


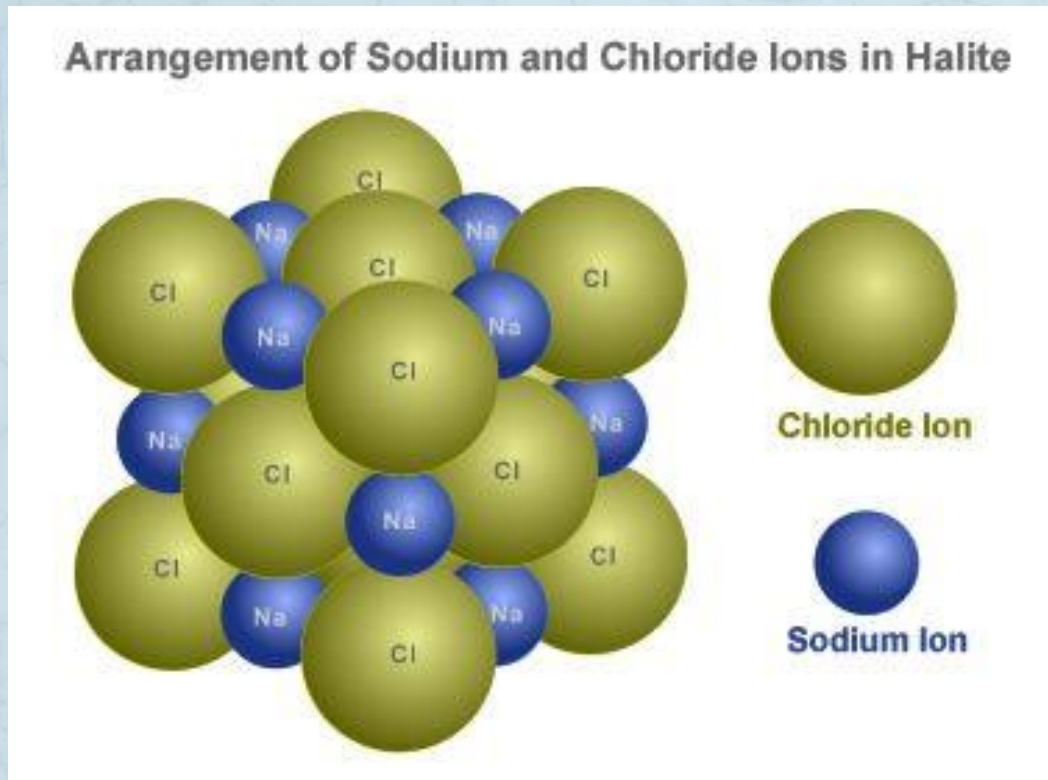
# CHAPTER 2 ELEMENTS AND MINERALS

## Minerals

Composition  
and  
Physical and Chemical Properties



# ELEMENTS AND MINERALS

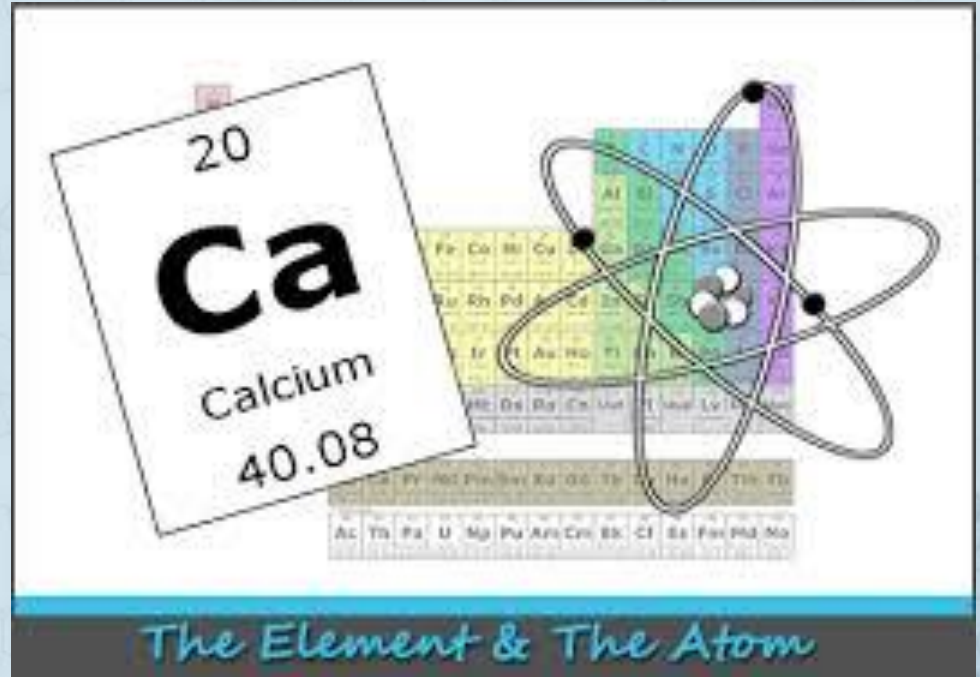


- Minerals are made of elements
- Elements are made up of atoms
- Atoms are the basic building blocks of all matter. They are invisible

# ELEMENTS AND MINERALS

## What is an element?

Elements are naturally occurring substance that have same number of proton i.e. same atomic number. Elements are chemically simplest substance and can't break by any chemical method.



# ELEMENTS AND MINERALS

## Elements

They contain 3 parts

1. *Protons*

Found in the nucleus

Positive charge

2. *Neutrons*

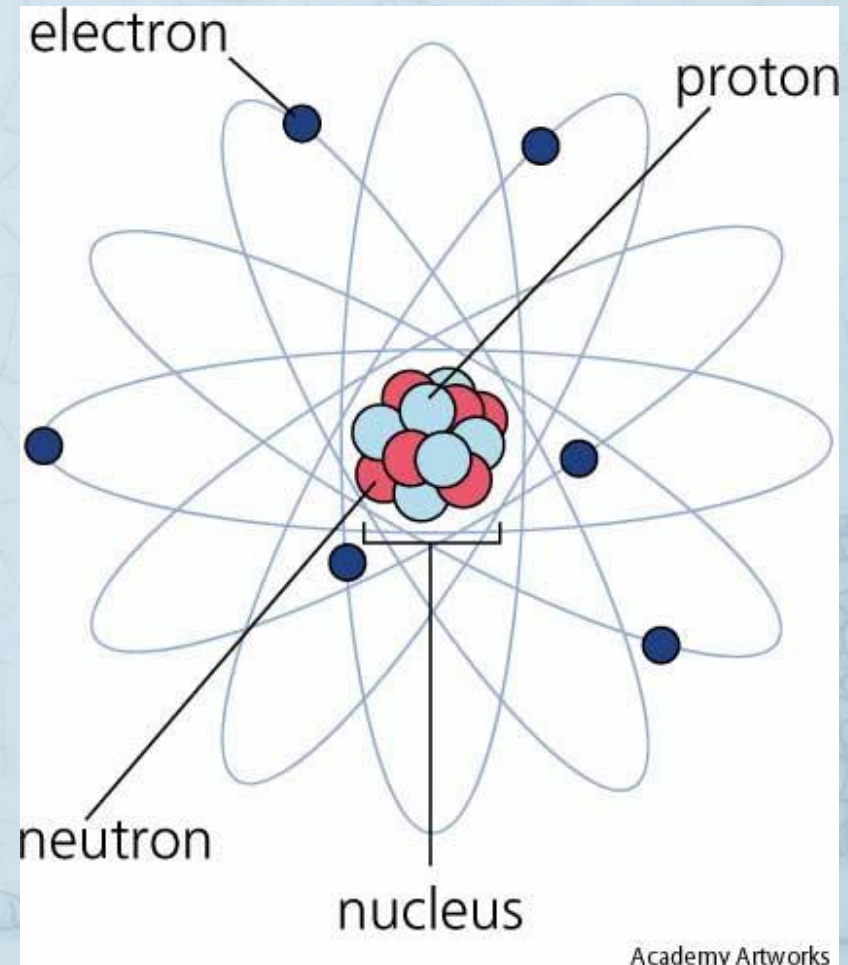
Found in the nucleus

Charge of 0

3. *Electrons*

Rotate in the orbits the  
nucleus

Negative charge



# ELEMENTS AND MINERALS

## Elements

A substance in which all of the atoms are the same.

