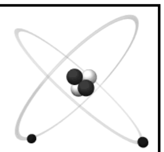
Atoms

Elements

Minerals



Atoms

The building blocks of all matter.

Atomic particles

Proton
+ve charge
atomic mass = 1

Atoms

The building blocks of all matter.

Atomic particles

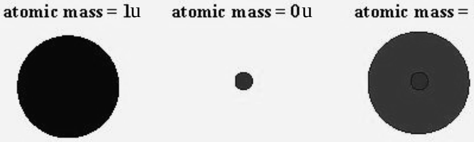
Proton	Electron
+ve charge	-ve charge
atomic mass = 1	atomic mass = 0

Atoms

The building blocks of all matter.

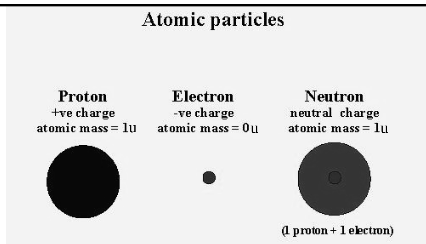
Atomic particles

Proton	Electron	Neutron
+ve charge	-ve charge	neutral charge
atomic mass = 1u	atomic mass = 0u	atomic mass = 1u



u, unified atomic mass or universal atomic mass

(1 proton + 1 electron)



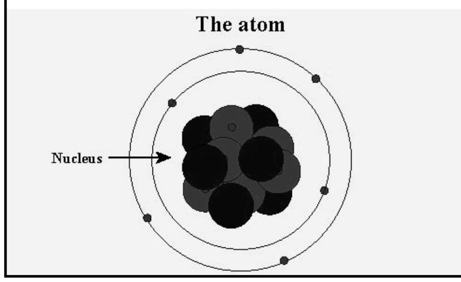
To be more precise:

An atomic mass of 1u = 1.67262158 × 10^{-24} grams

An electron has 0.05% of the mass of a proton.
(20 electrons would have 1% of the mass of a proton.

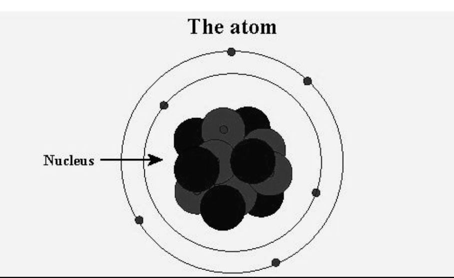
A proton has a mass equal to 99.8% of a neutron.

Atoms consist of a positively charged nucleus of protons and neutrons surrounded by electrons that move about the nucleus.

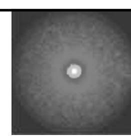


The number of electrons equals the number of protons in an atom's nucleus (their charges balance so that they are electrically neutral).

The number of protons does not always equal the number of neutrons.



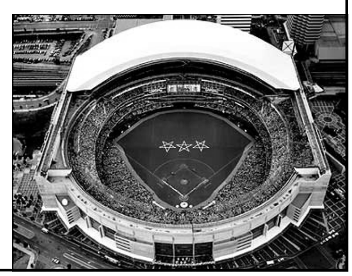
	Electrical Charge
6 protons	+6
6 neutrons	0
6 electrons	-6
Net charge =	0



The electrons form a "cloud" that surrounds the nucleus.

The entire electron cloud has a diameter that is is approximately 100,000 times the diameter of the nucleus.

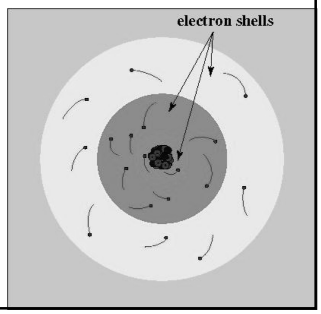
If the nucleus of a hydrogen atom were the size of a pea suspended in the centre of the stadium its electron cloud would fill the dome.



Electrons occur in spherical "shells" about the nucleus.

A "shell" is a particular region where electrons are most likely to be at a given instant in time as the "orbits" are not simple as shown below.

Electron shells are also termed "energy levels" and each contains a specific number of electrons.

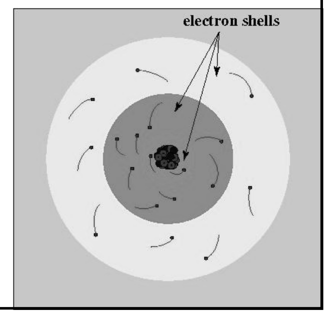


The innermost shell contains up to two electrons.

The 2nd and 3rd shells may each contain up to 8 electrons.

The most stable atoms have the maximum number of electrons in their outer, or valence, shell (and are termed valence electrons).

