Elements (NonMetals)

Responsible only for portion of notes discussed in class

Review Periodic Table and Periodic Trends

On periodic table:

Electronegativity (EN) increases going up and to right with max at F

Size of neutral atom increases going to left and down

Metals and Nonmetals (see e-notes on Solids)
Covalent bonds between nonmetals give molecules and network solids

Metallic bonds between metals give metallic solids

Ionic bonds between metals and nonmetals give ionic solids
Right side nonmetals form negative (-) ions (right receive electrons)
Left side metals form positive (+) ions (left lose electrons)
For acids in water H can act as positive ion (H+)

Hydrogen H

Lowest density of any chemical substance
Used in blimps in 1930s but flammable
Gas at room Temp B.P. –253°C (20K) and M.P.-259°C (14K)
Insoluble in water: 2mL gas/ 1L of water

Found in H_2O, organic and biological molecules
Most common element in universe

H_2 (H-H) isoelectronic with He
H has a small radius
Unique properties of both group 1 and 17
Bond energy 431kJ/mol – very strong bond

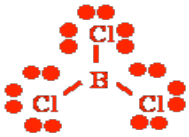
Boron B

Of group 13 elements only Boron is a nonmetal

Boron B^{3+} - never formed because it requires too much energy to remove the three electrons and energy can not be supplied by the lattice energy

Boron does not occur free in nature but found I a variety of different ores
Such as Borax $Na_2B_4O_7 \cdot 10H_2O$

Trigonal Planar, sp^2 hybrid - forms trigonal planar compounds



http://www.nightingale.org/teachers/fuller/Chemistry%20II/Bonding/Lewis%20Worksheet%20Answers.htm

Group 14 (IVA)

List

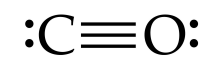
Element	Symb.	Outer e-	M.P. (°C)	
Carbon	C	$2s^2\ 2p^2$	3570	nonmetal
Silicon	Si	$3s^2\ 3p^2$	1420	metalloid
Germanium	Ge	$4s^2\ 4p^2$	959	metalloid
Tin	Sn	$5s^2\ 5p^2$	232	metal
Lead	Pb	$6s^2\ 6p^2$	327	metal

Properties
C found in CO_2 of atmosphere all plants and animals contain
Why are living organisms based on carbon molecules and not some other element to form backbone of complex biochemical molecules?

Carbon atoms have ability to form 4 bonds to form long chains or rings of like atoms and have other atoms attached to these chains and C-C bond is strong

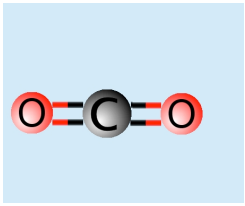
Si found in SiO_2 silicon dioxide silica. SiO_2 found in sand, quartz, and other minerals as a 3 dimensional network. It has a M.P. of 1700°C.
Pure Silicon made SiO_2 (l) + 2 C (s) → Si (l) + 2 CO (g)
Very pure silicon used in making semiconductors

Carbon monoxide- CO, gas at room temp.

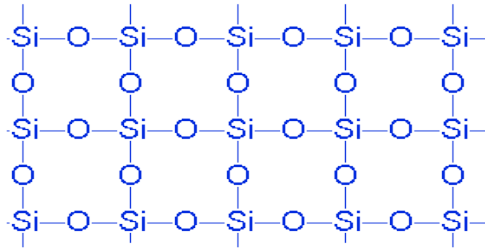


http://wps.prenhall.com/wps/media/objects/476/488316/ch10.html

Carbon dioxide- CO_2, gas at room temp.



Silicon dioxide silica- SiO_2, solid M.P. 1700°C, network crystal



http://members.optushome.com.au/scottsoftc/chapter04/section4.html

Group 15 (VA)

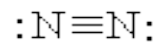
List and properties 5 outer electrons in orbitals s^2 p^3

Element	Symbol	Appearance	State	Type
Nitrogen	N	colorless	Gas	Nonmetal
Phosphorous	P (P_4)	white, red, black	Solid	Nonmetal
Arsenic	As	gray metallic	Solid	Metalloid
	As_4	yellow		
Antimony	Sb	gray metallic	Solid	Metalloid
	Sb_4	yellow		
Bismuth	Bi	gray metallic	Solid	Metal

Electronegativity increases going up - pull electrons toward atom
Ionization energies increase going up - harder to remove electrons from nonmetals

Ions	Only	Only
	nitride N^{3-}	Sb^{3+}
	phosphide P^{3-}	Bi^{3+}

Properties of nitrogen differ from other group 15 elements



http://courses.chem.psu.edu/chem38/mol-gallery/oxygen/oxygen.html

Diatomic molecule - very strong bond 941kJ/mol
very unreactive because of difficulty in breaking bond

Can form at most 4 covalent bonds (no d orbitals to make more) NH_4^+

For other group 15 elements can form up to 5 or 6 bonds using d orbitals, PCl_6^-
Oxidation state varies from 3- to 5+ for nitrogen

Allotropes

P

Red phosphorous	structure not known, intermediate reactive
Black phosphorous	layers, least reactive
White phosphorous	P_4, very reactive with O_2 at room temp.

As and Sb

Yellow	nonmetal
Gray metallic	soft metal (More stable form)

Yellow form easily converted to gray metallic form.

