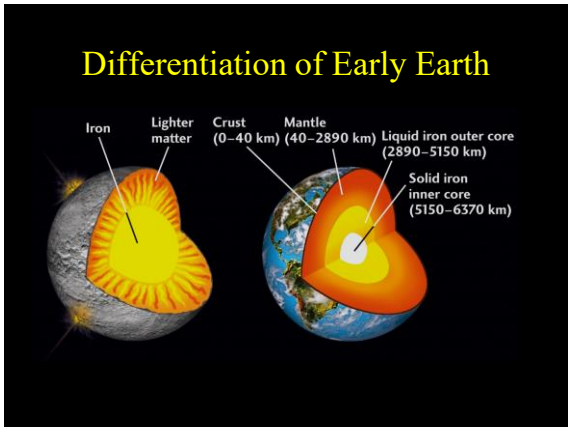
Matter and Minerals (Part 2)

- Average Abundances of Elements in Earth's Crust
- Silicate Minerals
- Silicate Structures
- Nonsilicate Minerals
- Economic Uses
- Gemstones

1

Differentiation of Early Earth



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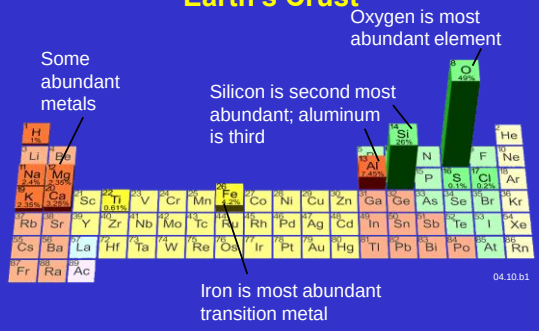
Average Abundances of Elements in Earth's Crust



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Minerals Are Subdivided Into Two Major Categories

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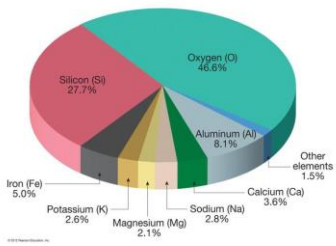
Silicate Minerals



- Silicate minerals are comprised of the two most abundant elements in Earth's crust, silicon and oxygen
- More than 800 silicate minerals are known
- Silicate minerals account for 92% of Earth's crust

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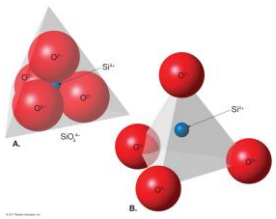
Silicon-Oxygen Tetrahedron



- Silicate minerals are comprised of Silicon-Oxygen Tetrahedra
- Silicon ion (Si^{4+}) is surrounded by four oxygen ions (O^{2-}) and represented by the formula $(SiO_4)^{4-}$
- General formula for silicates: $(SiO_4)^{4-}$ + cations (Mg^{2+}, Fe^{2+}, Ca^{2+}, Na^{+}, K^{+})

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Silicate Mineral Groups

Silicate minerals are subdivided into different groups based on the internal arrangement of silicon-oxygen tetrahedra

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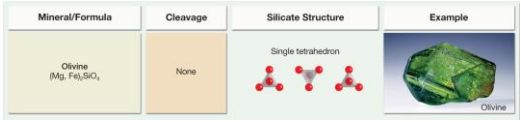
Silicate Structures: Independent Tetrahedron



Cations link together individual tetrahedra in the crystal structure

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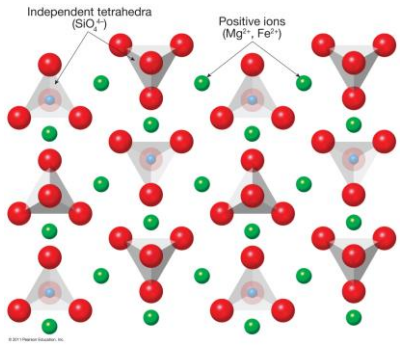
Structure of the Mineral Olivine