Atoms that do not have completely filled valence shells may take on or lose electrons so that the shells are filled.



When electrons are added or lost, the atom is no longer neutral, it has a charge that is either positive or negative.

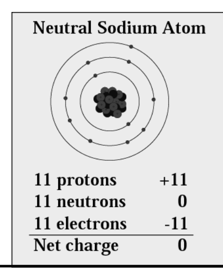
Such charged atoms are termed IONS.

Neutral atom:
number of protons (+) equal to number of electrons (-)
(net charge is 0, neutral)

Positive ion (Cation):
number of protons (+) is greater than number of electrons (-)
(net charge is +, ion has a positive charge)

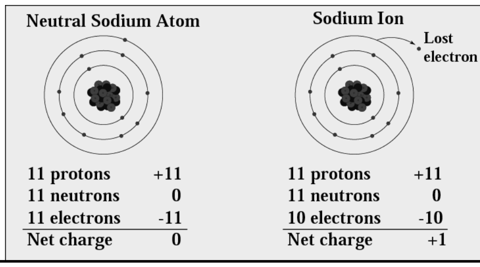
Negative ion (Anion):
number of protons (+) is less than number of electrons (-)
(net charge is -, ion has a negative charge)

An atom of sodium (Na) has 11 protons, 11 neutrons and 11 electrons; 2 electrons in the inner shell, 8 filling the 2nd shell and one electron in the valence shell.

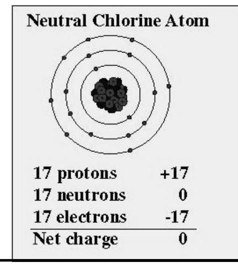


The sodium atom may lose the valence electron so that its outermost shell (the 2nd shell) is full

This creates a sodium ion which has a single positive charge due to the fact that it has one more proton than it has electrons. (This ion is given the symbol Na^+.)

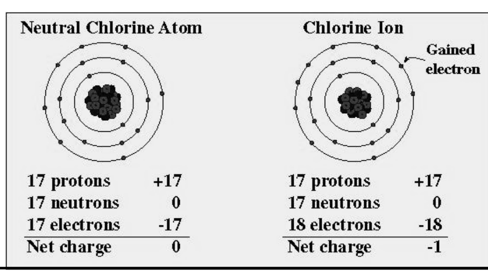


A chlorine atom (Cl) has 17 protons, 17 neutrons and 17 electrons; 2 electrons in the inner shell, 8 filling the 2nd shell and seven electrons in the valence shell.



The chlorine atom may gain an electron so that it's outermost shell (the 3rd shell) is full.

This creates a chlorine ion which has a single negative charge due to the fact that it has one more electron than it has protons. (This ion is given the symbol Cl^-.)



Elements

Element: the simplest kind of chemical; it cannot be broken down into simpler forms by any physical or chemical process.

Atoms are the smallest particle of an element that retains the characteristics of the element.

Elements are defined by the number of protons in the nuclei of their atoms.

Atomic Number: total number of protons in the nucleus of the atoms of an element.

Defines the element; if atomic number changes then the element changes.

Atomic mass (or weight): total mass of all protons and neutrons (electrons have negligible mass)

Notation:

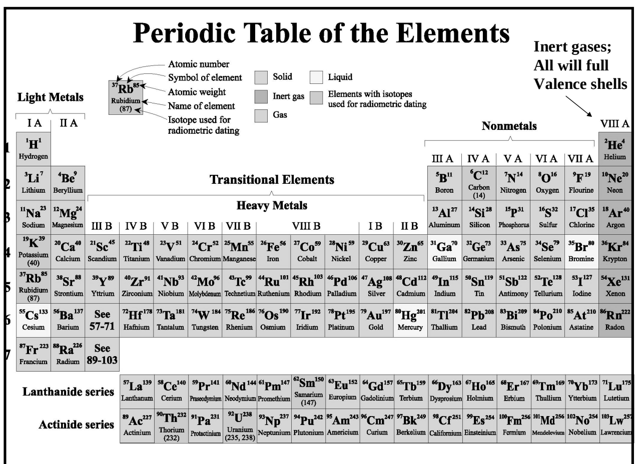
$$^{16}_{8}O$$

O = oxygen

8 = atomic number (8 protons)

16=atomic mass (8 protons + 8 neutrons = 16)

Periodic Table: the list of all known elements in order of increasing atomic number.



As of July 2006 116 elements have been discovered but it is certain that other elements exist (3 more were claimed but not approved by the International Union of Pure and Applied Chemistry).

Elements with very large atomic numbers are commonly very unstable and break down by radioactive decay within a fraction of a second (81 elements are stable).

