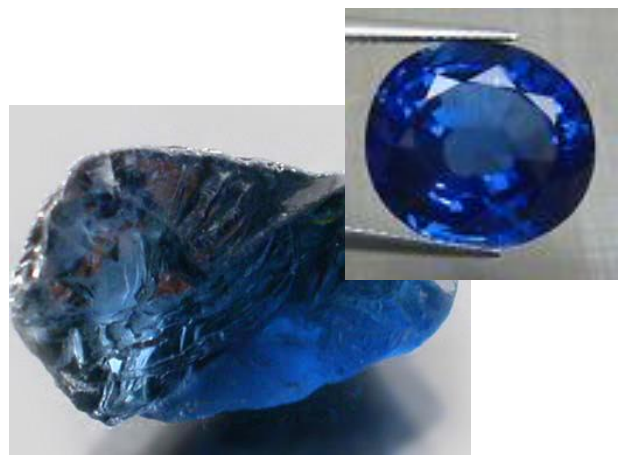
Halides Group (Cl^{1-}, F^{1-}) a.k.a. Salts

- Halite NaCl – table salt
- Fluorite CaF_2

Oxide group (O^{2-})

- Hematite Fe_2O_3

- Corundum(Al_2O_3)



Chromium impurities → red→ ruby
Titanium and Iron impurities → blue → sapphire

Sulfur minerals

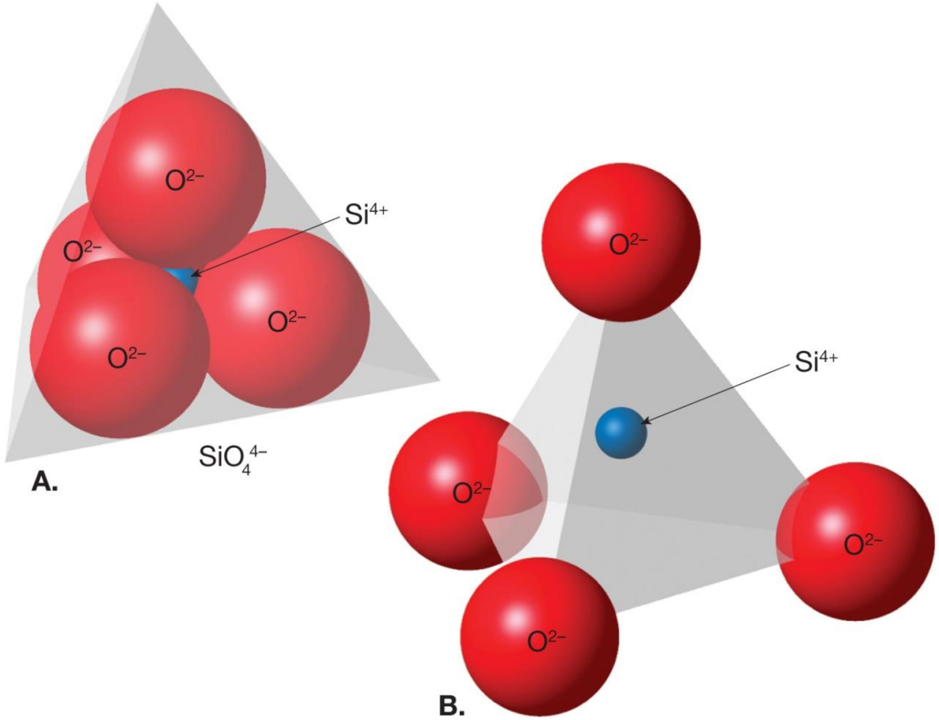
- There are various groups of minerals that are based on sulfur, for example:
- Sulfides Group
  - Pyrite

  Also known as fool's gold

- Sulfates Group
  - Gypsum

Silicate Group

- Comprise most common rock-forming minerals of the Earth's lithosphere
- Their building block is the Silica tetrahedron a simple structure made of 1 atom of silicon and 4 atoms of oxygen

