Hashemite University

Faculty of Natural Resources and Environment

Department of earth and environmental sciences

Mineralogy (1201220)

Isotopes And Gem Minerals

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Isotopes

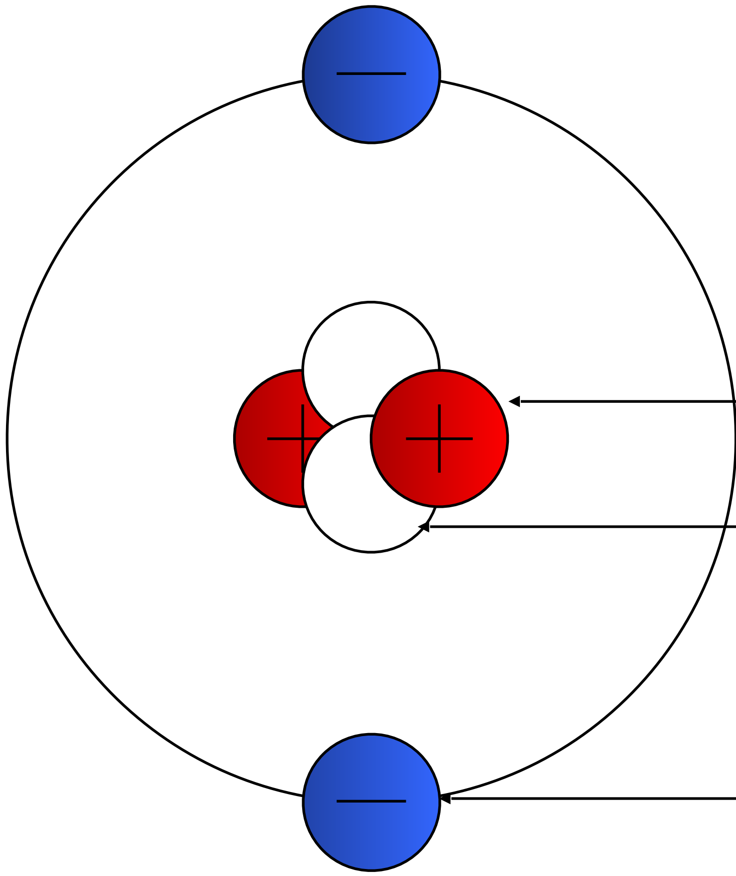
Isotope: any particular element contain the same number of protons, but different numbers of neutrons.

- Most of the isotopes which occur naturally are stable.
- A few naturally occurring isotopes are unstable.
- Unstable isotopes can become stable by releasing different types of particles.
- This process is called **radioactive decay** and the elements which undergo this process are called **radioisotopes**.

The Atom

The atom consists of two parts:

1. The nucleus which contains:



protons

neutrons

2. Orbiting electrons.

Mass number = number of protons + number of neutrons

$$^{A}_{Z}\mathrm{X}$$

Element symbol

Atomic number = number of protons

Number of neutrons = Mass Number – Atomic Number

$$^{235}_{92}U$$

$$^{238}_{92}U$$

A	235
Z	92
Number of protons	92
Number of neutrons	143

A	238
Z	92
Number of protons	92
Number of neutrons	146

Radioactive Decay

Radioactive decay results in the emission of either:

- an alpha particle (α),
- a beta particle (β),
- or a gamma ray(γ).

Alpha Decay

An alpha particle is identical to that of a <u>helium</u> nucleus.

