ATOM
INDIVISIBLE

ELEMENTS
- Nucleus = protons (+ charge) & neutrons (no charge)
- Electrons (- charge) orbit the nucleus in shells of 2, 8, 8 electrons (inner orbit outward)
- Atomic number = number of protons in an element
- Mass number = total weight of protons & neutrons in the nucleus

Energy is emitted and absorbed in packets.
1st shell holds 2 electrons
2nd shell holds 8 electrons
3rd shell holds 8 electrons
4th shell holds 18 electrons
5th shell holds 18 electrons
6th shell holds 32 electrons
7th shell holds 32 electrons

Figure 2.1 The Periodic Table of Elements. The periodic table groups all elements by electron configurations in their shells, their atomic number, and their physical and chemical properties.
IONS

- Atoms with an unequal number of protons and electrons
- If there are more protons than electrons the atom has a positive charge and is called a cation
- If there are more electrons than protons the atom has a negative charge and is called an anion
ISOTOPES

- Atoms with the same number of protons but different numbers of neutrons
- They have similar chemical properties (tendencies to form ions and bond with other elements) but differ in their mass.
  - This mass difference can allow certain isotopes to accumulate in a given reservoir more readily than other isotopes of the same element.

From atoms to the Earth

- Universe begins with Hydrogen (H) and Helium (He)
- Most common elements at the Earth’s surface are Oxygen (O), Silicon (Si), Aluminum (Al), Iron (Fe), Calcium (Ca), and Sodium (Na)
- Most common elements in the Earth’s core are Iron (Fe), and Nickel (Ni)

<table>
<thead>
<tr>
<th>Element</th>
<th>Abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen (O)</td>
<td>46.6%</td>
</tr>
<tr>
<td>Silicon (Si)</td>
<td>27.7%</td>
</tr>
<tr>
<td>Aluminum (Al)</td>
<td>8.1%</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>5.0%</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>3.6%</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>2.8%</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>2.6%</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>2.1%</td>
</tr>
</tbody>
</table>

These 8 elements make up 98.5% of the elements in the Earth’s crust.

Figure 2.2: Abundances of the chemical elements in the solar system in terms of atoms per 10^16 atoms of N. Data were derived primarily by analysis of remote-sensing spacecraft instruments and by optical spectroscopy of stars by astronomers. From: Elements and Isotopes. Copyright John Wiley & Sons, Inc. 1982.
NEBULAR HYPOTHESIS

1. Start with contracting cloud of H and He & a millionth of everything else. (A)
2. As cloud contracts any rotation increases.
3. Cloud forms a disc. Particles are drawn toward center forming a proto-Sun (B)
4. Because of rotation, some dust and gas orbit the center body as a flattened disc. (B)
5. Proto-Sun collapses, Temperature increases until H fuel is ignited (T-tauri stage, temp > 60 million °C) (B)
6. Proto-planets begin to accrete from orbiting dust and gas as temperature cools (C)
7. Solar system gets cleared of debris (D)
8. Gas-Solid Separation - elements with gaseous affinities were blown from terrestrial planets by solar wind
9. Differentiation - separation of heavier and light elements. Heavier elements "sink" toward core (Fe, Ni), lighter elements in mantle and crust (O, Si, Al, Fe, Ca, Na, K, Mg)
10. Age of Earth estimated to be 4.56 billion years old
Types of Atomic Bonds
How do atoms stick together to make matter?

- **Ionic bonds** - cations (+charge) stick to anions (-charge)
- **Covalent bonds** - share electrons rather than exchange them
  - Metallic bonds – one or more electrons migrate between one atom and the other
- **Van der Walls bonds** - outer electron shell of one atom attracts nucleus of other and vice versa.

**Ionic Bonding**

- Sodium (Na⁺) ion
  - Outer shell filled with 3 electrons
  - Nucleus with 11 protons
- Chlorine (Cl⁻) ion
  - Outer shell filled with 7 electrons
  - Nucleus with 17 protons

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Covalent Bonding

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Different categories of matter.