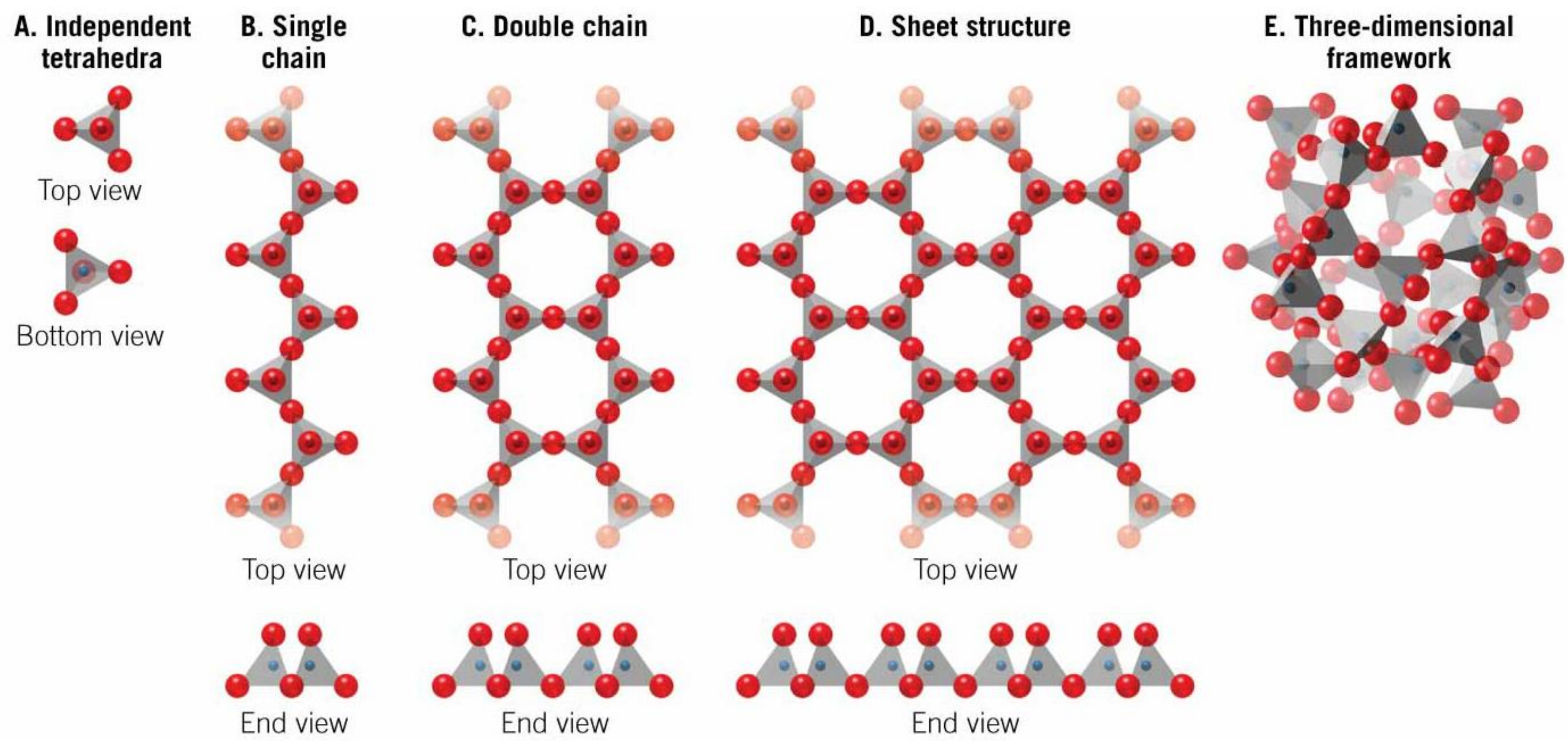


Two ways to illustrate the tetrahedron

Silicate structures

All silicates are made of these arrangements of silica tetrahedrons

The structures are arranged from simple to more complex



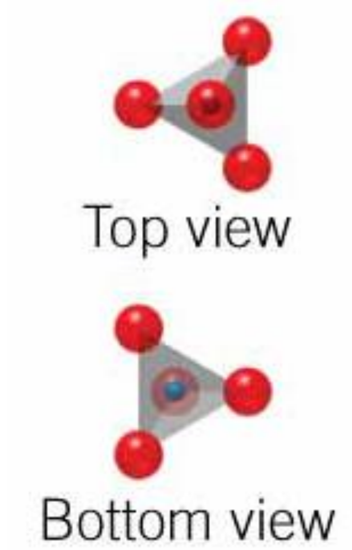
Single tetrahedron silicates

- Single silica tetrahedra + other elements at the corners of the tetrahedra.