The 6 most common elements on the earth are

- P Phosphorus
- C Carbon
- H Hydrogen
- O Oxygen
- N Nitrogen
- S Sulfur

**Periodic Table of the Elements**

**Legend:**

- Alkali Metals (Red)
- Alkaline Earth Metals (Orange)
- Transition Metals (Yellow)
- Other Metals (Light Green)
- Nonmetals (Green)
- Noble Gases (Blue)
- Inner Transition Metals (Light Blue)
- EI Gaseous State
- EI Liquid State
- EI Solid State
- EI Synthetically Prepared

1 H 1.0079																	2 He 4.0026
3 Li 6.941	4 Be 9.0122											5 B 10.81	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.179
11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.06	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.08	21 Sc 44.956	22 Ti 47.90	23 V 50.941	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.933	28 Ni 58.71	29 Cu 63.546	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.22	41 Nb 92.906	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.4	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.69	51 Sb 121.75	52 Te 127.60	53 I 126.90	54 Xe 131.30
55 Cs 132.91	56 Ba 137.33	57 La 174.97	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.4	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04		
87 Fr (223)	88 Ra (226)	89 Ac (227)	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237.05	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (254)	100 Fm (257)	101 Md (258)	102 No (259)		

**Lanthanide Series:** 57 La, 58 Ce, 59 Pr, 60 Nd, 61 Pm, 62 Sm, 63 Eu, 64 Gd, 65 Tb, 66 Dy, 67 Ho, 68 Er, 69 Tm, 70 Yb

**Actinide Series:** 89 Ac, 90 Th, 91 Pa, 92 U, 93 Np, 94 Pu, 95 Am, 96 Cm, 97 Bk, 98 Cf, 99 Es, 100 Fm, 101 Md, 102 No

\*Name Not Officially Assigned

A compound is a substance in which there are 2 or more types of atoms.

# ELEMENTS AND MINERALS

## Periodic Table

Where elements are arranged

Atomic number

Number of protons

Element abbreviation

Atomic mass

Number of protons + number of neutrons

The image shows an interactive periodic table interface. The main element displayed is Lithium (Li) with atomic number 3 and atomic mass 6.941. The interface includes a key for electronic configuration, a history button, and buttons for physical and chemical properties.

**KEY: Electronic Configuration**

Atomic Number	11	2	8	1
Name	Sodium			
Symbol	Na			
Atomic Mass	22.990			

**Lithium**  
**Li**  
6.941

History  
Physical Properties  
Chemical Properties

# ELEMENTS AND MINERALS

## Symbols To Know

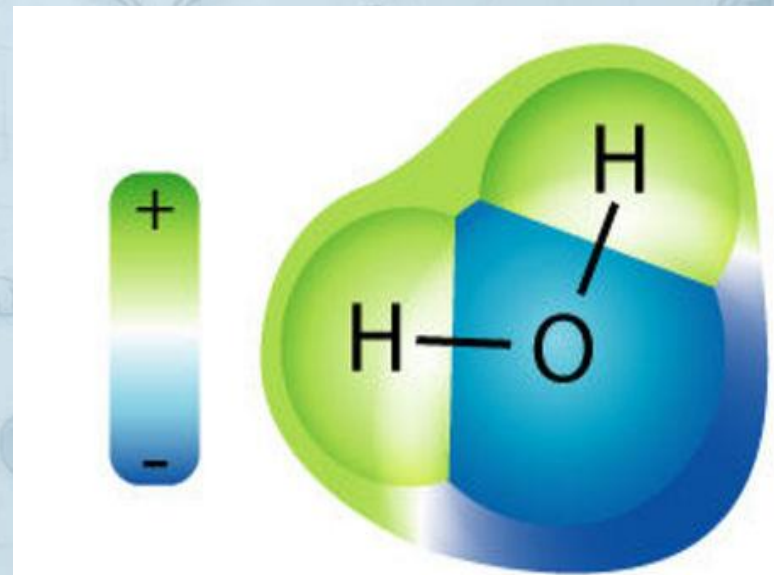
• Aluminum	-	Al	◇	• Argon	-	Ar
• Calcium	-	Ca	◇	• Magnesium	-	Mg
• Carbon	-	C	◇	• Mercury	-	Hg
• Chlorine	-	Cl	◇	• Nitrogen	-	N
• Copper	-	Cu	◇	• Oxygen	-	O
• Helium	-	He	◇	• Potassium	-	K
• Hydrogen	-	H	◇	• Silicon	-	Si
• Iron	-	Fe	◇	• Sodium	-	Na
• Lead	-	Pb	◇	• Sulfur	-	S
• Gold	-	Au	◇	• Uranium	-	U
			◇	Silver- Ag		

# ELEMENTS AND MINERALS

## Periodic Table

Where elements are arranged

Each element is made of all the same kind of atom. Elements can combine together to form compounds which have a definite chemical formula. Which elements combine depend on the electron configuration. Substances can combine to form mixtures.



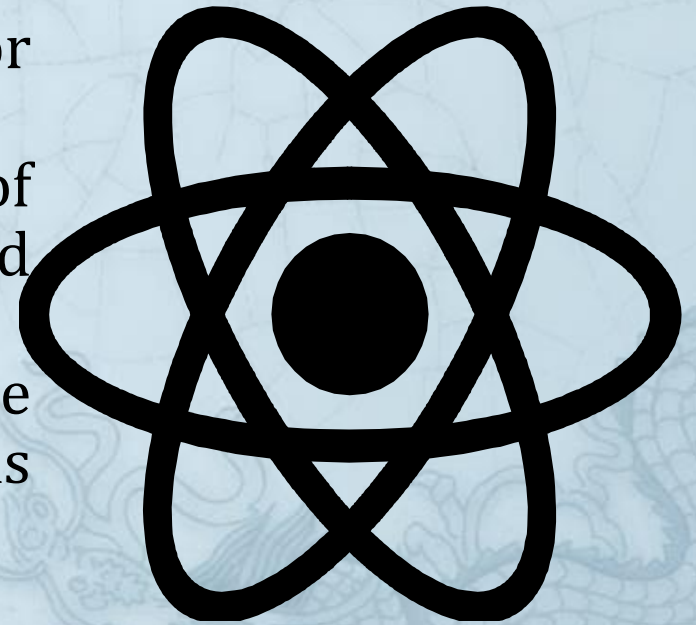
# ELEMENTS AND MINERALS

## Connection to Minerals

Minerals are made up of a single element or a compound.

Since compounds are combinations of elements, it is important to know how and why elements combine?

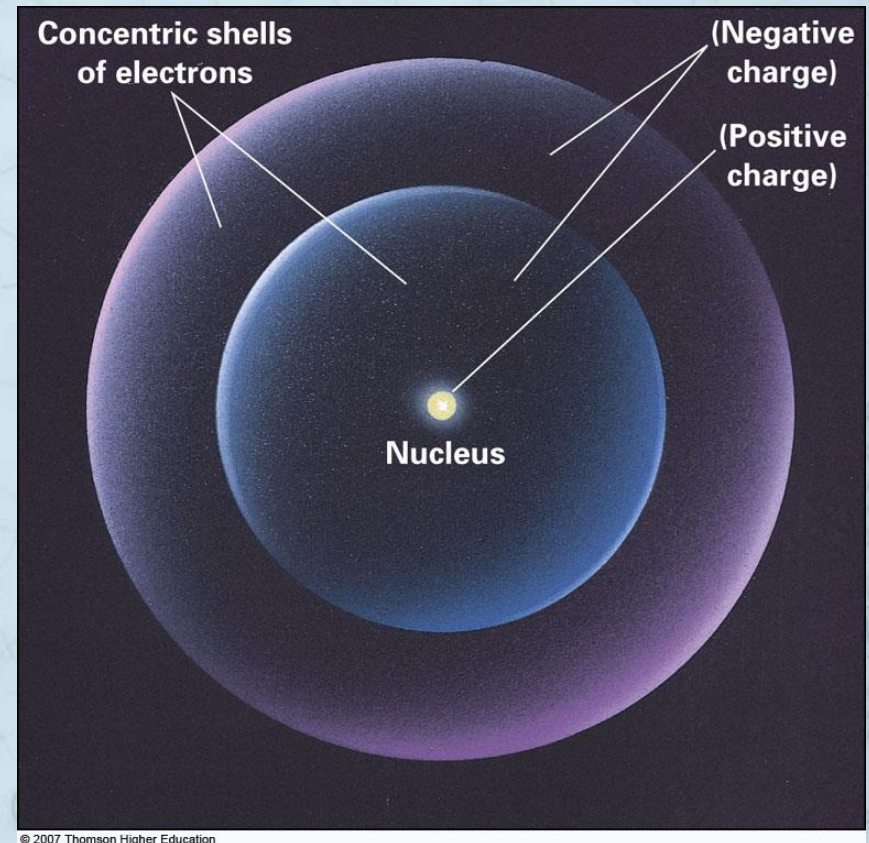
The properties of minerals are due to the internal structure of the atoms, known as their crystal arrangement.