Only 8 elements are common within geological materials:

Element (symbol)	Percentage by weight in the Earth's crust
Oxygen (O)	46.6
Silicon (Si)	27.7
Aluminum (Al)	8.1
Iron (Fe)	5.0
Calcium (Ca)	3.6
Sodium (Na)	2.8
Potassium (K)	2.6
Magnesium (Mg)	2.1
All other elements	1.5

Molecules are the product of the joining of two or more atoms (like or unlike atoms).

e.g., O_2 or CO_2

Chemical Compounds: substances formed by the union of atoms or ions of two or more different elements.

e.g., CO_2

Chemical Reactions involve the interaction of atoms or ions of one or more elements, bringing them together to form chemical compounds.

Most chemical reactions take place due to the interaction between electrons of the atoms or ions.

Elements commonly combine to form compounds by two different methods:

Ionic bonding and Covalent bonding

Ionic Bonding

Ions may be positively or negatively charged due to the loss or gain of electrons, respectively.

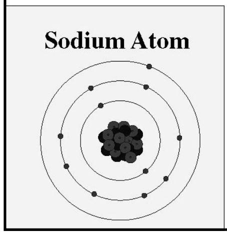
Oppositely charged ions attract each other and that attraction holds the two ions together to form a new compound.

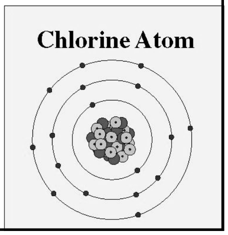
The gain and loss of electrons to form ions may take place due to an exchange of electrons between atoms that become ionically bound following the transfer of electrons.

Sodium and chlorine ions bond ionically to form sodium chloride (common table salt which is the mineral Halite)

A sodium atom has 11 protons, 11 neutrons and 11 electrons in three shells; there is one valence electron.

A chlorine atom has 17 protons, 17 neutrons and 17 electrons in three shells; there are 7 valence electrons



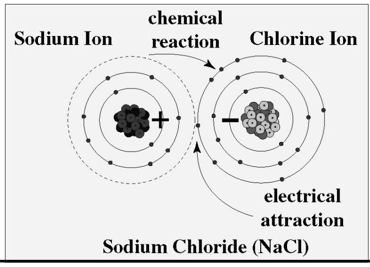


Sodium loses one electron to form a positive ion (Na^+).

Chlorine gains an electron to form a negative ion (Cl^-)

The attraction of the electrical charges bonds the two ions together to form sodium chloride.

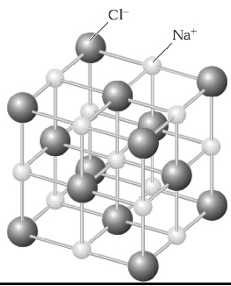
The sodium chloride molecule is electrically neutral.



All chemical compounds that form by ionic bonding are termed Ionic Compounds.

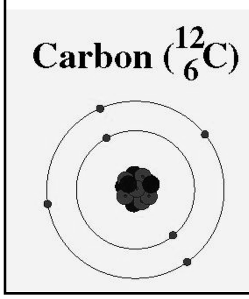
All Ionic Compounds are crystalline: they have a regular, ordered atomic structure.

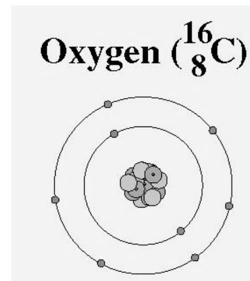
Sodium chloride forms a cubic crystal structure.



Covalent bonding

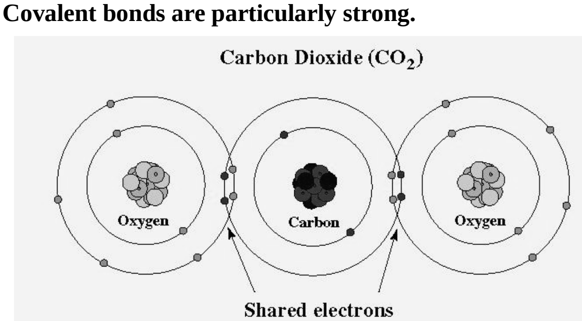
When two or more atoms fill their valence shells by sharing electrons.



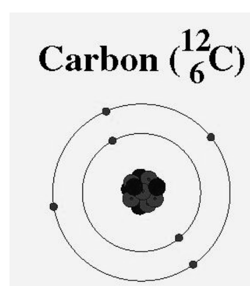


The carbon atom shares two electrons from each of two oxygen atoms (so that four electrons are shared in total) to form carbon dioxide.

