Minerals in granite

The igneous rock granite is composed of many separate grains of several main minerals

Figure 2.1
What is a *mineral*?

Naturally occurring solid

Specific chemical composition

Crystal structure
(regularly repeating units in 3 dimensions)
Structure of halite

Mineral composed of Na Cl

Sodium Na⁺

Chloride Cl⁻

Figure 2.2
What is a rock?

Naturally occurring solid aggregate

Made of one or more minerals
- Granite, basalt, rock salt, limestone

Consolidated aggregate of rock particles
- Sandstone, shale

Solid mass of rock-like materials
- Coal, obsidian (a volcanic glass)
Electron shells of an atom

Nucleus is a small part of the total volume

Nucleus – made of protons and neutrons
Electrons orbiting the nucleus
Filling electron shells

First shell – 2 electrons

Helium

2 protons

2nd shell – 8 electrons

Neon

10 protons in nucleus

Noble gases

Figure 2.4
Filling shells – Na and Cl

Na has only 1 electron in the outer (3rd) shell

Cl needs 1 more electron in the outer (3rd) shell

Figure 2.5
Alkali metals and halogens react

Transfer of an electron

Noble gases
The result: two ions

Each ion is much more stable than the neutral atoms

The two ions are attracted to each other by the electrical charge (similar to magnets)
Ionic bonds hold together NaCl

The 3-D repeating structure is a crystal, and forms the mineral *halite*

*Figure 2.18*
Covalent bonding of water

The hydrogen atoms and the oxygen *share* two electrons in the outer electron shell

Forms a *covalent bond*
Bonds between atoms & molecules

**Strong**  *Covalent bonds* – the electrons are shared between the atoms, keeping the nuclei close together

*Metalllic bonds* – nuclei stay close together, but the electrons are free to flow along a group of atoms

*Ionic bonds* – electrons stay on one atom, creating positive and negative ions

**Weak**  *Hydrogen bonding* (between molecules)
Crystals of carbon

Different configurations of covalent bonds

Diamond

Graphite
Covalent bonds are generally strongest.

Examples from the textbook:
graphite and diamond
Graphite – 2-D bonding

Sheets of C with strong covalent bonds

Van der Waals bonds between the sheets

** Weak **

Can’t withstand shearing force
Diamond

Interlocked 3-D framework
### Mineral groups

Table 3.3 in the textbook

<table>
<thead>
<tr>
<th>Mineral Group</th>
<th>Negatively Charged Ion or Radical</th>
<th>Examples</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbonate</td>
<td>$(\text{CO}_3)^{-2}$</td>
<td>Calcite</td>
<td>CaCO$_3$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dolomite</td>
<td>CaMg(CO$_3$)$_2$</td>
</tr>
<tr>
<td>Halide</td>
<td>$\text{Cl}^{-1}$, $\text{F}^{-1}$</td>
<td>Halite</td>
<td>NaCl</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fluorite</td>
<td>CaF$_2$</td>
</tr>
<tr>
<td>Native element</td>
<td></td>
<td>Gold</td>
<td>Au</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Silver</td>
<td>Ag</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diamond</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Graphite</td>
<td>C</td>
</tr>
<tr>
<td>Oxide</td>
<td>$\text{O}^{-2}$</td>
<td>Hematite</td>
<td>Fe$_2$O$_3$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Magnetite</td>
<td>Fe$_3$O$_4$</td>
</tr>
<tr>
<td>Silicate</td>
<td>$(\text{SiO}_4)^{-4}$</td>
<td>Quartz</td>
<td>SiO$_2$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Potassium feldspar</td>
<td>KAlSi$_3$O$_8$</td>
</tr>
<tr>
<td>Sulfate</td>
<td>$(\text{SO}_4)^{-2}$</td>
<td>Olivine</td>
<td>(Mg,Fe)$_2$SiO$_4$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Anhydrite</td>
<td>CaSO$_4$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Gypsum</td>
<td>CaSO$_4$ · 2H$_2$O</td>
</tr>
<tr>
<td>Sulfide</td>
<td>$\text{S}^{-2}$</td>
<td>Galena</td>
<td>PbS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pyrite</td>
<td>FeS$_2$</td>
</tr>
</tbody>
</table>
Carbonates