# ELEMENTS AND MINERALS

## Atoms make-up minerals

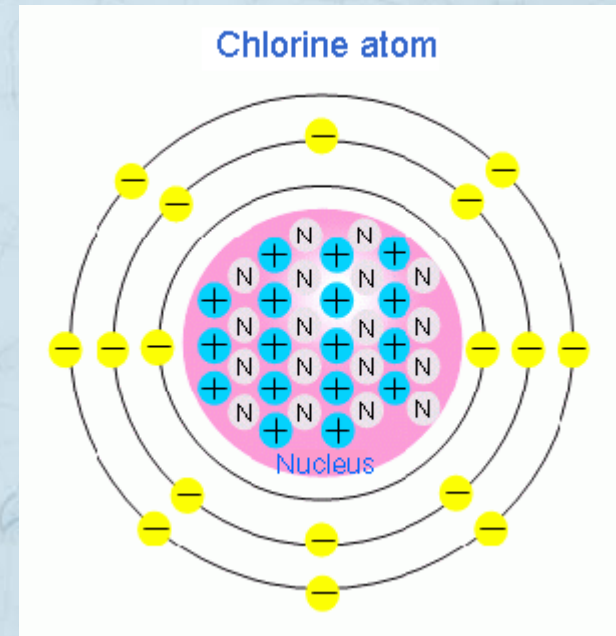
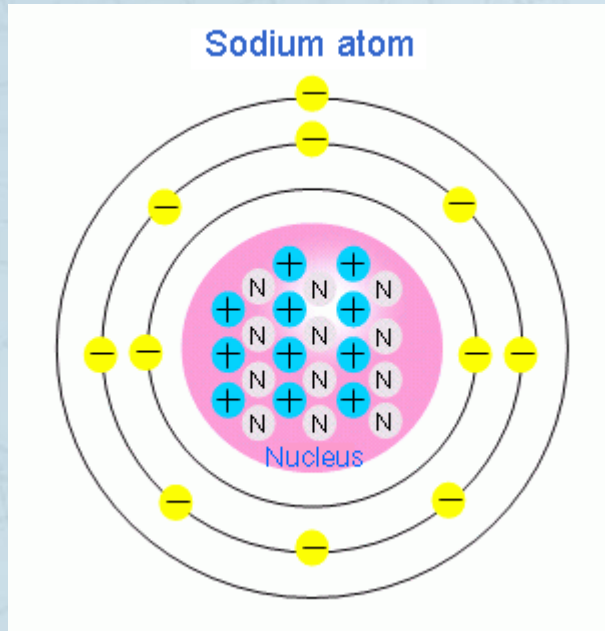
An atom is the smallest component of matter  
Each element is defined by the number of protons  
The atom must be electrically neutral  
The number of protons equals the number of electrons



# ELEMENTS AND MINERALS

## Atoms make-up minerals

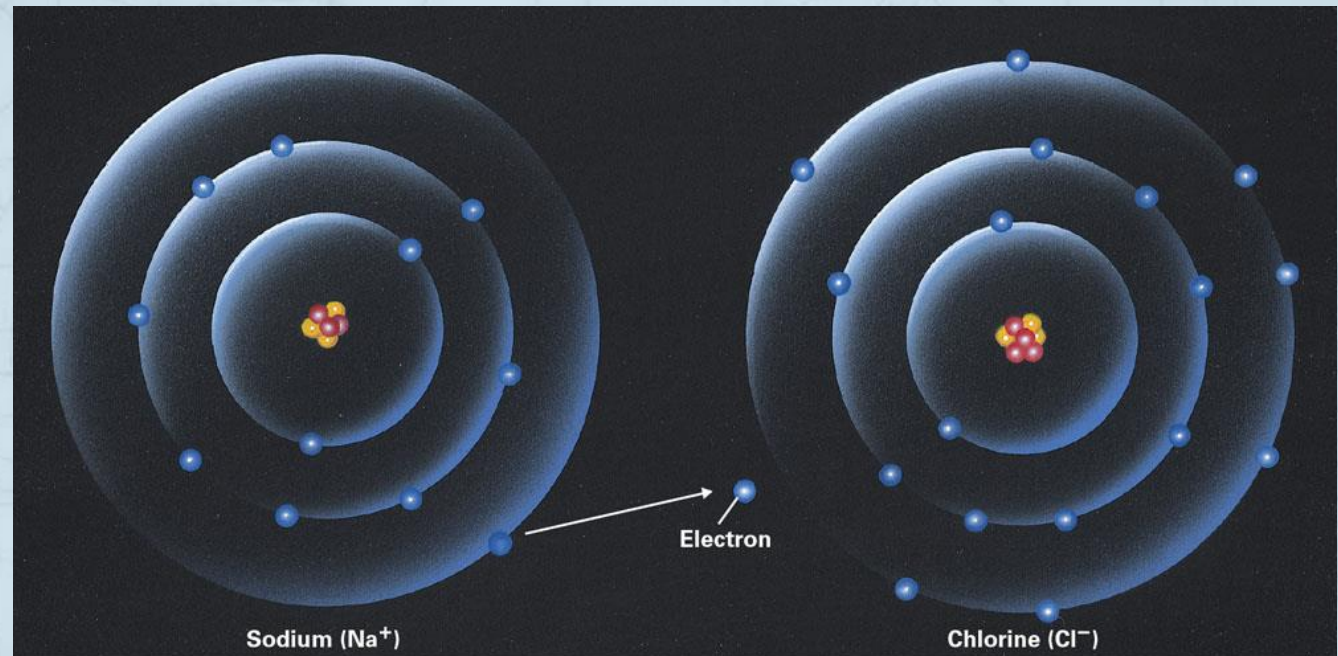
### Sodium chloride



# ELEMENTS AND MINERALS

## Why do sodium and chlorine combine to form salt?

The configuration of electrons determines if an atom will respond with another atom

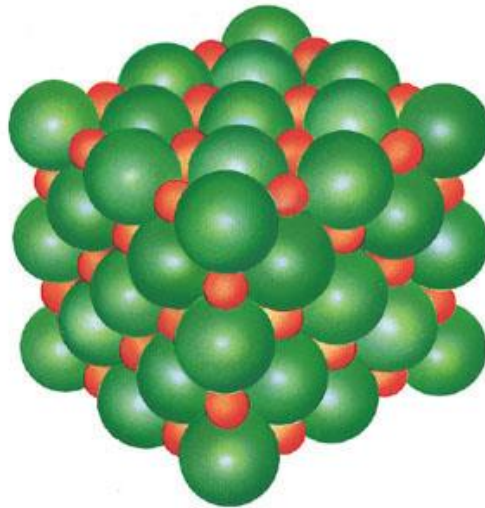
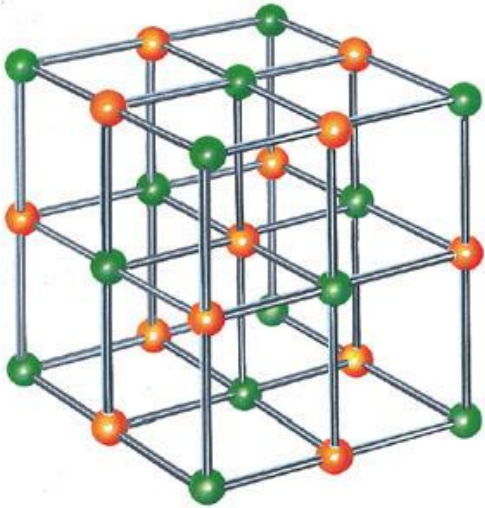


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The sodium atom has one electron on its outer ring. The Chlorine atom has 7 electrons on its outer ring. The two atoms share electrons forming an ionic bond.

# ELEMENTS AND MINERALS

Atomic structure determines the mineral's characteristics



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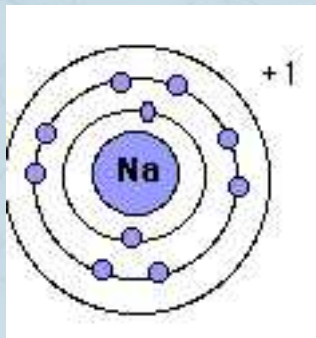
Salt or halite always has a cubic form and tastes salty

# ELEMENTS AND MINERALS

## Atomic structure determines the mineral's characteristics

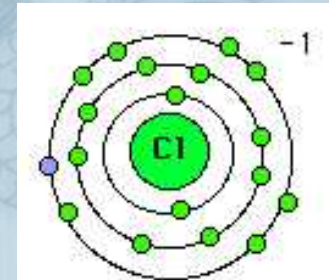
The one electron on the outer shell is given up

This leaves the sodium atom with more protons, +1



cation

- ◆ The one electron is added to Chlorines outer shell
- ◆ This leaves the chlorine atom with one more electron, -1



anion

# ELEMENTS AND MINERALS

## Characteristics of minerals

- Minerals are ingredient of rocks.
- This means many different minerals make up rocks.
- Characteristics of minerals
  - Naturally occurring
  - Inorganic
  - Solids
  - They have a specific chemical make-up.
  - Have a crystalline internal structure.