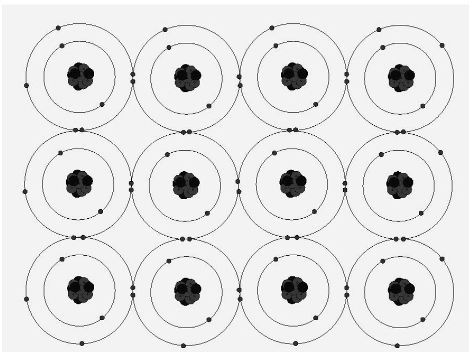
Covalent bonds are particularly strong.



The element carbon tends to bond by electron sharing with other carbon atoms.



Elemental carbon is made up of carbon atoms that are each joined to four other carbon atoms.

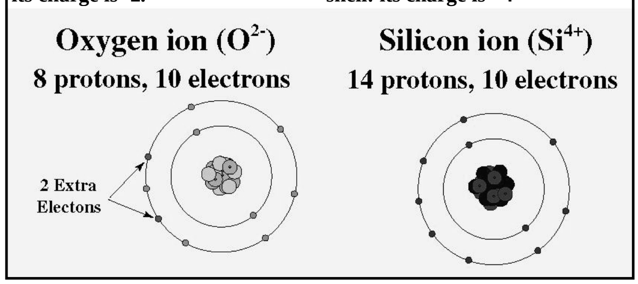


Not all molecules are electrically neutral.

If the charges of the ions do not balance then the resulting molecule retains a charge.

An oxygen ion has two extra electrons to fill its valence shell: its charge is -2.

A silicon ion has four less electrons to empty its valence shell: its charge is +4



The silicate ion is made up of 4 O^{2-} ions bonded covalently with 1 Si^{4+} ion.

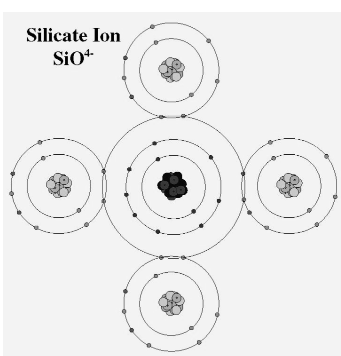
Balance of charges:

Oxygen ion: 4 X –2 = -8

Silicon ion: 1 X 4 = +4

Net charge: -4

Such ions can form ionic bonds with other ions to form ionic compounds.



Minerals

A minerals is:

"A naturally occurring, solid crystalline substance, generally inorganic, and with a specific chemical composition."

Press and Siever, 2001, *Understaning Earth*, W.H. Freeman and Co., New York.

Naturally occurring: synthetic gemstones and most mineral supplements are not real minerals.

Solid, crystalline substance: excludes gases and liquids (e.g., oil and gas); the internal structure of atoms is ordered.

Solid Earth materials that are not crystalline are said to be glassy or amorphous (lacking structure).

Generally inorganic: excludes material that forms from the decay of once living organisms (e.g., coal and peat).

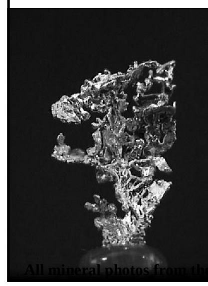
Does not exclude crystalline material that is produced by organisms (e.g., shell material).

Specific chemical composition: every mineral is characterized by a specific chemical composition that determines the properties of the mineral.

> **E.g., Halite, rock salt, always has the same chemical composition (NaCl).**

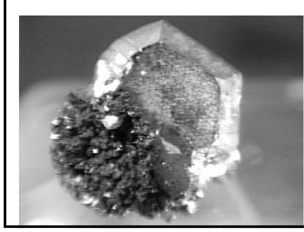
Some Common Chemical Classes of minerals:

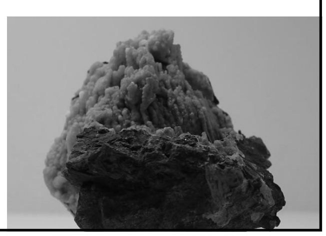
Class	Defining Anions	Examples
Native elements	None, there are no charged ions.	Gold, copper



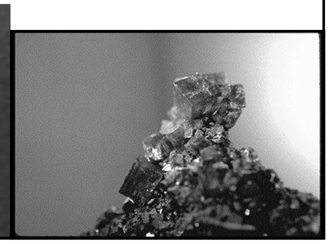
All mineral photos from the Minerals Gallery at http://mineral.galleries.com/default.htm

Class	Defining Anions	Examples
Oxides and hydroxides	O^{2-} and OH^- (hydroxyl ion)	Hematite Fe_2O_3, Gibbsite $Al(OH)_3$