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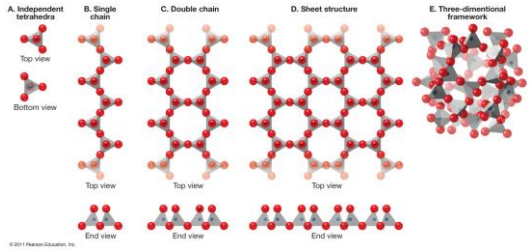
Silica Tetrahedra Also Bond Together Into Chains, Double Chains, Sheets Or 3-dimensional Framework



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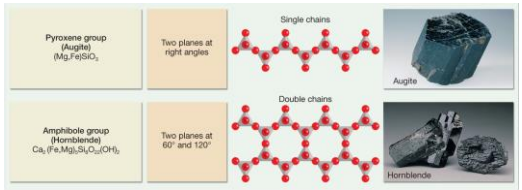
Silicate Structures: Single And Double Chains of Tetrahedra



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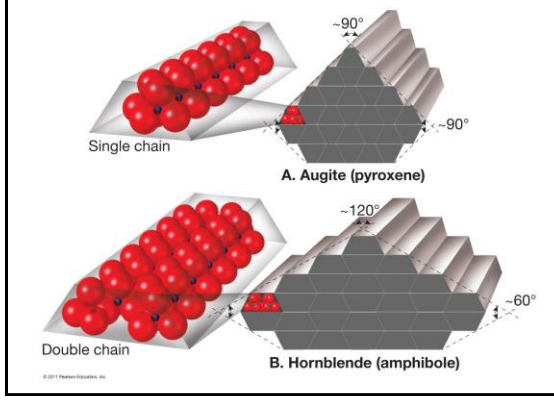

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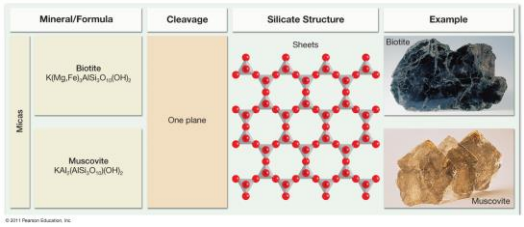
Silicate Structures: Sheets of Tetrahedra



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Micas Are Examples of Sheet Silicates

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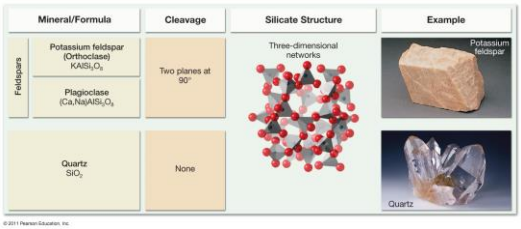
Silicate Structures: Framework Silicates Comprised of Three-Dimensional Networks of Tetrahedra



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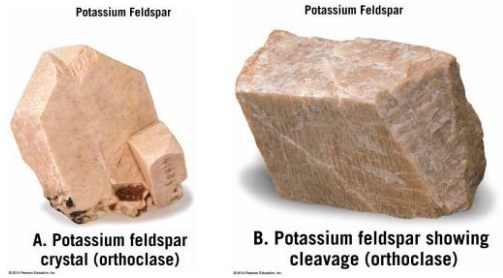
Feldspars Are Examples of Framework Silicates



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Plagioclase Feldspar With Striations

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Quartz Is A Common Framework Silicate

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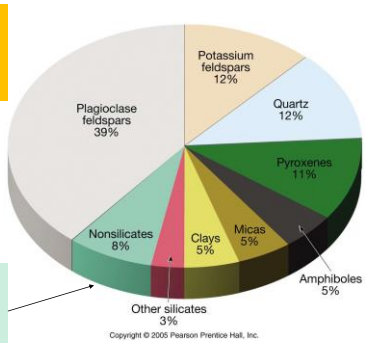
Silicates comprise over 92% of Earth's crust



Nonsilicates comprise only 8% of Earth's crust

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Nonsilicate Minerals

- Nonsilicate minerals do not have silicon in their chemical formula
- Many occur as economic ore deposits such as lead, zinc, copper, and mercury
- Some nonsilicates are used in construction material such as portland cement and plaster
- Other nonsilicates are utilized for/as drilling mud, fertilizer, electrical conductors, sulfa drugs, photography, and jewelry