# ELEMENTS AND MINERALS

## Mineral Formation

Minerals are formed in two different ways

1. Cooling of magma  
This is the most common.  
The slower the rate of cooling the larger the crystal.
2. Evaporation of water  
- As it evaporates the water leaves the mineral behind.



# ELEMENTS AND MINERALS

Eight elements make-up 99% of the Earth's crust

**Silicon and oxygen make-up 70 % of the Earth's crust**

**Table 2.1 The Eight Most Abundant Chemical Elements in the Earth's Crust\***

<b>Element</b>	<b>Symbol</b>	<b>Weight Percent</b>	<b>Atom Percent</b>	<b>Volume Percent†</b>
Oxygen	O	46.60	62.55	93.8
Silicon	Si	27.72	21.22	0.9
Aluminum	Al	8.13	6.47	0.5
Iron	Fe	5.00	1.92	0.4
Calcium	Ca	3.63	1.94	1.0
Sodium	Na	2.83	2.64	1.3
Potassium	K	2.59	1.42	1.8
Magnesium	Mg	2.09	1.84	0.3
	Total	98.59	100.00	100.00

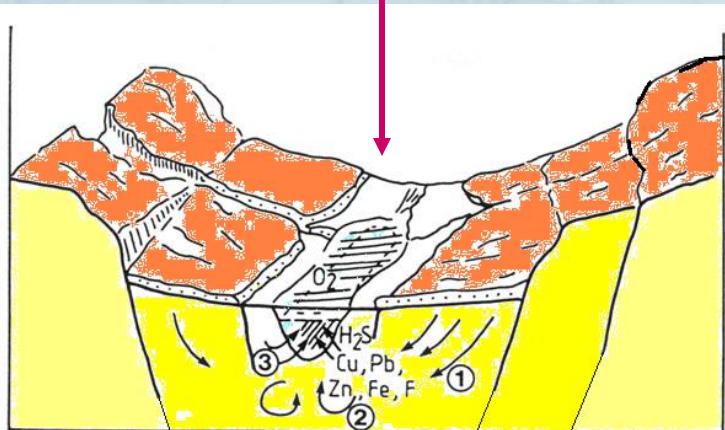
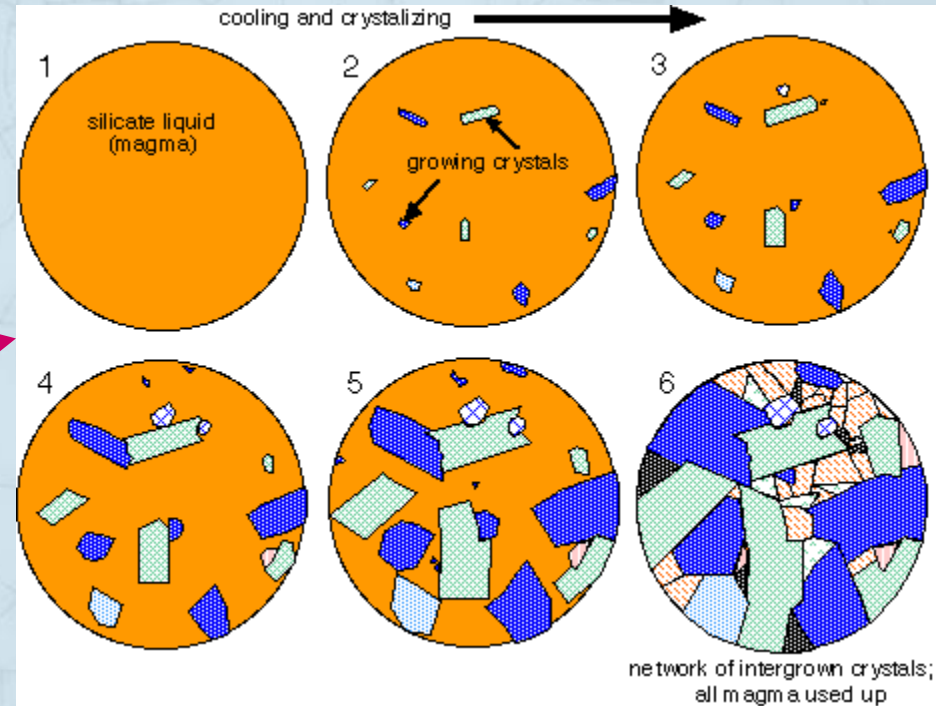
# ELEMENTS AND MINERALS

## Mineral Formation

Cooling of magma: crystallization

Evaporation: salt

Hydrothermal

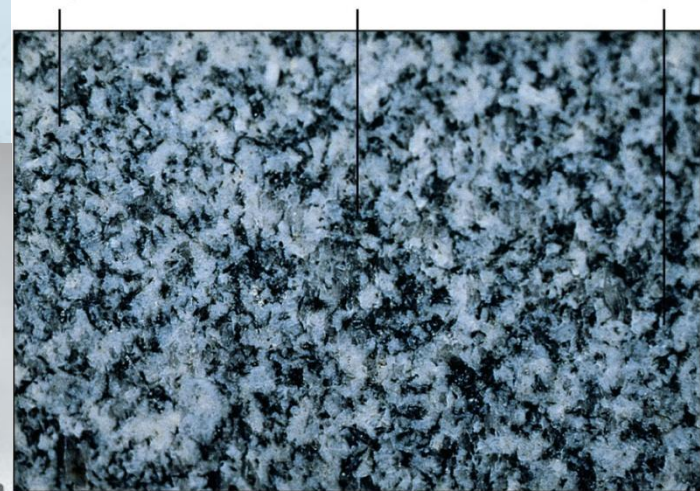


# ELEMENTS AND MINERALS

Minerals are the building block of rocks



Feldspar                      Biotite                      Quartz



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# ELEMENTS AND MINERALS

## Properties of Minerals

*Physical and Chemical properties*

### Physical Properties:

- Color
- Streak
- Luster
- Hardness
- Cleavage/Fracture
- Crystal Form
- Specific Gravity
- Special Properties

Over 3000 different minerals exist, but only 50 are common. These minerals are identified using 8 basic characteristics.

# ELEMENTS AND MINERALS

## Properties of Minerals

*Physical and Chemical properties*

### ***Physical Properties:***

Color:

Although an obvious feature, it is often unreliable to use to determine the type of mineral. Color of a mineral may be useful for determining any impurities that are present in the mineral

For example – Rose quartz has iron impurities; green quartz has chlorite impurities.



# ELEMENTS AND MINERALS

## Properties of Minerals

*Physical and Chemical properties*

### ***Physical Properties:***

Streak:

The color of a mineral in its powdered form; obtained by rubbing the mineral against an unglazed porcelain plate.

Streak is usually less variable than color but it can be very different from color!



# ELEMENTS AND MINERALS

## Properties of Minerals

*Physical and Chemical properties*

### ***Physical Properties:***

Luster:

This property describes the appearance of reflected light from the mineral's surface. Luster is either “metallic” or “nonmetallic”  
Nonmetallic minerals are described using the following terms: vitreous, pearly, silky, resinous, and earthy.



# ELEMENTS AND MINERALS

## Properties of Minerals

*Physical and Chemical properties*

### ***Physical Properties:***

#### Hardness:

This is the resistance of the mineral to abrasion or scratching. This property doesn't vary greatly from sample to sample of the same mineral, and thus is highly diagnostic. A value is obtained by comparing the mineral to a standard scale devised by Moh, which is comprised of 10 minerals ranging in hardness from talc (softest) to diamond (hardest).



The diagram shows a triangular stack of 10 dark rectangular blocks, each representing a mineral on the Mohs scale. The blocks are arranged from top to bottom, with the largest block at the top and the smallest at the bottom. The top block is labeled '10 Diamond', and the bottom block is labeled '1 Talc'. The labels for the other minerals are '9 Corundum', '8 Topaz', '7 Quartz', '6 Feldspar', '5 Apatite', '4 Fluorite', and '3 Calcite'. The entire diagram is set against a dark, textured background.