Basic polyatomic ion – $\text{CO}_3^{-2}$

Most common forms:

$\text{Ca}^{+2} \text{CO}_3^{-2}$ calcite and aragonite

$(\text{Ca}^{+2}, \text{Mg}^{+2}) \text{CO}_3^{-2}$ dolomite

** These minerals make up limestone, ** and stalactites in caves
Halides (from *halogen*) – salts

Fluorite – CaF$_2$

Halite – NaCl
Native metals

Native gold

Native gold in quartz
hydrothermal
Oxides – metals combined with oxygen

Commonly with water \((\text{oxyhydroxides})\)

Limonite – iron oxyhydroxide
The sulfides – sulfur with no oxygen

Galena – PbS$_2$ lead sulfide

Pyrite – FeS$_2$ iron sulfide

Common hydrothermal minerals
Sulfates – sulfur with oxygen

Basic polyatomic ion – $\text{SO}_4^{-2}$

Some common forms:

$\text{Ca}^{+2} \text{ SO}_4^{-2} \times \text{H}_2\text{O}$ gypsum

Calcanthite

$\text{CuSO}_4 \times 5\text{H}_2\text{O}$

Hydrated Copper Sulfate
The silicates – most of the planet

Basic polyatomic ion – SiO$_4^{-4}$

Most common forms:

- Olivine \((Fe,Mg)SiO$_4\)
- Feldspar \((XAlSi$_3$O$_8\)) \(X = \text{Ca, Na, K}\)
- Quartz \(SiO$_2\)
Two major groups of silicates:

**Ferromagnesian**
Fe Mg SiO₄⁻– iron & magnesium silicates

**most common minerals on Earth**
make up most of the mantle
and oceanic lithosphere

**Non-ferromagnesian**
X SiO₄⁻– silicates without Fe & Mg
typically substitute Ca, Na, K

**most common minerals of continents**
make up most of granite
Telling them apart

*Ferromagnesian* dark, black or greenish

- Olivine
- Augite
- Hornblende
- Biotite mica
Telling them apart

*Non-ferromagnesian* light, white, or clear

- Quartz
- Orthoclase
- Plagioclase
- Muscovite
Minerals and igneous rock types

Granite – Diorite – Gabbro
A quick review: Phases of matter
States (or Phases) of Matter

- GAS: disorder
- LIQUID: short range order
- SOLID: long range order
What Is Heat?

Heat results from the **vibrations** of atoms – this is **kinetic energy**

Heat is transferred along a **gradient**
- **conductive** – particle to particle
- **radiative** – by electromagnetic radiation
  - infra-red radiation

Heat is measured with a thermometer

**BUT**, how does a thermometer work?
The effect of heat on **density** of matter

Density = mass per unit volume

**Cool rock**

**What changed?**
- Mass
- Volume
- Density

**ADD HEAT**

**Expands**

**Hot rock**
The effect of heat on **density** of matter

As temperature increases:

- atoms (or molecules) vibrate faster and with greater amplitude
- these vibrations “push” the atoms farther apart
- which lowers the density of the material

**So... how does a thermometer work?**
Phase Transitions

**Melting** is the transition from solid to liquid
**freezing** is the reverse

**Evaporation** (vaporization) is the transition from liquid to gas
**condensation** is the reverse
Phase transitions are controlled by:
- **heat** (energy available – outward force)
- **pressure** (constraining force)
Phase transitions and rocks

Most rocks are made of more than one mineral. Each mineral melts at a different temperature.

So, a rock can be *partially molten* – with liquid in between solid crystals.
Phase transitions and rocks

Can a rock in the upper mantle melt without an increase in temperature?

Earth surface

- Uplifted, pressure reduced
- Partial melting
- Produces magma
- Rock initially at a temperature close to melting