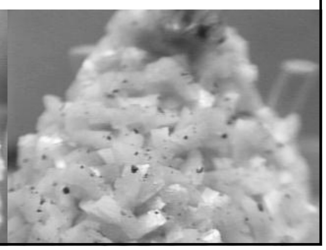




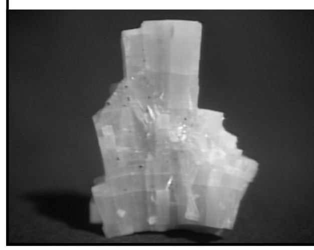
Class	Defining Anions	Examples
Halides	Chlorine (Cl^-), Fluorine (F^-), Bromine (Br^-), Iodine (I^-)	Halite (NaCl), Fluorite (CaF_2)



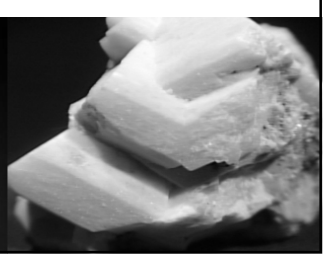
Class	Defining Anions	Examples
Carbonates	Carbonate ion CO_3^{2-}	Calcite ($CaCO_3$) Dolomite ($MgCO_3$)

Class	Defining Anions	Examples
Sulfates	Sulfate ion SO_4^{2-}	Anhydrite ($CaSO_4$) Barite ($BaSO_4$)




Class	Defining Anions	Examples
Silicates	Silicate ion SiO_4^{4-}	Quartz (SiO_2) Albite ($NaAlSi_3O_8$)

Almost 3,500 minerals have been identified and all are classified on the basis of their chemical composition.

The chemical composition determines the properties of minerals that we use to identify them.

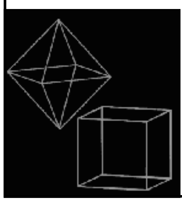
Crystal form

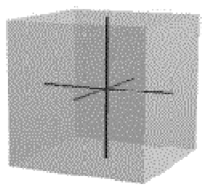
The overall geometry of a single crystal of a mineral that is determined by the regular arrangement of atoms and/or ions that make up the mineral.

There are six classes of crystal form that a mineral may exhibit (called crystal systems):

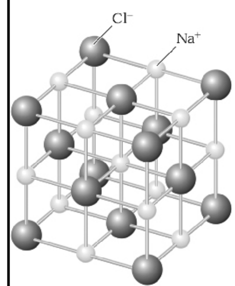
Cubic (Isometric) Crystal:

A crystal with three axes that are of equal length and at 90 degrees to each other.



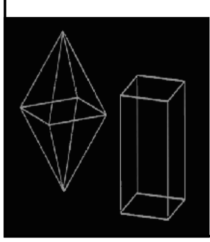


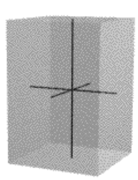
E.g. Halite (NaCl)



Tetragonal Crystal:

A crystal with three axes, two of which are equal in length, the third being unequal; all three axes are at 90 degrees to each other.

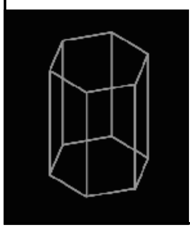


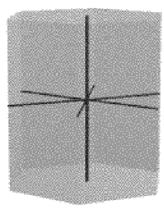


Chalcopyrite ($CuFeS_2$) forms tetragonal crystals.

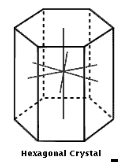
Hexagonal Crystals:

A crystal with four axes, three of which are of equal length and are at 120 degrees to each other. The fourth axis is either longer or shorter but at 90 degrees to the other three.





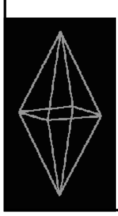
The mineral Beryl ($Be_3Al_2SiO_6$) forms hexagonal crystals.

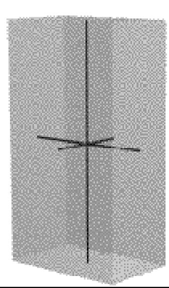


Photos from: http://encarta.msn.com/media_461518741_761570052_-1_1/Hexagonal_Crystal.html

Orthorombic Crystal:

A crystal with three axes, all of different length and all at 90 degrees to each other.

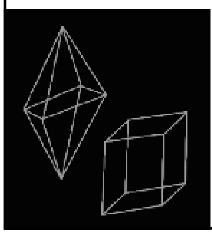


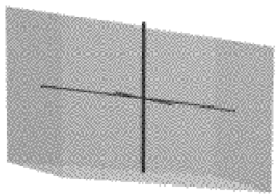


Barite ($BaSO_4$) forms orthorhombic crystals.