Hardness	Mineral
10	Diamond
9	Corundum
8	Topaz
7	Quartz
6	Feldspar
5	Apatite
4	Fluorite
3	Calcite
2	Gypsum
1	Talc

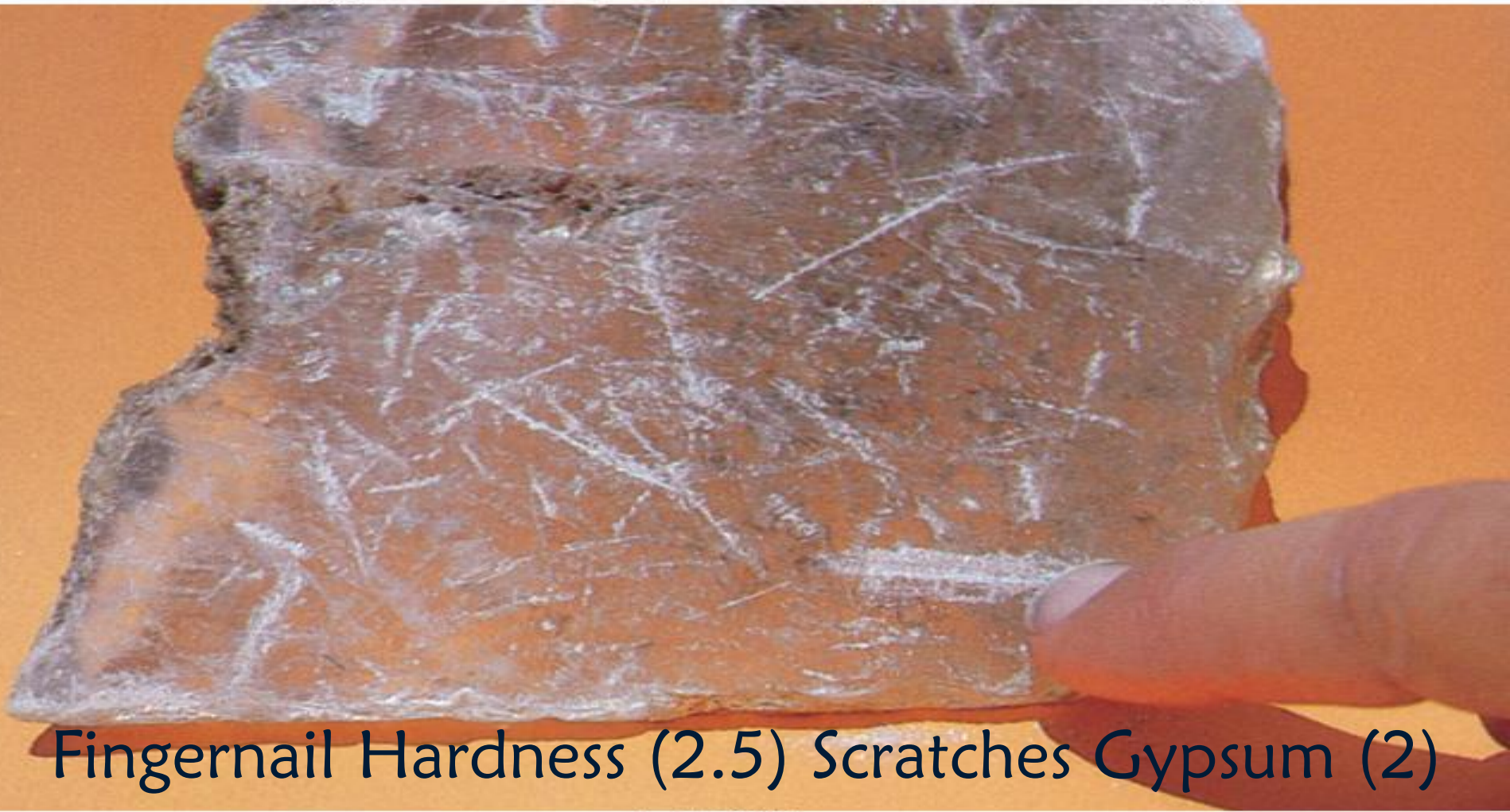
Mohs Hardness Scale

# ELEMENTS AND MINERALS

## Properties of Minerals

*Physical and Chemical properties*

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Fingernail Hardness (2.5) Scratches Gypsum (2)

# ELEMENTS AND MINERALS

## Properties of Minerals

*Physical and Chemical properties*

### **Physical Properties:**

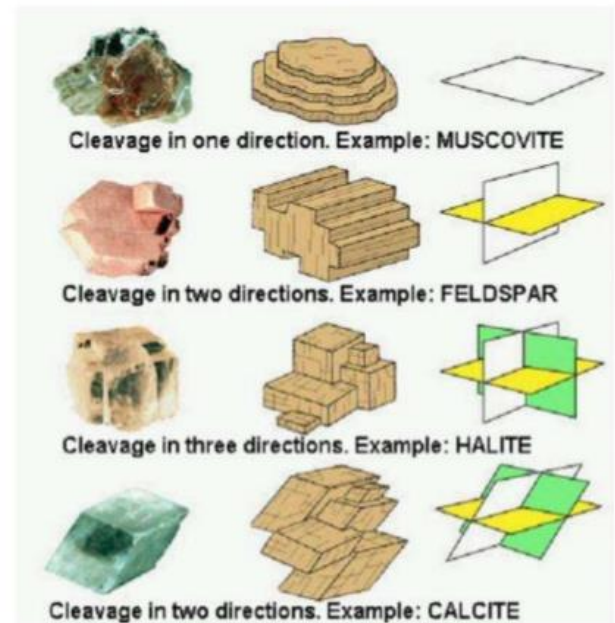
#### Cleavage:

Orientation and number of planes of weakness within a mineral. Directly reflects the orientation of weak bonds within the crystal structure. This feature is also very useful

#### **Cleavage**

Depending on how their constituent atoms are arranged, minerals may break along specific surfaces of weakness called cleavage planes.

Cleavage planes mark those parts of the mineral where ions are connected by relatively weak ionic bonds.



# ELEMENTS AND MINERALS

## Properties of Minerals

*Physical and Chemical properties*

### ***Physical Properties:***

Fracture :

This describes how a mineral breaks if it is not along well defined planes. In minerals with low symmetry and highly interconnected atomic networks, irregular fracture is common.

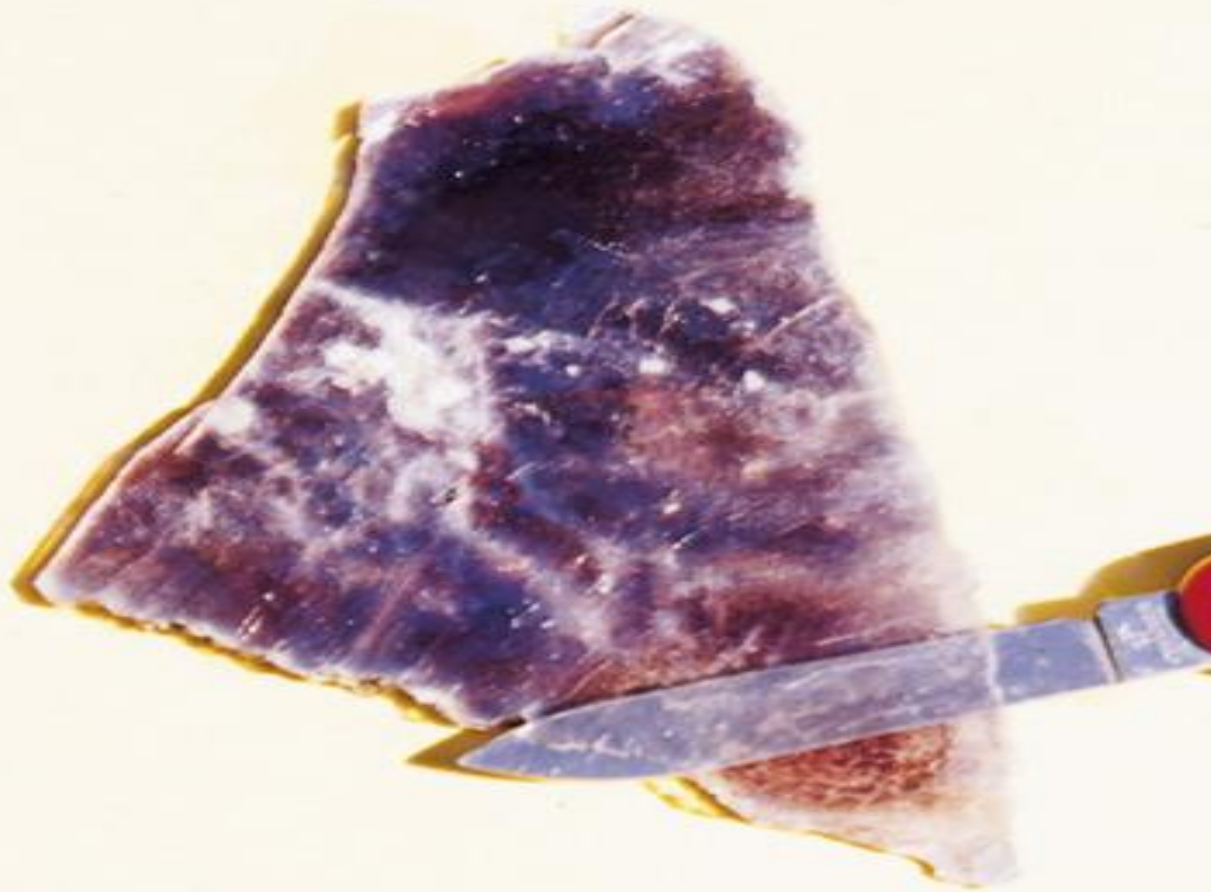


# ELEMENTS AND MINERALS

## Properties of Minerals

*Physical and Chemical properties*

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Planer Cleavage in Mica

A

Photo by C. C. Plummer

# ELEMENTS AND MINERALS

## Properties of Minerals

*Physical and Chemical properties*

### ***Physical Properties:***

Crystal form or habit:

The shape of crystals generally reflects the internal arrangement of their atoms in their crystal lattice. This can be altered, however, if the mineral crystallized in an environment that did not allow it to grow properly.