- Most common silicate built this way is Olivine: (a.k.a. Peridot, if gem quality) is made of silica tetrahedrons + Iron and Magnesium atoms

- Olivine is the most common mineral in the lithospheric mantle

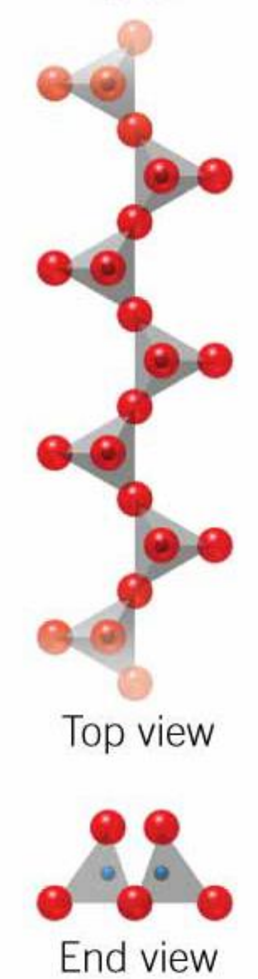
- Silicates rich in Iron and magnesium are called Mafic, they are generally dark gray, green, black



Green olivine crystals

“Chain” structure silicates – single chain

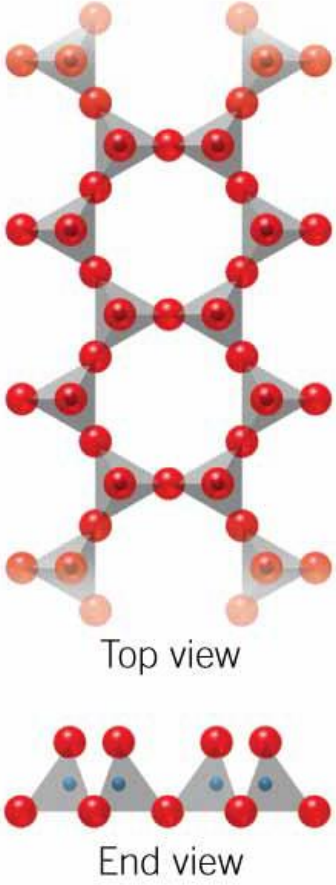
- Pyroxene are Mafic silicates and make most of the oceanic lithosphere



“pyroxene” is a general name for many mafic silicates built this way, in books and labs you can learn additional names, for this class you need only the general name.

"Chain" structure silicates – double chains

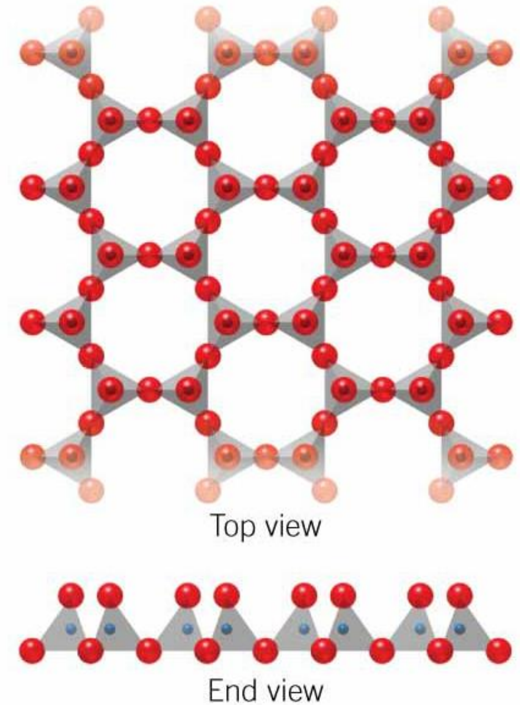
- Amphiboles are also Mafic Silicates, and they are common dark minerals in the continental lithosphere



"amphibole" is a general name for many mafic silicates built this way, in books and labs you can learn additional names, for example, hornblende; for this class you need only the general name.

Layer structure silicates phyllosilicates

- Layers/sheet structures silicates are built by layers upon layers of silica tetrahedrons
- The layers are held together by weak ionic bonding; because of their framework, these minerals split easily in between the layers
- There are two important groups of silicates with this structure the MICA and the CLAY groups



Mica group

Mica is a very large group of phyllosilicates, some of the most common are:

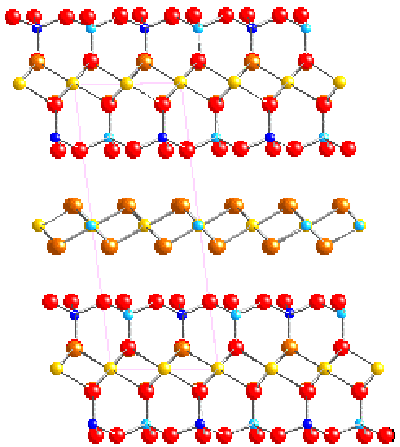
mafic variety: BIOTITE

Felsic variety: MUSCOVITE

Biotite and Muscovite are common minerals found <u>in the continental crust</u>

Sheet Silicates: the Clay group

- These minerals have a very complex layered structure of silica tetrahedra.
- They usually crystallize as microcrystals**,** (very small, hardly visible without magnification). Microcrystals form "aggregates", where billion of microcrystal form together
- Clay minerals are very common all over the crust, they are very useful mineral resource