<u>It contains two protons and two neutrons.</u>

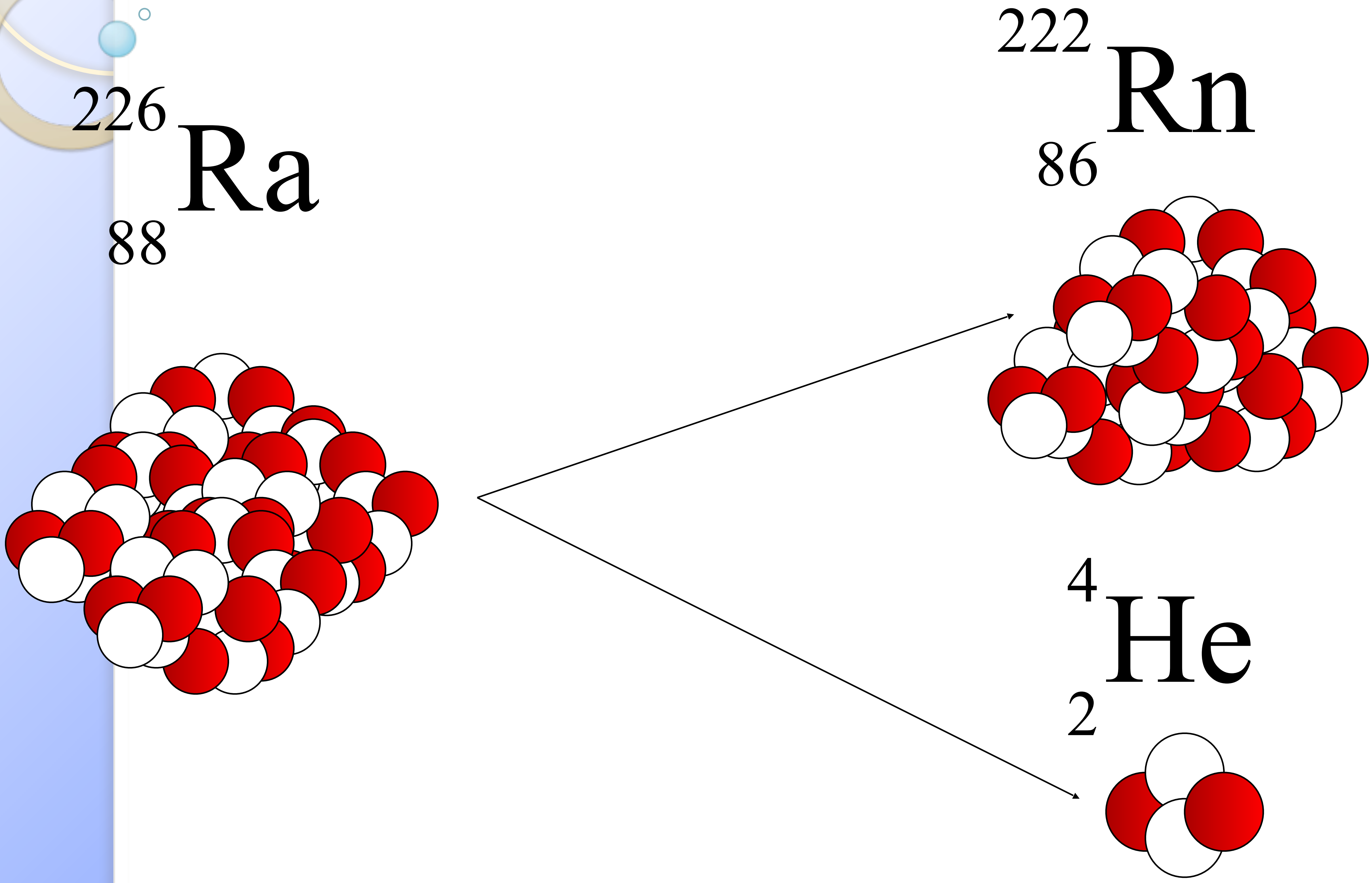
$$^{A}_{Z}X \longrightarrow \, ^{A-4}_{Z-2}Y + \, ^{4}_{2}He$$