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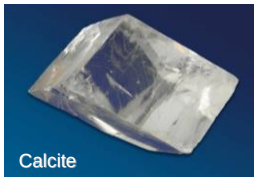
Carbonates

- Basic unit is the $(CO_3)^{2-}$ complex
- There are different carbonate minerals depending on which cation is attached to the carbonate complex:

$(CO_3)^{2-}$ + cations

- Two important carbonates:
  - Calcite [$CaCO_3$]
  - Dolomite [$CaMg(CO_3)_2$]



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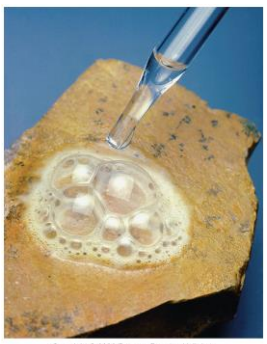
Calcite Exhibits Double Refraction And Reacts With Dilute HCl



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Uses For Carbonate Minerals

Calcite	$CaCO_3$	Portland cement, lime
Dolomite	$CaMg(CO_3)_2$	Portland cement, lime

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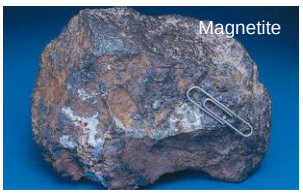
Oxides

- Cations are bounded to oxygen

O^{2-} + cations

- Two important oxides:
  - Hematite (Fe_2O_3)
  - Magnetite (Fe_3O_4)



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Some Economic Uses for Oxides

Hematite	Fe_2O_3	Ore of iron, pigment
Magnetite	Fe_3O_4	Ore of iron
Corundum	Al_2O_3	Gemstone, abrasive
Ice	H_2O	Solid form of water

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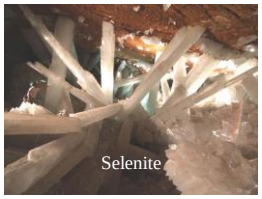
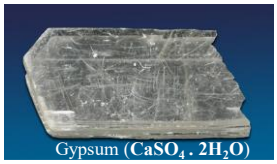
Sulfates

- Sulfur is present as the sulfate ion $(SO_4)^{2-}$

  $(SO_4)^{2-}$ + cations

- Two important sulfates:
  - Anhydrite ($CaSO_4$)
  - Gypsum ($CaSO_4 \cdot 2H_2O$)





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Uses For Sulfate Minerals

Gypsum	$CaSO_4 \cdot 2H_2O$	Plaster
Anhydrite	$CaSO_4$	Plaster
Barite	$BaSO_4$	Drilling mud

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Sulfides

- Many important ore deposits exist as sulfides

  S^{2-} + cations

- Two important sulfides:
  - Pyrite (FeS_2)
  - Galena (PbS)

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Sulfide Mineral Uses

Galena	PbS	Ore of lead
Sphalerite	ZnS	Ore of zinc
Pyrite	FeS_2	Sulfuric acid production
Chalcopyrite	$CuFeS_2$	Ore of copper
Cinnabar	HgS	Ore of mercury

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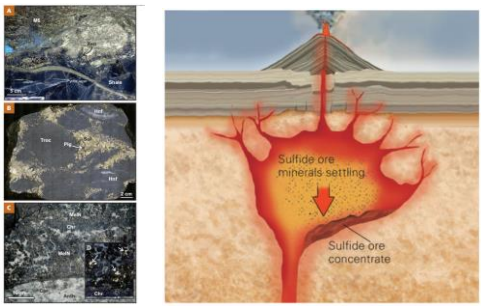
Sulfide Ore Minerals Settling In A Magma Chamber



Barnes et al. (2017)

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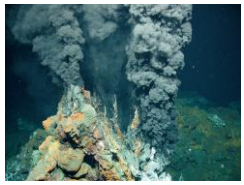
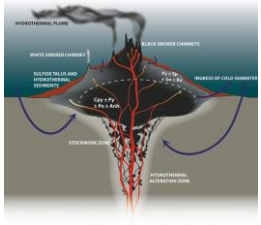
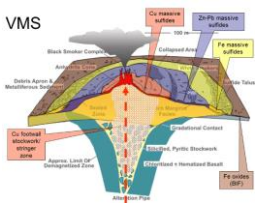
Volcanic Massive Sulfide Deposits In Hydrothermal Vents, Mid-Ocean Ridge