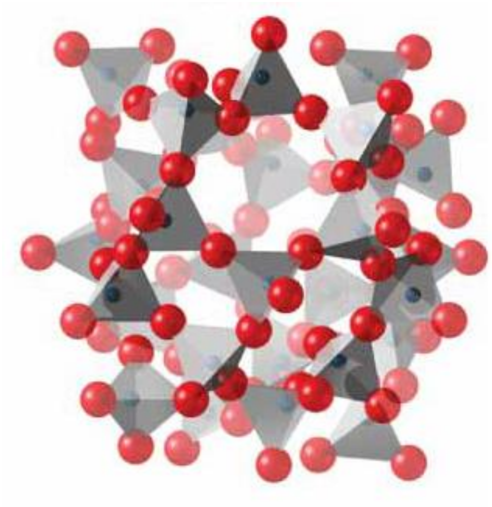


Aggregate of clay minerals

3D framework silicates: Quartz

SiO_2 Quartz

Quartz is the second-most abundant mineral in the continental crust and the only common mineral made completely of silicon and oxygen

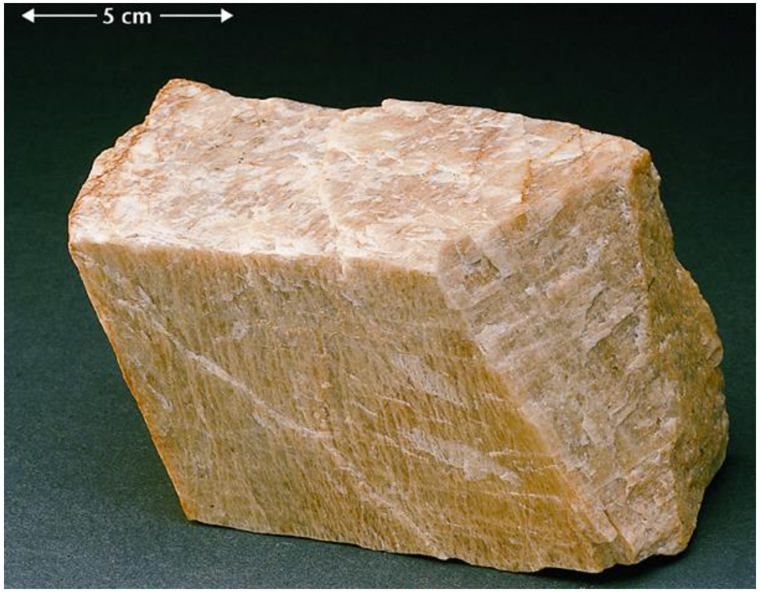


3D silicates: the Feldspar group

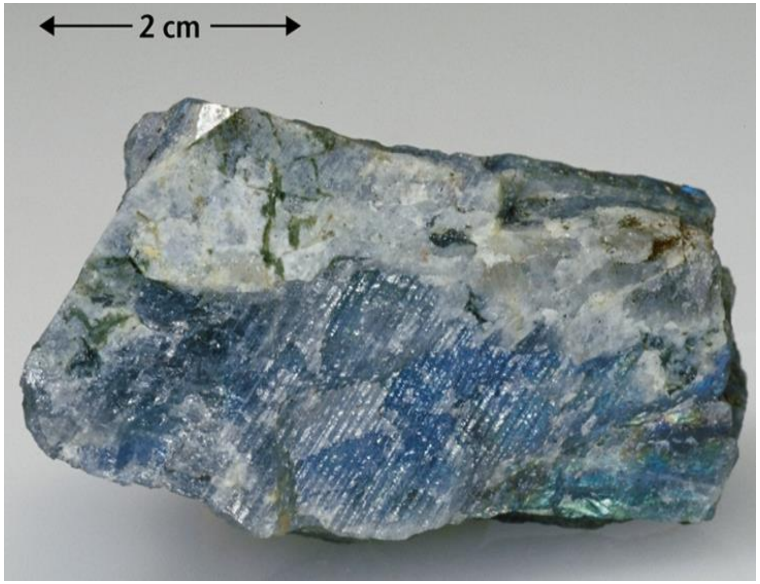
Feldspars are the most common minerals in the crust

There are many types of feldspars the two most common are:

Orthoclase or (K- feldspar)
Most common in the continental lithosphere



Plagioclase (Na, Ca feldspar)
Present in both continental and oceanic lithosphere

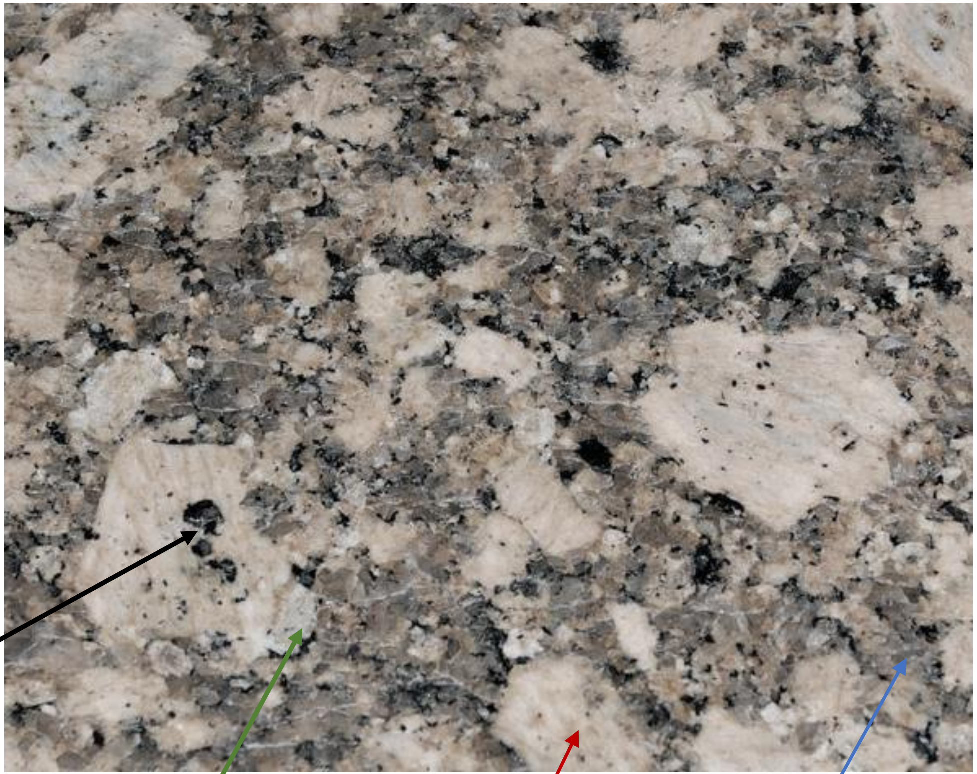


Formation of minerals

All minerals form by crystallization from fluids solutions such as:

- Cooling magma

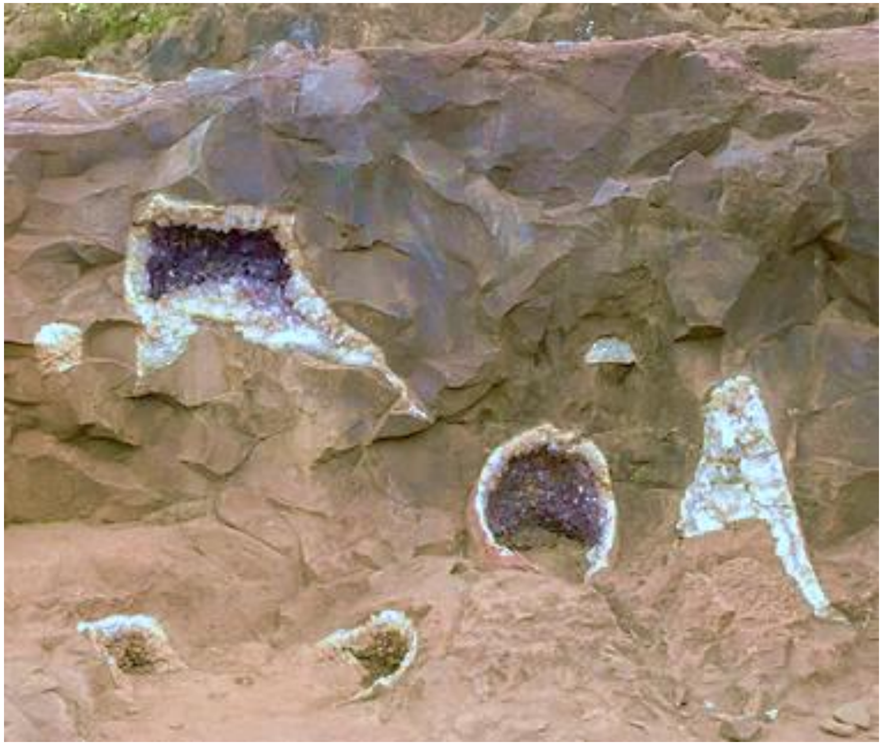
Example: <u>minerals in granite </u> you can see the typical silicate feldspars



Formation of minerals

- Precipitation from fluids solutions
- trapped in rock cavities or spaces left by cracks and pores.