unstable atom

alpha particle

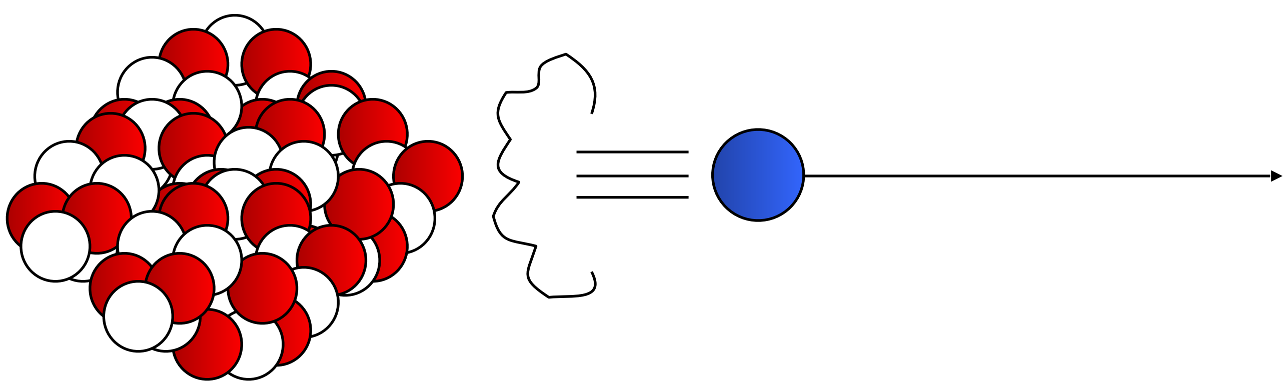
more stable atom

Alpha Decay



Beta Decay

A beta particle is a fast moving electron which is emitted from the nucleus of an atom undergoing radioactive decay.



$$^{0}_{-1}\beta$$

Gamma Decay

Gamma rays are electromagnetic radiation with high frequency.

When atoms decay by emitting α or β particles to form a new atom, the nuclei of the new atom formed may still have too much energy to be completely stable.

This excess energy is emitted as gamma rays (gamma ray photons have energies of $\sim 1 \times 10^{-12}$ J).

Where do these particles come from ?

- These particles generally come from the nuclei of atomic isotopes which are not stable.

- The decay chain of Uranium produces all three of these forms of radiation.

URANIUM 238 (U238) RADIOACTIVE DECAY

type of radiation	nuclide	half-life
α	uranium—238	4.5×10^{9} years
β	thorium—234	24.5 days
β	protactinium—234	1.14 minutes
α	uranium—234	2.33×10^{5} years
α	thorium—230	8.3×10^{4} years
α	radium—226	1590 years
α	radon—222	3.825 days
α	polonium—218	3.05 minutes
β	lead—214	26.8 minutes
β	bismuth—214	19.7 minutes
α	polonium—214	1.5×10^{-4} seconds
β	lead—210	22 years
β	bismuth—210	5 days
α	polonium—210	140 days
	lead—206	stable

Radioactive Decay

Radioactive elements are unstable. They decay, change, into different elements over time. Here are some facts to remember:

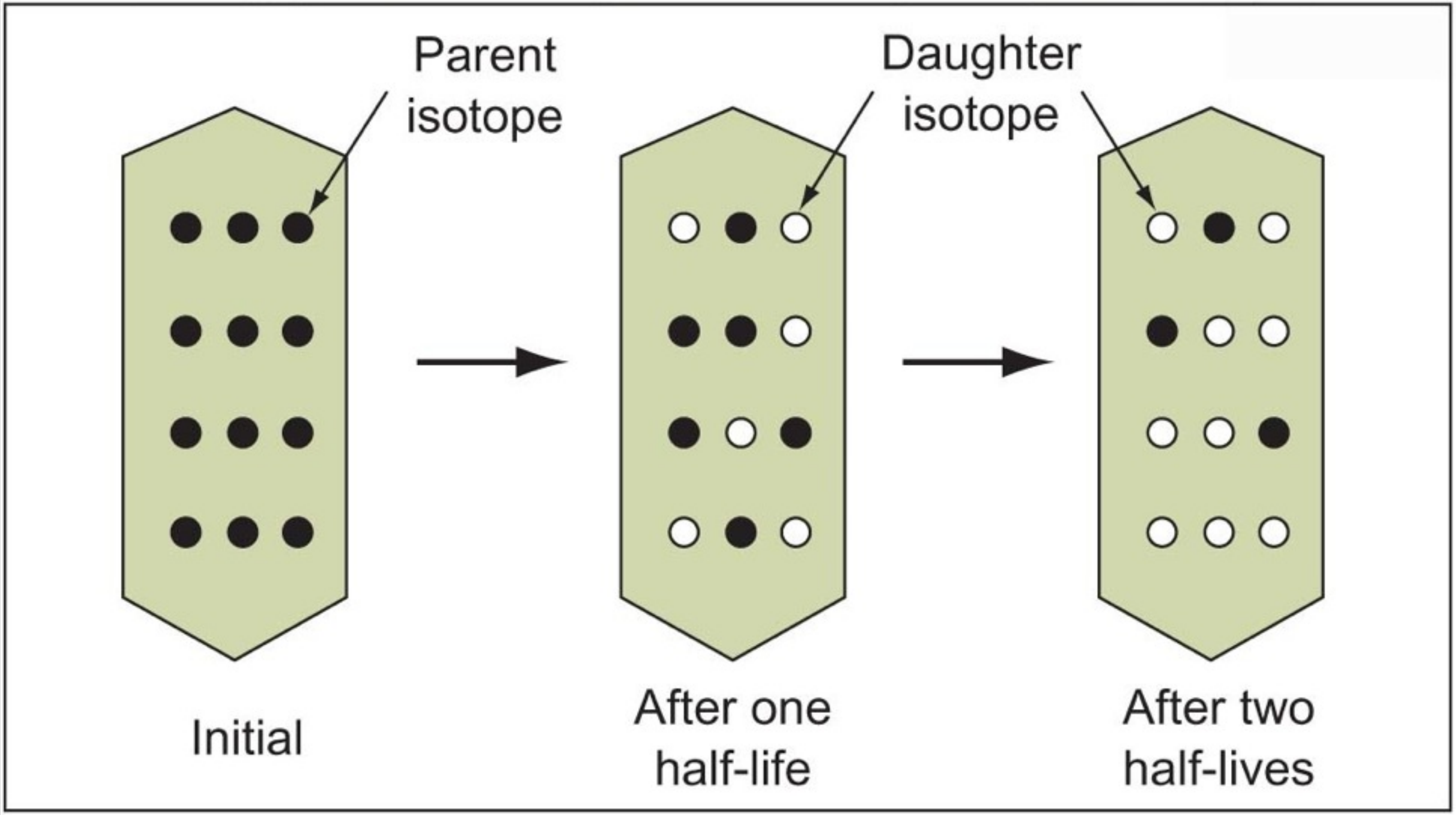
The half-life of an element is the time it takes for half of the material you started with to decay.