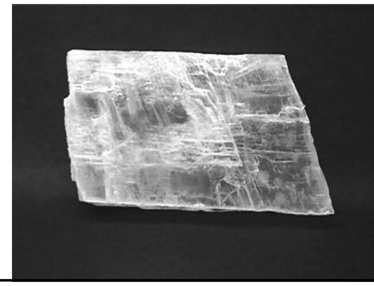
Monoclinic Crystal:

A crystal with three axes, all of different length; two axes are at 90 degrees to each other and the third is not.



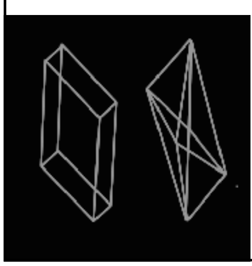


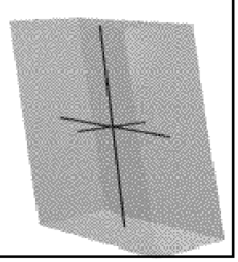
Gypsum forms monoclinic crystals.



Triclinic Crystal:

A crystal with three axes of unequal length and none are at 90 degrees to each other.





Microcline is a plagioclase feldspar that forms triclinic crystals.

Two factors control the arrangement of atoms and ions that, in turn, control the crystal form:

The number of neighbouring atoms or ions.

The size of the atoms or ions.

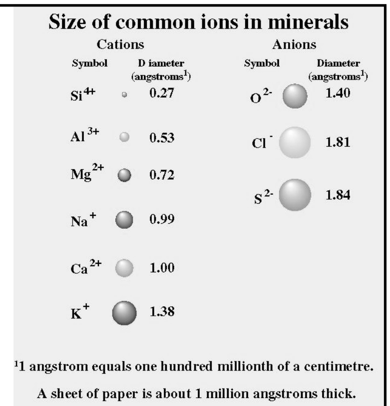
Diameter increases with the number of electrons and electron shells.

E.g., O^{2-} vs S^{2-}

${}_{8}O^{2-}$ has 10 electrons in 2 electron shells.

${}_{16}S^{2-}$ has 18 electrons in 3 electron shells.

S^{2-} is 1.3 times the size of O^{2-}



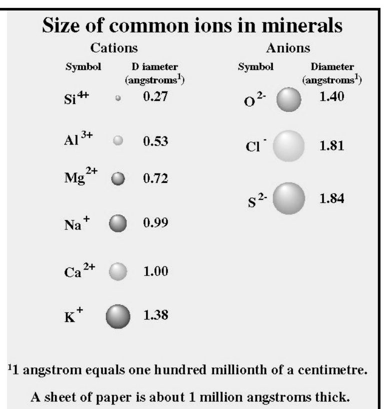
The stronger the positive charge of a cation the smaller the diameter for a given number of electrons.

Eg. Na+ vs Si^{4+}

${}_{11}Na^{+}$ has 10 electrons

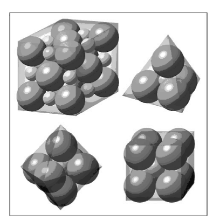
${}_{14}Si^{4+}$ has 10 electrons

Na^{+} is 3.6 times the size of Si^{4+}



The strong attraction of the positively charged Si^{4+} nucleus pulls the electrons in so that its diameter is smaller.

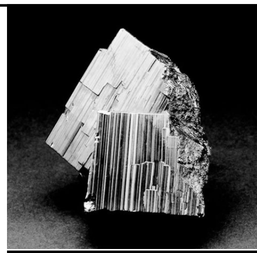
The types of ions making up the mineral determine their arrangement which, in turn determines the form of the crystal.



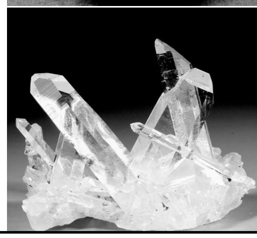
The types of ions also determine the chemistry of the mineral.

Therefore, the crystal form of a mineral is diagnostic of that mineral….it will always have that form.

Well-formed crystals of Pyrite (FeS_2) will always have a cubic crystal form.



Well-formed quartz crystals (SiO_2) will always have well-developed hexagonal crystal forms with pyramidal shaped ends.



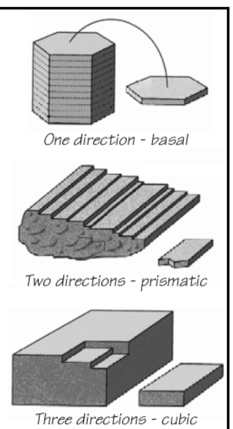
Cleavage

The property of a mineral that reflects the tendency for a crystal to break along flat planar surfaces.

Cleavage reflects the relative strength between bonds within the crystal.

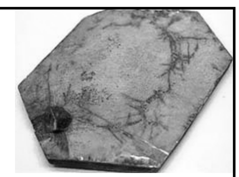
If weak bond strength occurs along planar surfaces within the crystal it will preferentially break along those surfaces.