  Example: geodes started as empty spaces in rocks that become filled with quartz



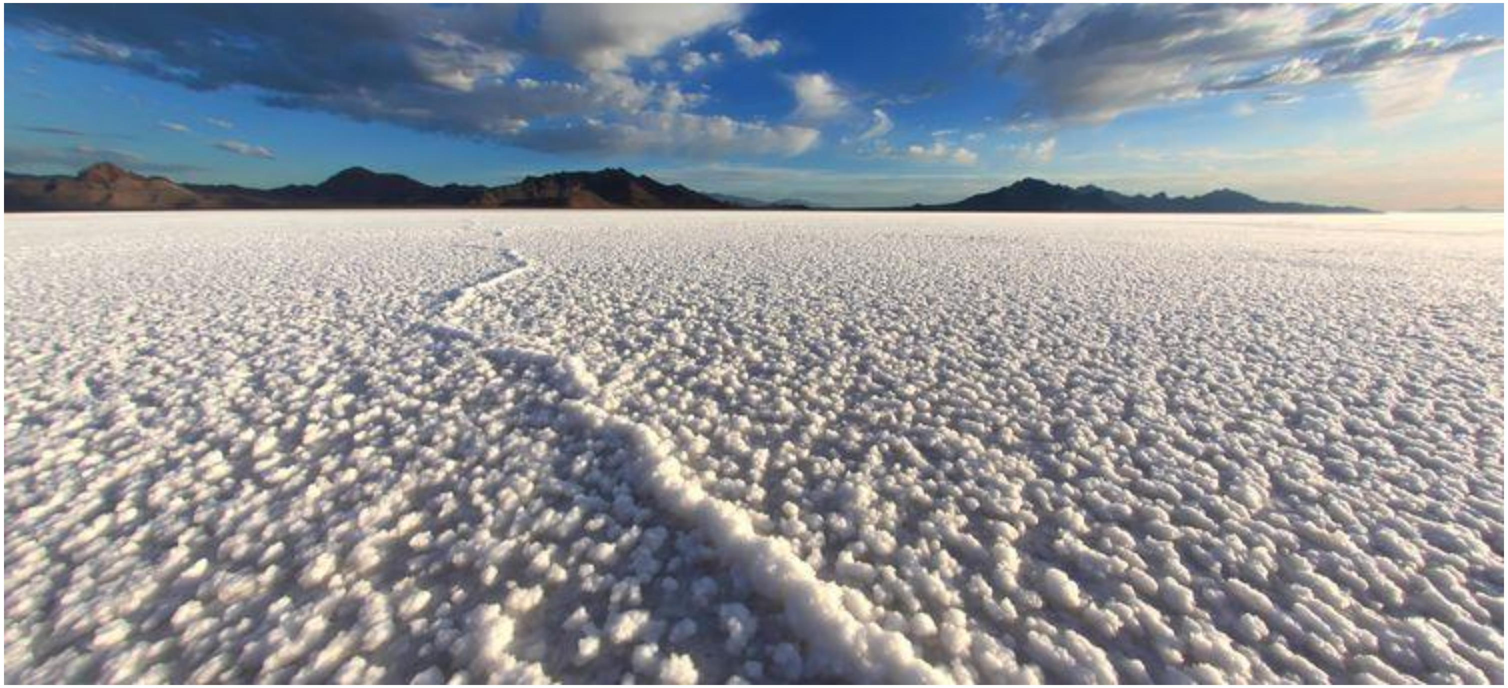
A geode extracted from the rock

- Another example: calcite deposit forming in water heaters, …

Formation of minerals

- Evaporation

From water-based fluid solutions, like the salt pans in desert areas



Close up of salt crystals from Bonneville salt flats, Utah

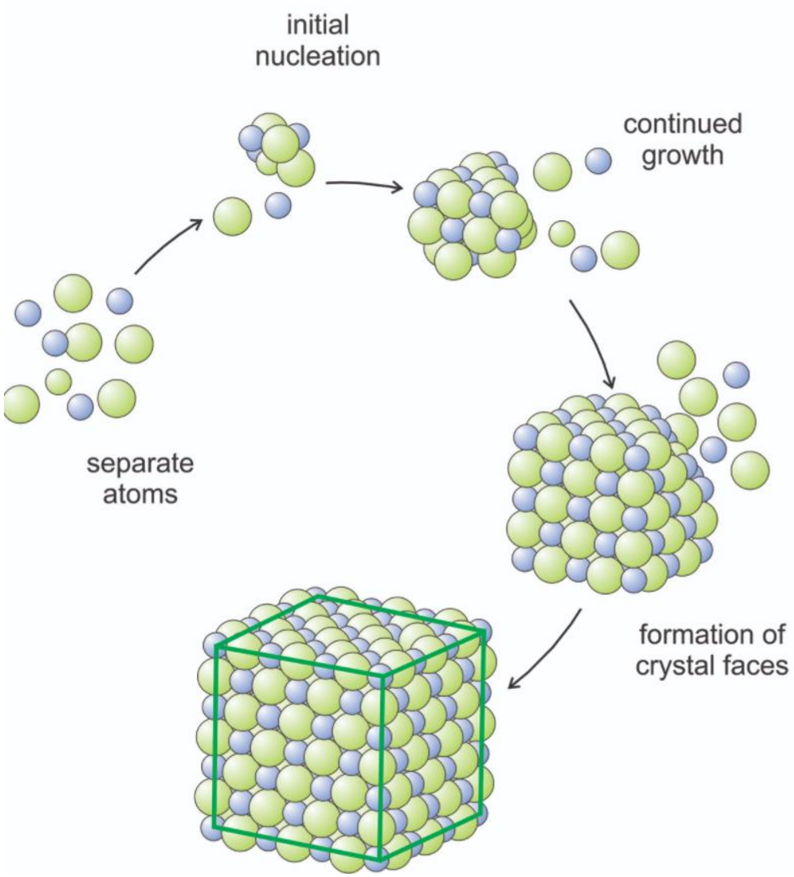
Formation of minerals

- Condensation

For example, sulfur crystals forming from hot gases released at volcanic centers

How minerals "grow"

- Minerals grow by adding molecules specific to a mineral's own chemical formula to the crystalline structure
- How fast and how big minerals can grow depends on the conditions of the growing environment



Mineral aggregates

Mineral aggregates are minerals that commonly grow in large number of very small microscopic crystals. Some common examples:

- Hematite

- Clay minerals

How big can crystals grow?

- As long as there are the needed chemical elements/molecule in abundance, AND the right conditions of pressure and temperature AND available space, crystals will keep growing!

These two Topaz crystals are in exhibit at the Smithsonian. They weight 31.8 kg (70 lb.) and 50.4 kg (111 lb.) respectively. The cut gems is a ~ 23,000 carat (10.10 lb.) American Golden Topaz gemstone.

The largest crystals in the world are in a gypsum mine in Mexico

Paragenesis: diverse minerals growing together

Different minerals can form together, growing independently in the same environment.
By definition, a rock is formed by many minerals growing together!