Each element has it's own half-life

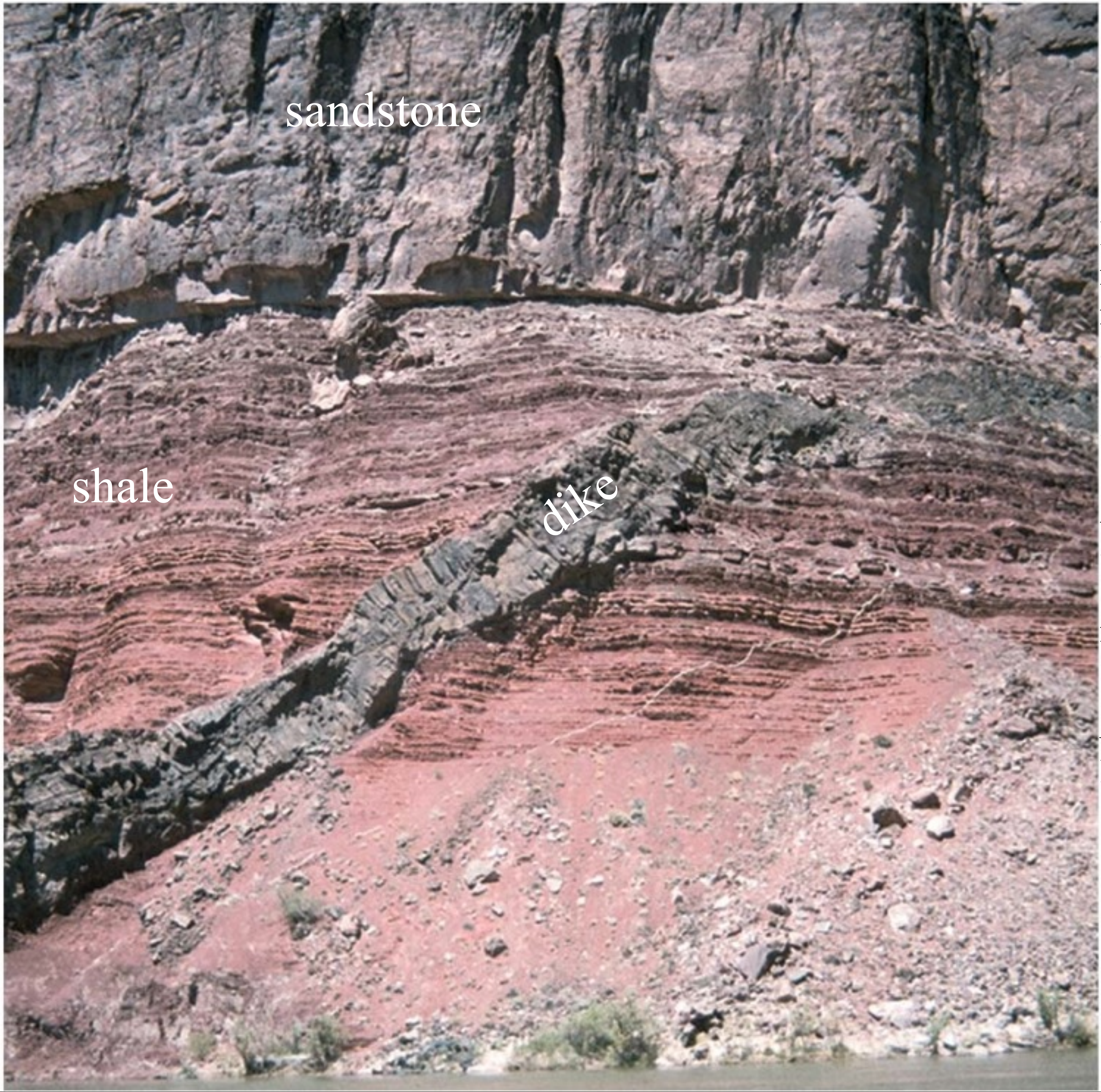
The half-life of each element is constant.