Cleavage is described in terms of the number of cleavage planes, the angular relationship between the planes and the quality of the cleavage.

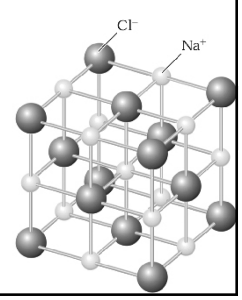


Types of Cleavage

Muscovite has perfect cleavage in one direction.



Halite has three perfect cleavage planes at 90 degrees to each other.

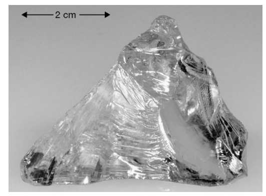


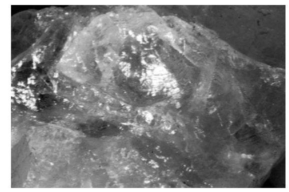
Amphiboles (a group of minerals) have two cleavage planes at 60 and 120 degrees to each other; the quality of a cleavage surface is fair to good.

Fluorite has four perfect cleavage planes.

Some rocks have no cleavage and will "fracture" or break unevenly (the bonds are equally strong in all directions).

Conchoidal fracture: displays smooth, curved, surfaces.





The mineral Kyanite has a splintery or fibrous fracture.

Hardness

Measured by scratching the surface of a mineral.

Governed by the strength of the bonds between ions that make up the mineral.

The smaller the ions, the smaller the distance between them, the stronger the bond.

The larger the charges on the ions the stronger the bond.

The closer packed the ions the stronger the bond.

The stronger the bonds the harder the mineral.

Moh's Hardness	Example	Simple test	Cutting Hardness
10	Diamond		140,000
9	Corundum		1,000
8	Topaz		175
7	Quartz	Scratches glass.	120
6	Feldspar	Scratched by steel file.	37
5	Apatite	Can be scratched by a knife.	6.5
4	Fluorite	Easily scratched by knife.	5
3	Calcite	Scratched by copper coin.	1.5
2	Gypsum	Scratched by fingernail.	1.25
1	Talc	Scratched by fingernail.	0.03

Lustre

The way in which a mineral's surface reflects light.

Metallic	**Opaque mineral that reflects light strongly.**
Vitreous (Glassy)	**Non-opaque mineral that reflect light strongly as if it was reflected off glass.**
Greasy	**Reflects light as if the surface was covered with oil.**
Pearly	**Reflects with a soft iridescence like that of a pearl.**
Silky	**The sheen of a fibrous material such as silk.**

Colour and Streak

Colour of a mineral is rarely diagnostic of the type of mineral.

Colour may vary widely in a single mineral type.

E.g. Quartz can be clear and colourless, pink, black or purple depending on impurities within the crystal.

Crystal quartz

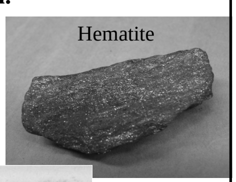
Citrine (yellow to orange)

Amethyst

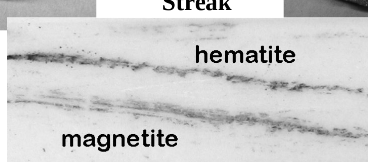
Smokey quartz

Streak is the colour of a mineral in a fine powdered form (e.g., the residue left when a mineral is scratched on a rough porcelain plate).

The mineral Hematite may come in a variety of colours but its streak is always reddish brown.



Streak



Density and Specific Gravity

The density of any material is its weight per unit volume.

E.g., Quartz (SiO_2) has a density of 2,650 kg/m^3.

Density varies with the atomic weight of the atoms making up the material and with their packing density.

Magnetite (Fe_3O_4) has a density of 5,100 kg/m^3.

The density of Quartz is about 50% of the density of Magnetite

The density of Quartz is about 50% of the density of Magnetite

Atomic weights: Si (28), O (16), Fe (56)

Quartz: SiO_2 Total atomic mass: 28 + 2 x 16 = 60

Magnetite: Fe_3O_4 Total atomic mass 3 x 56 + 4 x 16 = 232

The total atomic mass of Quartz is about 25% of the total atomic mass of Magnetite.

Quartz hardness: 7 Magnetite hardness: 3.5 - 4

The ions in Quartz are more closely packed than in Magnetite giving Quartz a greater hardness.

Therefore, the actual density of quart is greater than if it had the same ionic packing density as magnetite.

Specific gravity: wt. of a specimen/wt. of water in a volume equal to that of the specimen.

Feeling the weight of a mineral specimen compared to that of another specimen of similar size can give an indication of the mineral's density or specific gravity.