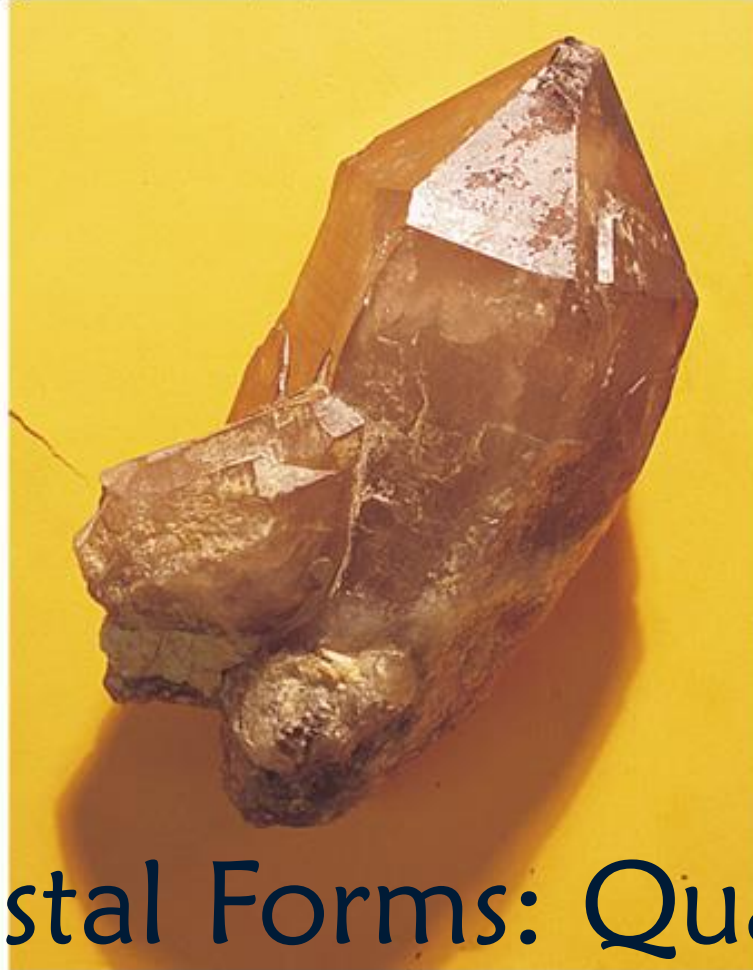
Imagine wearing shoes that are too tight – your foot will change its shape to match the shoes!

# ELEMENTS AND MINERALS

## Properties of Minerals

*Physical and Chemical properties*

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Crystal Forms: Quartz

A

Photo by C. C. Plummer

# ELEMENTS AND MINERALS

## Properties of Minerals

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Intergrown cubic crystals of fluorite

C

Photo by C. C. Plummer

# ELEMENTS AND MINERALS

## Properties of Minerals

*Physical and Chemical properties*

### ***Physical Properties:***

#### **Special Properties**

***Magnetism:*** Magnetite ( $\text{Fe}_3\text{O}_4$ ) has this property and it can be used to distinguish it from other non-magnetite iron oxides, such as hematite ( $\text{Fe}_2\text{O}_3$ ).

***Double Refraction:*** Seen in calcite crystals. Light is split or refracted into two components giving rise to two distinct images.

***Taste/Smell:*** Halite has a salty taste; Sulfur smells of rotten eggs

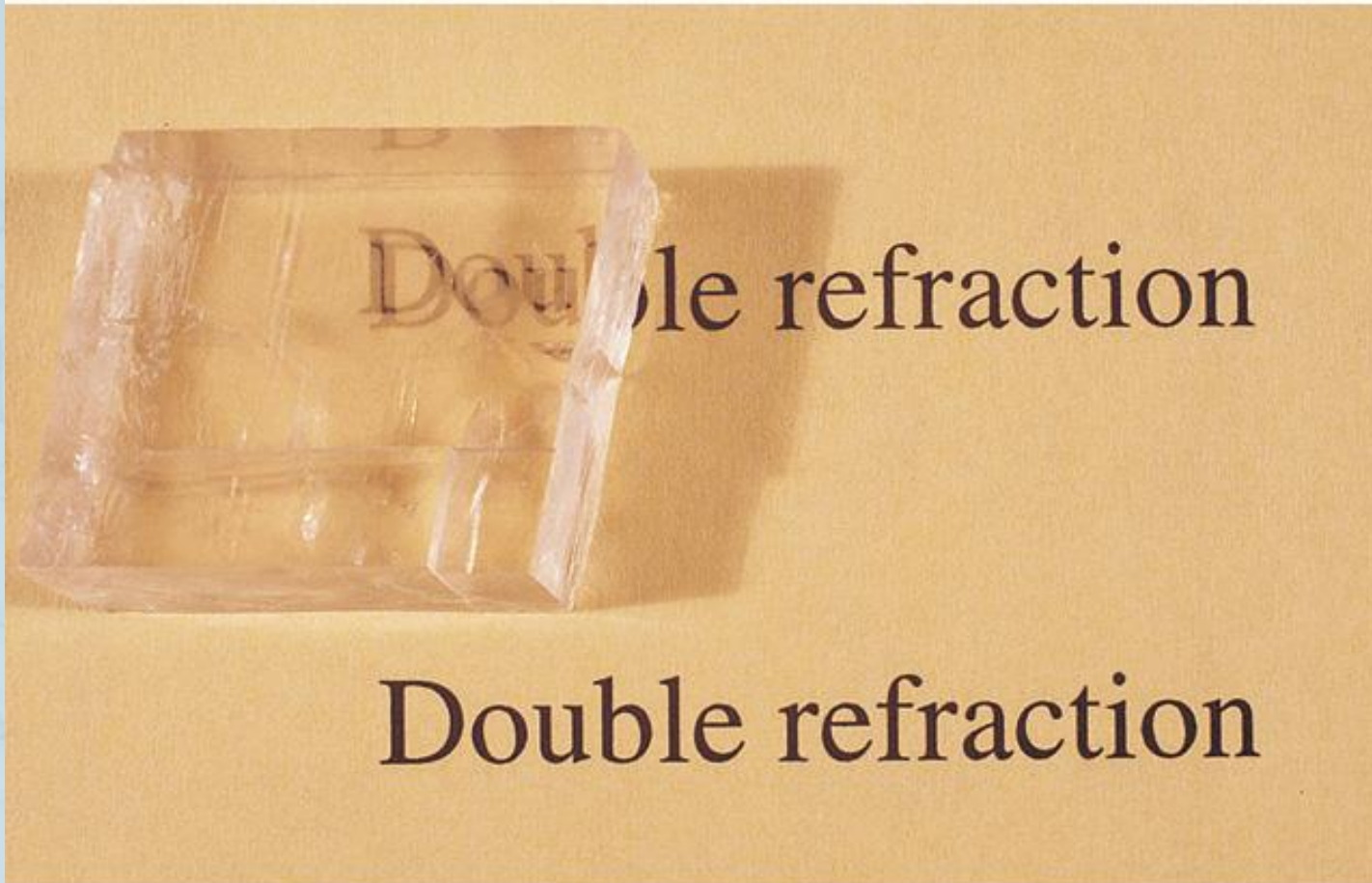
**Reactions with acid:** Calcite fizzes on reaction with acid

# ELEMENTS AND MINERALS

## Properties of Minerals

*Physical and Chemical properties*

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# ELEMENTS AND MINERALS

## Properties of Minerals

*Physical and Chemical properties*

### ***Chemical Properties:***

The chemical properties of minerals mainly reflect the chemical properties of the atoms present in each. However, even here these properties depend on the way the atoms are bound in the mineral's crystal structure. Let us examine the property known as solubility — the ability of a mineral to dissolve in a liquid, like salt and water.