Example of paragenesis diverse minerals

Mineral inclusions

- Minerals growing in paragenesis might do that at different rates.
- Example, Quartz is a fast-growing crystal that can assimilate nearby crystals, generating inclusions

Quartz assimilated some other needle like crystals

The larger crystals of quartz grew around the pyrite crystals later.

Twins

- While growing, crystals are extremely sensitive to changes. A misplaced atom—or a slight change in temperature, pressure, composition, or impurities—can interfere with the growing structure of a mineral.
- Crystal twins are groups of two or more crystals of the same mineral connected at precise angles. The angles are controlled by the crystal's atomic structure.

EVERY YEAR: 40,209 pounds of new minerals must be provided for every person in the United States to make the things we use daily

10,603 lbs. — **Stone** is used to make roads, buildings, bridges, landscaping and other construction uses, and for numerous chemical uses.

6,952 lbs. — **Sand and Gravel** are used to make concrete, asphalt, roads, blocks and bricks.

794 lbs. — **Cement** is used to make roads, sidewalks, bridges, buildings, schools and houses.

265 lbs. — **Iron Ore** is used to make steel for buildings, cars, trucks, planes, trains, and for other construction and containers.

390 lbs. — **Salt** is used in various chemicals, for highway deicing, and in food and agriculture.

159 lbs. — **Phosphate Rock** is used to make fertilizers to grow food and in animal feed supplements.

146 lbs. — **Clays** are used to make floor and wall tile, dinnerware, kitty litter, bricks, cement and paper.