• Element: most fundamental substance matter can be separated into by ordinary chemical means.
• Compound: one or more kinds of anion combined with one or more kinds of cation in a specific ratio.
  – Formula always written with cations first.
• Molecule: the smallest unit that retains all the properties of a compound.

What is a mineral?

• Naturally occurring
• Inorganic
• Solid
• Orderly internal structure (crystalline)
• Chemical composition and physical properties that are fixed or vary within a defined range
Is ice a mineral?
- Naturally occurring
- Inorganic
- Solid
- Has a crystalline structure
- Has specific physical properties
- Specified chemical composition

Is glass a mineral?
- Naturally occurring
- Inorganic
- Solid
- Crystalline structure
- Physical properties may vary
- Specified chemical composition

Primary physical properties of minerals:
- Color
- Specific gravity
- Luster
- Crystal form
- Cleavage/Fracture
- Hardness
- Streak (color of streak on porcelain)

COLOR

Specific Gravity
- Ratio of the weight of an object to the weight of an equal volume of water.
- Most minerals have a specific gravity of 2.5-3

Luster
- Metallic
- Non-metallic
- Earthy (dull)
- Vitreous (glassy)
- Pearly
- Silky
- Resinous
Fracture

Hardness

• The Moh’s scale of hardness ranks the resistance a mineral has to being scratched on a scale from 1-10
• Some minerals have more than one hardness value depending on the direction they are scratched.
1. Talc
2. Gypsum
3. Calcite
4. Fluorite
5. Apatite
6. Feldspar
7. Quartz
8. Topaz
9. Corundum
10. Diamond

**Streak**

- Some minerals leave a characteristic color of powder when scraped across a porcelain plate
  - Graphite = black
  - Hematite = red

**Special physical properties**

- Feel
- Taste
- Odor
- Radioactivity
- Fluorescence
- Effervescence
- Striations
- Triboluminescence
- Optical properties
- Magnetism
- Elasticity

**Double refraction**
ROCK FORMING MINERALS

- There are over 4000 known minerals
- Only 25-30 are commonly found in rocks

Mineral Groups

- The most common mineral type at the Earth’s surface are the: SILICATES

All silicate minerals are based on the silica tetrahedron

$\text{SiO}_4^{4-}$
Non-Silicate Mineral Groups

- Carbonates
- Halides
- Oxides
- Sulfides
- Sulfates
- Native elements

Carbonates

- Contain the $\text{CO}_3^{2-}$ complex
- Calcite = $\text{CaCO}_3$
- Dolomite $\text{Ca}_2\text{Mg}($$\text{CO}_3)_2$

Halides

- Contain $\text{Cl}^-$, $\text{F}^-$, or $\text{Br}^-$
- Halite = $\text{NaCl}$
- Fluorite = $\text{CaF}_2$
- Sylvite = $\text{KCl}$

Oxides

- Contain $\text{O}^{2-}$
- Hematite = $\text{Fe}_2\text{O}_3$
- Magnetite = $\text{Fe}_3\text{O}_4$
- Corundum = $\text{Al}_2\text{O}_3$
- Ice = $\text{H}_2\text{O}$

Sulfides

- Contain $\text{S}^{2-}$
- Galena = $\text{PbS}$
- Sphalerite = $\text{ZnS}$
- Pyrite = $\text{FeS}_2$
- Chalcopyrite = $\text{CuFeS}_2$
- Cinnabar = $\text{HgS}$

Sulfates

- Contain $\text{SO}_4^{2-}$
- Gypsum = $\text{CaSO}_4\cdot 2\text{H}_2\text{O}$
- Anhydrite = $\text{CaSO}_4$
- Barite = $\text{BaSO}_4$
Native Elements

- Consist of a single element
- Gold = Au
- Copper = Cu
- Diamond = C
- Sulfur = S
- Graphite = C
- Silver = Ag
- Platinum = Pt