# ELEMENTS AND MINERALS

## Properties of Minerals

*Physical and Chemical properties*

### ***Chemical Properties:***

Nearly all minerals are soluble in water. But most dissolve to such a limited extent as to go almost unnoticed. A liquid is called a solvent when its action on a solid substance is to break apart the atoms of the crystal structure, thus dissolving it.

# ELEMENTS AND MINERALS

## The Unit Cell

*Unit Cell* is the smallest 3D repeating unit of a crystal structure representative of its:

- *atomic structure*
- *chemical composition*
- *crystal symmetry*

Unit Cell is a regularly ordered arrangement of atoms with a fixed geometry relative to one another

The atoms are arranged in a 'box' with parallel sides, the unit cell, which is repeated by simple translations to make up the crystal. Unit cell dimensions measured in *angstroms* with  $1\text{\AA} = 10^{-10}\text{m}$ .

# ELEMENTS AND MINERALS

## The Unit Cell

TEM (transmission electron microscopy) image of *Cordierite* ( $\text{Mg}_2\text{Al}_4\text{Si}_5\text{O}_{18}$ ) showing ordered structure typical of crystalline structures



*Micro*

20A

Macrocrystals of *Cordierite* showing well developed flat crystal faces that characterise crystals in their macro form



*Macro*

# ELEMENTS AND MINERALS

## Crystal Systems: common groups of symmetry

Crystal symmetry is defined by:

*Planes of symmetry*

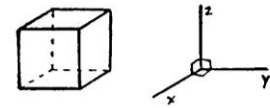
*Axes of rotation*

*Axes of inversion*

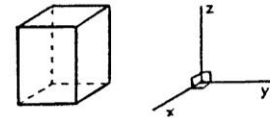
All properties of a crystal substance conform to symmetry, Symmetry is the defining property of a crystal

CRYSTAL SYSTEMS (Fig 1)

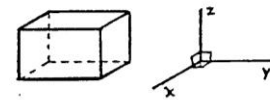
Cubic



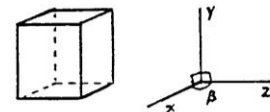
Tetragonal



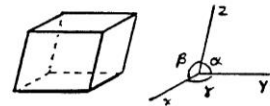
Orthorhombic



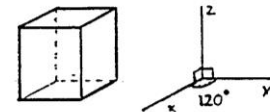
Monoclinic



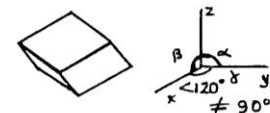
Triclinic



Hexagonal



Trigonal - rhombohedral



# ELEMENTS AND MINERALS

## Unit cell dimensions of the seven crystal systems

### CUBIC

$$a = b = c; \alpha = \beta = \gamma = 90$$

### TETRAGONAL

$$a = b \neq c; \alpha = \beta = \gamma = 90$$

### ORTHORHOMBIC

$$a \neq b \neq c; \alpha = \beta = \gamma = 90$$

### MONOCLINIC

$$a \neq b \neq c; \alpha = \gamma = 90 \beta > 90$$

### TRICLINIC

$$a \neq b \neq c; \alpha \neq \beta \neq \gamma \neq 90$$

### HEXAGONAL

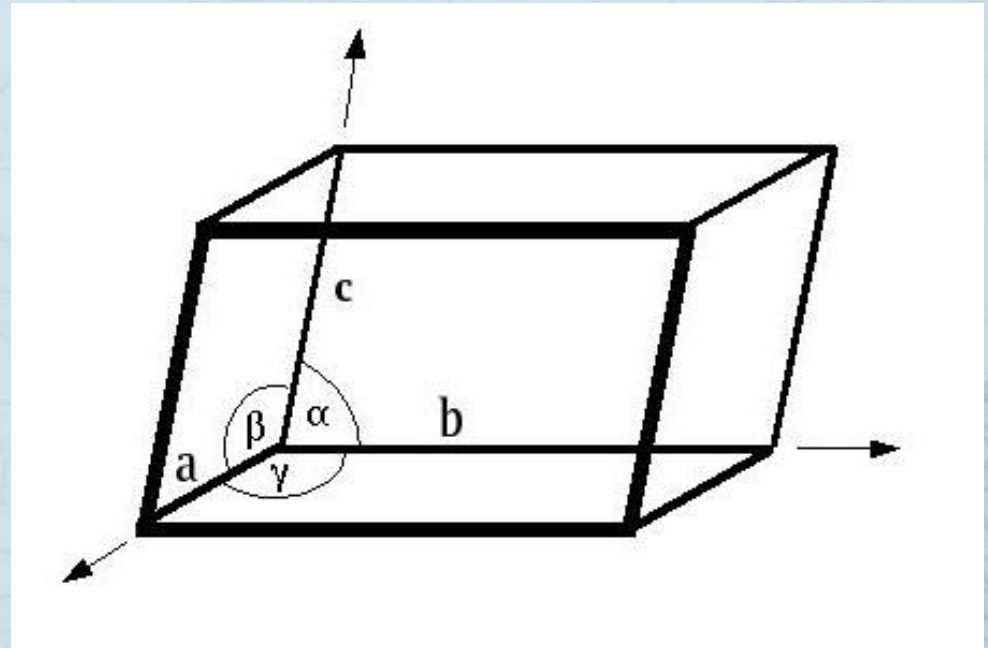
$$a = b \neq c; \alpha = \beta = 90; \gamma = 120$$

### TRIGONAL – Hexagonal

$$a = b \neq c; \alpha = \beta = 90; \gamma = 120$$

### TRIGONAL – Rhombohedral

$$a = b = c; \alpha = \beta = \gamma \neq 90 < 120$$



*Where a, b, and c are the unit cell axes dimensions and  $\alpha$ ,  $\beta$ , and  $\gamma$  are the inclination angles of the axes in the unit cell.*

# ELEMENTS AND MINERALS

## Crystal Structures

All crystal structures can be envisaged as: the packing together of spherical ions/atoms bonded by ionic and/or covalent and/or metallic bonds

### *Ionic bond:*

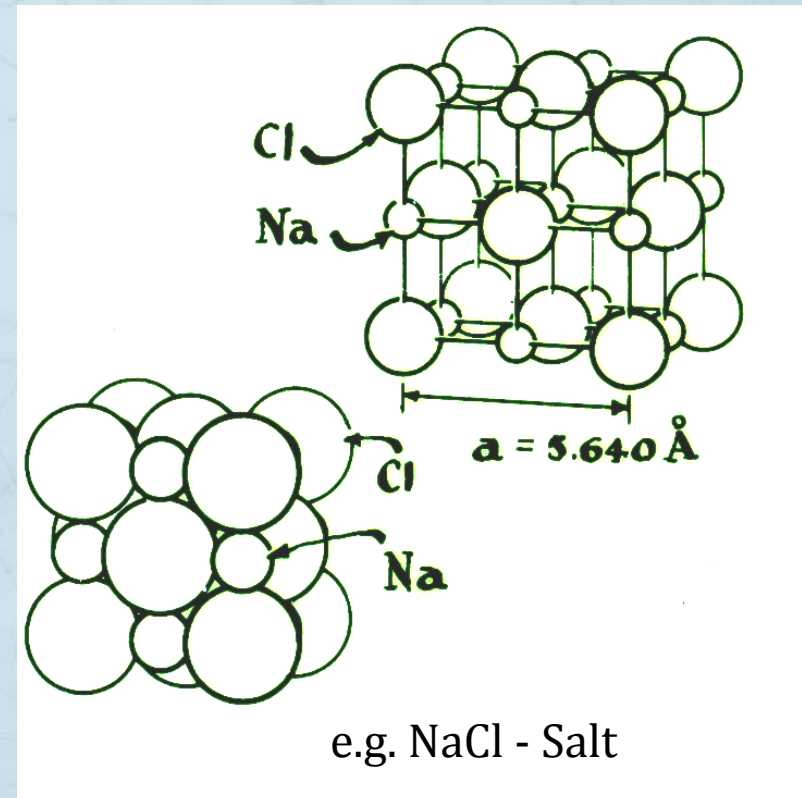
Electrical attraction between ions of opposite charge ( $\text{Na}^+$ ,  $\text{Cl}^-$ )  
90% minerals are ionic compounds

### *Covalent bond:*

shared electrons where electrons not readily lost/gained  
E.g. Diamond

### *Metallic bond:*

free-electron sharing in metallic atoms (loose electrons)



# ELEMENTS AND MINERALS

## Crystal Growth

Crystal growth can be envisaged as addition of unit cells in three dimensions

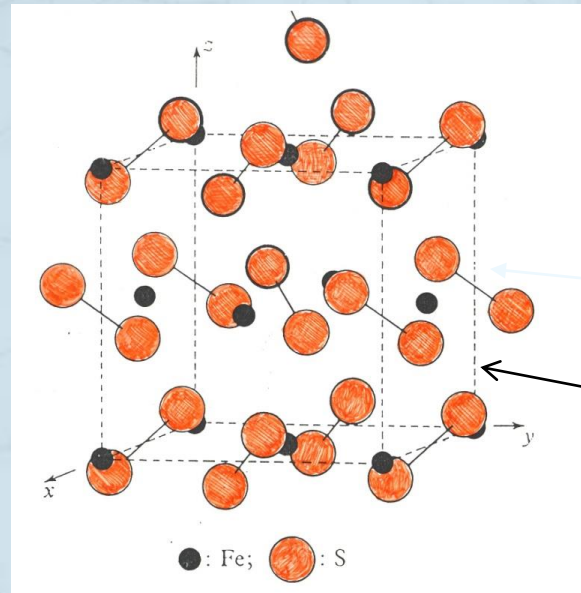
If this occurs at the same rate in all directions the shape of the unit cell will be retained in the macro crystals

If the rate of addition of unit cells is not the same in all directions the shape of the macro crystals need not reflect the unit cell shape

The symmetry of the macro crystals ALWAYS reflects at least the minimum symmetry of the crystal system of the unit cell.