Each element decays into a new element
C^{14} decays into N^{14} while U^{238} decays into Pb^{206} (lead), etc.

Now let's see how we can use half-life to determine the age of a rock or other artifact.



Schematic diagram showing decay of radioactive *parent* isotope (e.g. U-238) to a *daughter* (e.g. Pb-206). The original isotope was sealed in a mineral grain at time of crystallization. Note changing ratio of parent/daughter after 2 half-lives. Note that to get an estimate of the geologicc age, you need the ratio of the parent isotope to the daughter isotope, e.g. two measurements.



Establishing absolute geologic age.

Example of cross-cutting relationships that establish relative ages: an igneous dike cuts through red shales and is truncated by overlying sandstone.

A radiometric date on the dike will give a minimum age for the shale and a maximum age for the sandstone.

Note the combination of "Geologic" age and absolute age techniques.

Half-Life calculation

For example, suppose we had 20,000 atoms of a radioactive substance.

If the half-life is 1 hour, how many atoms of that substance would be left after:

Time	#atoms remaining	% of atoms remaining
1 hour (one lifetime) ?	**10,000**	**(50%)**
2 hours (two lifetimes) ?	**5,000**	**(25%)**
3 hours (three lifetimes) ?	**2,500**	**(12.5%)**

Radioactive elements

- Not all elements are radioactive. Those that are and are the most useful for geologic dating are:

- U-238 Half-life = 4.5 By
- K-40 Half-life = 1.25 By
- C-14 Half-life = 5.73 years

- Also, Sm-147, Rb 87, Th-232, U-235

Gems

Gemstone is a mineral, stone, or organic matter that can be cut and polished or otherwise treated for use as jewelry or other ornament.

A precious gemstone has beauty, durability, and rarity, whereas a semiprecious gemstone has only one or two of these qualities.

Diamondماس , corundum ياقوت(ruby and sapphire),زمرد زبرجد او beryl (emerald and aquamarine), topaz, and عقيقopal are generally classed as precious stones.

All other gemstones are usually classed as semiprecious.

Geologic environment

Gems tend to be

- scattered sparsely throughout a large body of rock، or
- crystallized as small aggregates، or
- fill veins and small cavities.

- The average grade of the richest diamond kimberlite pipes in Africa is about 1 part diamond in 40 million parts "ore." Kimberlite, a plutonic igneous rock, ascends from a depth of at least 100 kilometers

Geologic environment

Most gemstones are found in igneous rocks and alluvial gravels, but sedimentary and metamorphic rocks may also contain gem materials.