19 lbs. — **Aluminum (from bauxite)** is used to make buildings, beverage containers, autos and airplanes.

0.02 lb. — **Lithium** – 80% of lithium mined is used to make batteries, increasingly important in many technological devices and electric vehicles.

13 lbs. — **Copper** is used in buildings, transportation, plumbing, electrical and electronic parts, and is integral in renewable energy production.

11 lbs. — **Lead** is primarily used in lead-acid batteries in vehicles and other power systems, such as in communications.

6 lbs. — **Zinc** is used to make metals rust-resistant, to make various metals and alloys, paints, rubber, and in skin creams, health care and nutritional supplements.

30 lbs. — **Soda Ash** is used in all kinds of glass, powdered detergents, medicines, as a food additive, and for water treatment.

6 lbs. — **Manganese** is used to make almost all steel for construction, and in machinery and transportation.

665 lbs. — **Other Nonmetals** are used in glass, chemicals, soaps, paper, computers, cell phones, and more.

23 lbs. — **Other Metals** are used in electronics, TV and video equipment, recreation equipment, and more.

0.04 lb. — **Silver** is used in cars, solar technology, batteries and medical equipment.

Including These Energy Fuels

- 1,111 gallons of Petroleum
- 95,633 cu. ft. of Natural Gas
- 3,077 lbs. of Coal
- 0.14 lb. of Uranium

To generate the energy each person uses in one year.

SME FOUNDATION
MEC
MINERALS EDUCATION COALITION

 MineralsEducationCoalition.org SME Foundation

These numbers are comparable to those of other industrialized Countries

ELEMENTS OF A SMARTPHONE

ELEMENTS COLOUR KEY: ALKALI METAL · ALKALINE EARTH METAL · TRANSITION METAL · GROUP 13 · GROUP 14 · GROUP 15 · GROUP 16 · HALOGEN · LANTHANIDE

SCREEN

49 In Indium · 50 Sn Tin · 8 O Oxygen

Indium tin oxide is a mixture of indium oxide and tin oxide, used in a transparent film in the screen that conducts electricity. This allows the screen to function as a touch screen.

13 Al Aluminium · 14 Si Silicon · 8 O Oxygen · 19 K Potassium

The glass used on the majority of smartphones is an aluminosilicate glass, composed of a mix of alumina (Al_2O_3) and silica (SiO_2). This glass also contains potassium ions, which help to strengthen it.

39 Y Yttrium · 57 La Lanthanum · 65 Tb Terbium · 59 Pr Praseodymium · 63 Eu Europium · 66 Dy Dysprosium · 64 Gd Gadolinium

A variety of Rare Earth Element compounds are used in small quantities to produce the colours in the smartphone's screen. Some compounds are also used to reduce UV light penetration into the phone.

ELECTRONICS

29 Cu Copper · 47 Ag Silver · 79 Au Gold · 73 Ta Tantalum

Copper is used for wiring in the phone, whilst copper, gold and silver are the major metals from which microelectrical components are fashioned. Tantalum is the major component of micro-capacitors.

28 Ni Nickel · 66 Dy Dysprosium · 59 Pr Praseodymium · 65 Tb Terbium · 60 Nd Neodymium · 64 Gd Gadolinium

Nickel is used in the microphone as well as for other electrical connections. Alloys including the elements praseodymium, gadolinium and neodymium are used in the magnets in the speaker and microphone. Neodymium, terbium and dysprosium are used in the vibration unit.

14 Si Silicon · 8 O Oxygen · 51 Sb Antimony · 33 As Arsenic · 15 P Phosphorus · 31 Ga Gallium

Pure silicon is used to manufacture the chip in the phone. It is oxidised to produce non-conducting regions, then other elements are added in order to allow the chip to conduct electricity.

50 Sn Tin · 82 Pb Lead

Tin & lead are used to solder electronics in the phone. Newer lead-free solders use a mix of tin, copper and silver.

BATTERY

3 Li Lithium · 27 Co Cobalt · 8 O Oxygen · 6 C Carbon · 13 Al Aluminium

The majority of phones use lithium ion batteries, which are composed of lithium cobalt oxide as a positive electrode and graphite (carbon) as the negative electrode. Some batteries use other metals, such as manganese, in place of cobalt. The battery's casing is made of aluminium.

CASING

6 C Carbon · 12 Mg Magnesium · 35 Br Bromine · 28 Ni Nickel

Magnesium compounds are alloyed to make some phone cases, whilst many are made of plastics. Plastics will also include flame retardant compounds, some of which contain bromine, whilst nickel can be included to reduce electromagnetic interference.