VMS



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Volcanogenic massive sulfide ore deposit at Kidd Mine, Ontario,Canada, formed 2.7 billion years ago on an ancient seafloor

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Halides

- Generally form ionic bonds
- Some precipitate from salty water (seawater)
- Important halides:
  - Halite (NaCl)
  - Sylvite (KCl)
  - Fluorite (CaF_2)

Sylvite (KCl)

Halite (NaCl)

Fluorite (CaF_2)

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Some Economic Uses For Halides

Cryolite Na_3AlF_6	**Fluorite** CaF_2	**Halite** NaCl

Sylvite (KCl)

Halite	NaCl	Common salt
Fluorite	CaF_2	Used in steelmaking
Sylvite	KCl	Fertilizer

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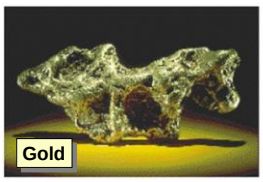
- Native Element Minerals are composed of only one element:
  - Graphite (C)
  - Diamond (C)
  - Copper (Cu)
  - Gold (Au)
  - Sulfur (S)

Copper



Gold

Diamond

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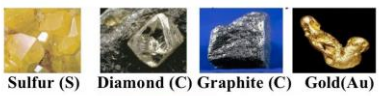
Native Element Uses



Sulfur (S) Diamond (C) Graphite (C) Gold(Au)

Silver (Ag) Copper (Cu) Platinum (Pt)

Gold	Au	Trade, jewelry
Copper	Cu	Electrical conductor
Diamond	C	Gemstone, abrasive
Sulfur	S	Sulfa drugs, chemicals
Graphite	C	Pencil lead, dry lubricant
Silver	Ag	Jewelry, photography
Platinum	Pt	Catalyst

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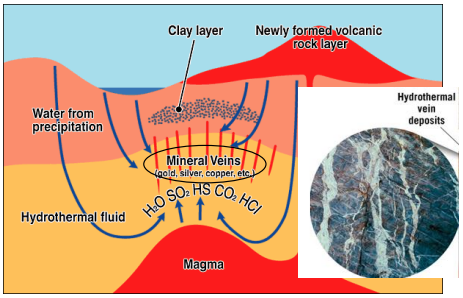
Many Native Element Minerals Deposited In Veins Associated With Hydrothermal Fluids And Magma



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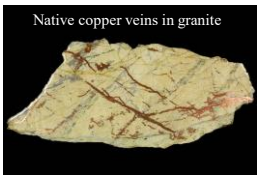
Native silver in hydrothermal vein

Gold with quartz



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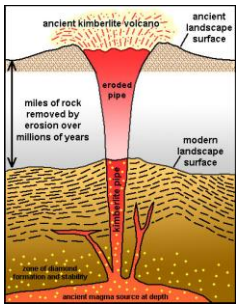
Diamonds From Kimberlite Pipes



Kimberlite pipes of South Africa contain diamonds originating at depths of at least 150 km (90 miles)

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Beryl Crystals

Australian Sapphires

Table 3.A Important Gemstones

Gem	Mineral Name	Prized Hues
Precious		
Diamond	Diamond	Colorless, yellows
Emerald	Beryl	Greens
Opal	Opal	Brilliant hues
Ruby	Corundum	Reds
Sapphire	Corundum	Blues
Semiprecious		
Alexandrite	Chrysoberyl	Variable
Amethyst	Quartz	Purples
Cat's-eye	Chrysoberyl	Yellows
Chalcedony	Quartz (agate)	Banded
Citrine	Quartz	Yellows
Garnet	Garnet	Reds, greens
Jade	Jadeite or nephrite	Greens
Moonstone	Feldspar	Transparent blues
Peridot	Olivine	Olive greens
Smoky quartz	Quartz	Browns
Spinel	Spinel	Reds
Topaz	Topaz	Purples, reds
Tourmaline	Tourmaline	Reds, blue-greens
Turquoise	Turquoise	Blues
Zircon	Zircon	Reds

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