# ELEMENTS AND MINERALS

Unit Cell of  
pyrite

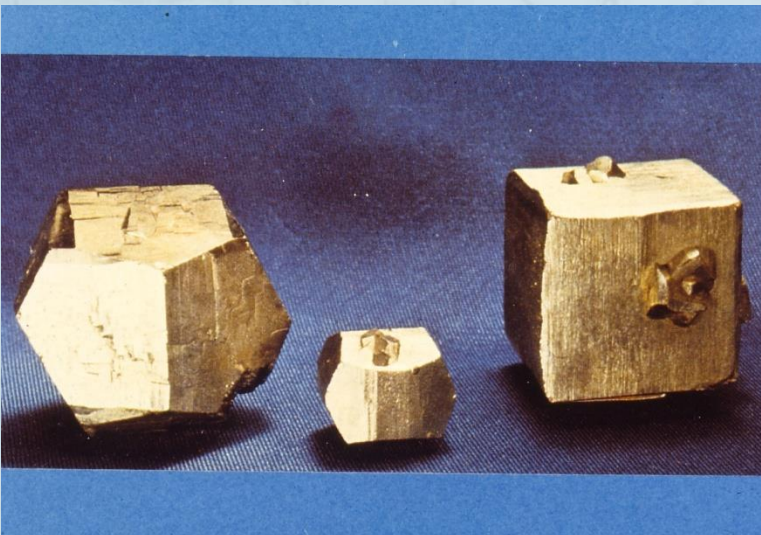


*Pyrite*

Unit cell

Pyrite crystals:  
ideal growth

Pyrite nodular aggregate:  
confined growth



# ELEMENTS AND MINERALS

**Some common minerals on the Earth....!!**



# ELEMENTS AND MINERALS

## Quartz $\text{SiO}_2$

Quartz is a silicate mineral and is the second most common mineral in the Earth's crust.

It is usually white or colorless but has a wide range of colors; some of its colored varieties are semi-precious gems such as *amethyst* and *citrine*.

Quartz is used to make glass and computer chips.

Quartz commonly forms nicely shaped 6-sided crystals that are widely available.

Quartz is common in igneous and metamorphic rocks. It is resistant to chemical weathering and is a common constituent of sediments such as sand and sedimentary rocks because it is resistant to weathering.



# ELEMENTS AND MINERALS

**Feldspar  $\text{NaAlSi}_3\text{O}_8$  -  $\text{CaAl}_2\text{Si}_2\text{O}_8$  -  $\text{KAlSi}_3\text{O}_8$**

Feldspar is a large, complex family of silicate minerals and is the most common mineral in the Earth's crust.

Since it has a wide range of chemical compositions, its appearance may also vary widely.

Feldspar is commonly white to dark gray in color. Some common varieties are pink.

Feldspars are used in the manufacturing of specialized glasses and ceramics. It is commonly used in aggregate and, because it is so common, is commonly used in construction (building facing, etc.).



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## Pyrite $\text{FeS}_2$

Pyrite is a sulfide mineral and is one of the most common of the minerals with metallic luster. It is also known as “fool’s gold.”

Although it usually forms massive groups of indistinct crystals, it may also form beautifully formed cubic and soccer ball-shaped crystals.

It also commonly replaces organic material and forms fossils.

It has no economic importance now, but in the past, it was an important source of iron and sulfur.



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## **Magnetite $\text{Fe}_3\text{O}_4$**

Magnetite is an oxide mineral and is a common iron ore mineral.

It is usually black in color and has a black streak. Its luster is commonly metallic but may appear submetallic.

Magnetite forms massive groups of small indistinct crystals, but may rarely form octahedral crystals.

The most distinguishing property of magnetite is that it is magnetic.



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## **Talc** $\text{Mg}_2\text{Si}_4\text{O}_{10}(\text{OH})_2$

Talc is a silicate mineral and is commonly found in metamorphic rocks.

Although it is not a very common mineral, it is a good one to show to students because of its very low hardness. The extreme softness of the mineral gives it a slippery feel.

It is usually white to light green in color and may exhibit one-direction of cleavage. Its nonmetallic luster may appear glassy to pearly in appearance.

Talc is used as an industrial lubricant, as a filler in paints and plastic and commonly as a major ingredient in talcum powder and cosmetics.



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## Mica

**Muscovite**  $\text{KAl}_2(\text{Si}_3\text{O}_{10})(\text{OH},\text{F},\text{Cl})_2$

**Biotite**  $\text{K}(\text{Fe},\text{Mg})_3\text{AlSi}_3\text{O}_{10}(\text{OH})_2$

Muscovite and biotite are silicates and are two of the most common types of mica.

The micas are a complex group of minerals that are characterized by excellent cleavage in one direction - thus, it can be split into thin flexible sheets.

Muscovite and biotite can be distinguished from one another by color: muscovite is clear to tan-brown and biotite is dark brown to black. The hardness of the micas ranges 2-3.



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## **Hornblende $\text{Ca}_2(\text{Mg,Fe})_4\text{Al}(\text{Si}_7\text{Al})\text{O}_{22}(\text{OH,F})_2$**

Hornblende is a silicate and is the most common member of a complex family of minerals known as the amphiboles.

Hornblende is common in igneous and metamorphic rocks. It is uncommon in sedimentary rocks because it quickly alters to other minerals at the Earth's surface.

Hornblende has a Moh's hardness of 5-6 so that its hardness is approximately that of glass.

Hornblende has 2 directions of cleavage - thus it can be easily distinguished from biotite mica.



# ELEMENTS AND MINERALS

## Fluorite $\text{CaF}_2$

Fluorite is a distinctive but relatively uncommon halide mineral. It is most commonly associated with hydrothermal deposits.

It comes in a wide range of colors - clear, yellow, purple and green are common.

It has a Moh's hardness of 4 and has excellent cleavage in 4 directions.

Fluorite is our primary source for fluorine.



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## Calcite $\text{CaCO}_3$

Calcite is a common carbonate mineral, especially in sedimentary rocks. It is also associated with biological activity in the production of shells.

Calcite is usually colorless to white in color but may show a range of pale colors including yellow, pink and green.

It has 3 directions of cleavage - forming rhombohedra (“smooshed” cubes).

Calcite is most distinguished by its vigorous reaction to acid.

Calcite is used to manufacture cement and as a calcium dietary supplement.



# ELEMENTS AND MINERALS

## Uses of Minerals

Copper is used for wiring  
Gold is used for jewelry  
Talc is used for baby powder  
Quartz is used for glass  
Limestone can be processed to make concrete  
Gems are brighter and more colorful than common minerals. This makes them rare and highly prized.  
Ores are minerals that contain useful substances that can be mined for profit. A common example is bauxite which is turned into aluminum.



# ELEMENTS AND MINERALS

## Uses of Minerals

Glass is made from 6 minerals

- Silica
- Limestone
- Magnesium
- Boric acid
- Soda
- Aluminum



# ELEMENTS AND MINERALS

## Uses of Minerals

### Salt

Early people collected salt before they understood how important the mineral is for survival



# ELEMENTS AND MINERALS

**Any Question?**



# ELEMENTS AND MINERALS

## Questions ????

1. Why and how the elements are combined to form a compound?
2. Describe the characteristics of minerals?
3. Describe briefly the physical properties of the minerals?
4. Write down the chemical formulas of the minerals including in Moh's scale of hardness?
5. Describe the unit cell of a crystal structure?
6. What are the common minerals on the earth?

Thanks  
for your  
attention

Blind