Major characteristics

- Hardness and
- specific gravity

Examples of geologic environments in which gemstones are found:

- **Pegmatite** a coarse-grained intrusive igneous rock body,
- **Stream gravels** (placers) deposits. Often tourmaline, beryl, and many other gem-quality minerals have eroded out of the original rock in which they formed and have moved and been concentrated locally by water in streams.
- **Metamorphic rocks** that have been altered by great heat, pressure, or both. Garnet, for example.

Organic gemstones

The four organic gemstone groups listed below are highly prized for their beauty and rarity. However, they are not as durable as gemstones from minerals:

1. **Amber** A mixture of hydrocarbons
2. **Coral** Formed mainly of calcite (calcium carbonate)
3. **Jet** Carbon plus various hydrocarbon compound
4. **Pearl** Formed within a mollusk, such as an oyster

In Pegmatite	In Alkali Syenite Pegmatite	In Syenitic Rocks	In Peridotite	In Skarn
Aquamarine	Sapphire	Sapphire	Peridot	Painite
Topaz	Spinel	Spinel	Enstatite	Badeleyite
Danburite	Schorl	Sphene	Hornblende	Anatase
Morganite	Almandite	Almandite	Chrysoprase	Sphene
Tourmaline		Zircon		Poudretteite
Goshenite				Sodalite
Amethyst				Hackmanite
Moonstone				Sinhalite
Fluorite				Serendebite
Rock crystal				
Citrine				
Herderite				
Scheelite				
Rhodochrosite				
Ilmenorutile				
Amazonite				
Hassonite				
Zircon				

Mohs Scale of Hardness

The following is a chart of mineral gemstones and gemstone-like materials you're most likely to find used in jewellery.

Gemstone Name	Hardness	Gemstone Name	Hardness
Agate	7.0	Jet*	2.5
Alexandrite	8.5	Kunzite	7.0
Amber*	2.5	Kyanite	7.0/5.0
Amethyst	7.0	Labradorite	6.0
Ametrine	7.0	Lapis Lazuli	5.5
Andalusite	7.5	Malachite	4.0
Apatite	5.0	Moonstone	6.0
Aquamarine	7.5	Morganite	7.5
Aventurine	7.0	Obsidian	5.0
Azurite	3.5	Onyx	7.0
Beryl	7.5	Opal	6.0 - 6.5
Bloodstone	7.0	Pearl*	3.0
Blue Chalcedony	7.0	Peridot	6.5
Carnelian	7.0	Rhodochrosite	4.0
Cat's Eye - Chrysoberyl	8.5	Rhodonite	6.0
Cat's Eye - Quartz	7.0	Ruby	9.0
Chrysoprase	7.0	Sapphire	9.0
Citrine	7.0	Sardonyx	7.0
Coral*	3.5	Scapolite	6.0
Diamond	10.0	Serpentine	2.5-5.0
Emerald	7.5	Sillimanite	7.5
Fluorite	4.0	Quartz	7.0
Garnet	6.5 - 7.5	Sodalite	5.5
Goldenite	7.0	Spectrolite	6.0
Goshenite	7.5	Spinel	8.0
Heliodor	7.5	Sunstone	6.0
Hematite	6.5	Tanzanite	6.5
Hiddenite	7.0	Tiger's Eye	7.0
Howlite	3.5	Topaz	8.0
Iolite	7.0	Tortoiseshell*	2.5
Ivory*	2.5	Tourmaline	7.5
Jade	6.5 - 7.0	Turquoise (Stabilized)	6.0
Jasper	7.0	Zircon	7.5

* Not technically a gemstone or mineral these materials are organic but used in jewellery.


Black Diamond
Crystal
Shadow Crystal
Morion
Light Azore
Indian Sapphire
Indicolite
Dark Sapphire
Cobalt
Aquamarine
Light Sapphire
Sapphire
Montana
Capri Blue
Blue Zircon
Turquoise
Chrysolite
Lime
Erinite
Light Emerald
Medium Emerald
Turmaline
Emerald
Jonquil
Peridot
Light Olivine
Olivine
Topaz
Light Colorado Topaz
Smoked Topaz
Light Topaz
Citrine
Sun
Light Smoked Topaz
Smoky Quartz
Fireopal
Light Peach
Padparadscha
Rose Alabaster
Light Rose
Rose
Fuchsia
Indian Red
Burgundy
Light Siam
Siam
Ruby
Garnet
Light Amethyst
Amethyst
Violet
Tanzanite
Lilac
Jet
White Alabaster