Mineral Resources

Minerals and rocks that have industrial uses (abrasives, metals, building materials, etc.) or other economic value (e.g., gemstones).

Classified as metallic minerals and nonmetallic resources

Metallic minerals:

Base metals: metals that oxidize when heated in contact with air (e.g., lead, copper, manganese, mercury, tin, uranium, zinc).

Precious (noble) metals: metals that are resistant to oxidation and other corrosion (e.g., gold, silver, platinum).

Examples of Nonmetallic Resources:

Aggregate and stone: used for road and building construction.

Quartz: required for making glass.

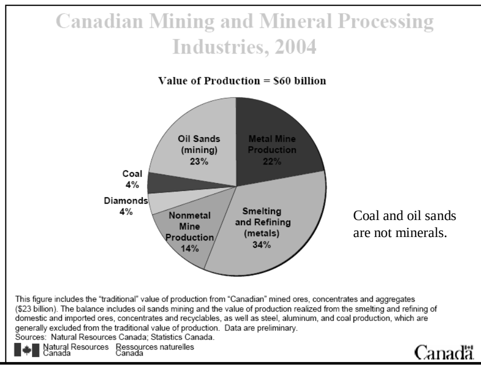
Gypsum: plaster of paris, drywall.

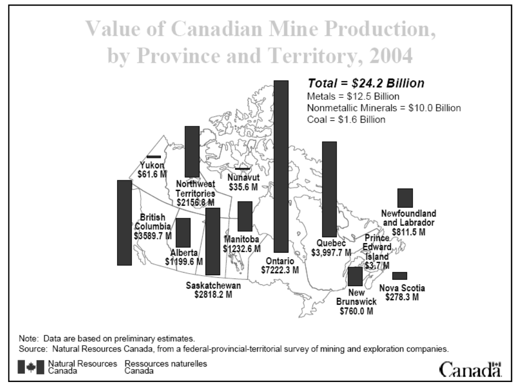
Halite: table salt, chemicals, ice control.

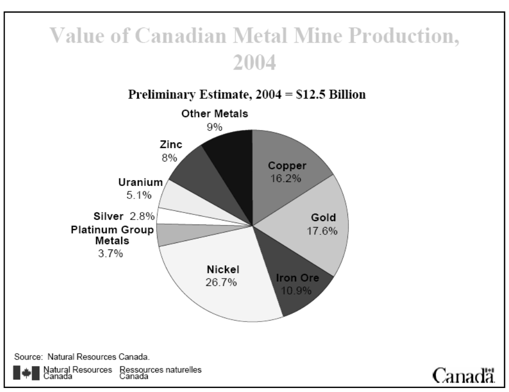
Asbestos: incombustible materials.

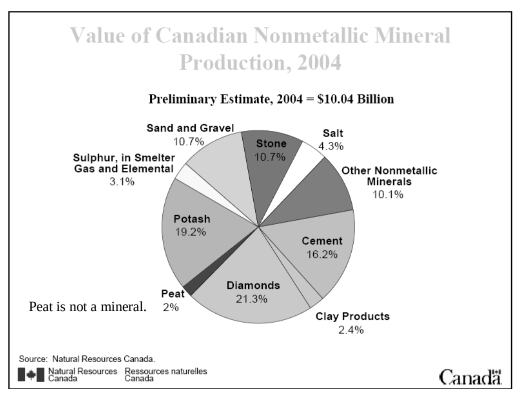
Diamond: gemstones and abrasives.

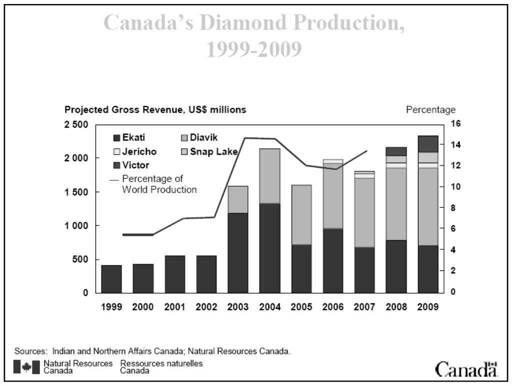
Canadian production of economic minerals amounted to $24.2 Billion; mining and processing contributed $60 billion to the Canadian economy in 2004.











Victor Project – De Beers Canada

PROJECT STATISTICS	
Impact area	5,000 hectares
Kimberlite tonnes mined	27.4 million tonnes
Grade	0.23 carats per tonne
Production rate	7,350 tonnes per day 2.7 million tonnes per year 600,000 carats per year
Employees	400 during production
Investment to date	CDN $305 million
Capital cost	CDN $982 million
Operating Costs	CDN $41 per tonne CDN $101 million per year
Value per tonne	CDN $117 per tonne