Bi

Gray metallic	soft metal

Group 16 (VIA)

List

O	Oxygen
S	Sulfur
Se	Selenium
Te	Tellurium
Po	Polonium - product of radioactive decay

Properties

Group 16 elements are 2e- short of noble gas and either:

1. accept to 2e- to form ion S^{2-}
2. or form two covalent bonds -S-

O	$2s^2 2p^4$	Oxygen
S	$3s^2 3p^4$	Sulfur
Se	$4s^2 4p^4$	Selenium
Te	$5s^2 5p^4$	Tellurium

Symb.	Formula	State at room T	Color
O	O_2	gas	colorless
S	S_8 ring, S chain	solid	yellow
Se	Se_8 ring, Se chain	solid	red to black
Te	Te chains	solid	silver to white

Size increases going down the group.
Electronegativity increases going up the group.

O stong oxidizing agent that reduces to gain electrons (removes from other atoms)

O 2nd highest electronegativity, only F is stronger
Oxides of most metals are ionic

Free oxygen, 21% atmosphere O_2
Sand silica SiO_2 – silicon dioxide
Oxygen in many minerals (Fe_2O_3)
Water mostly oxygen
Body 60% oxygen by mass

Almost all O_2 produced from air
Liquefy and distill

O_2 B.P. = -183°C
N_2 B.P. = -196°C

As air warms N_2 bubbles off

Some very pure O_2 by electrolysis
$2\ H_2O \rightarrow 2\ H_2\ (g) + O_2\ (g)$

<u>O_2 – CO_2 cycle in nature:</u>

Animals $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O +$ energy
Plants light energy $+ 6\ CO_2 + 6\ H_2O \rightarrow C_6H_{12}O_6 + 6\ O_2$

<u>Pollution</u>

CO incomplete combustion binds with hemoglobin so no O2 can be carried to body tissue

Atmosphere
$2\ SO_2 + O_2 \rightarrow 2\ SO_3$

Burning coal or treating metal sulfides
$Cu_2S + O_2 \xrightarrow{\text{Heat}} 2\ Cu + SO_2$
Atmposphere
$SO_3 + H_2O \rightarrow H_2SO_4 + H^+ + HSO_4^-$

SO_2 causes respiratory damage and damage to plant life

Acid rain in northeast and Canada

Copperhill 50 sq. miles of plant with no trees
1900s plant for producing sulfuric acid, 10% of country's production
15 million trees planted to replace ones lost

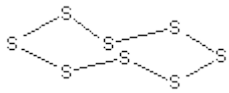
<u>Ozone</u> - Pale blue gas with punget odor

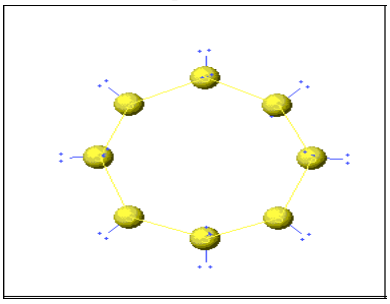
http://www.chm.bris.ac.uk/motm/ozone/CHEM.htm

S, Se, Te

allotropes- different structural forms of same

O_2	O_3
S_8 ring	long chains called plastic sulfur
Yellow	red (rubbery)
Vapor	
S_8, S_6, S_4, S_2	



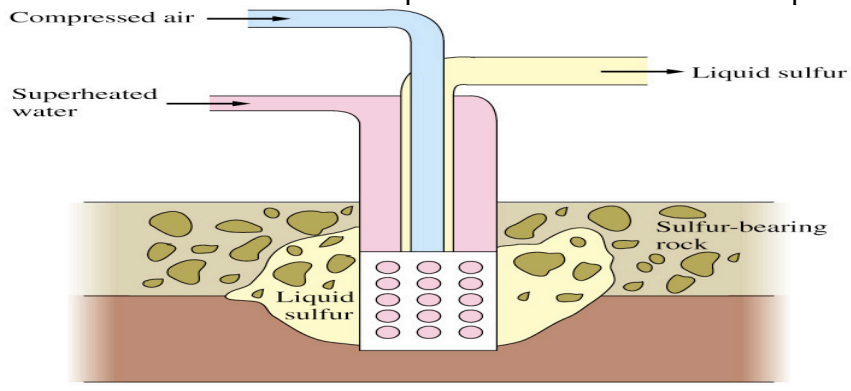


http://www.molecules.org/experiments/Dunlavy/animation1.html

Write in equations as S

Production of Sulfur:
Found as free element in underground deoposits
Also in some minerals Ca_2S, FeS_2 pyrite (fools gold), $CaSO_4 \cdot 2\ H_2O$ gypsum
Te, Se primarily found in copper deposits

Frasch Process:Hot water 170° pressurized- heats sulfur -compressed air in



http://cwx.prenhall.com/petrucci/medialib/media_portfolio/23.html

99.5% pure sulfur obtained

Halogens Group 17 (VIIA)

Fluorine, Chlorine, Bromine, and Iodine

Halogen is greek for salt former
They are found in nature as halide salts (NaCl) and as ions in water (Cl^-).

Properties

F	$2s^2 2p^5$
Cl	$3s^2 3p^5$
Br	$4s^2 4p^5$
I	$5s^2 5p^5$

Valence electrons (above) and 1 short of noble gas so generally a single covalent bond or -1 ion

Pure element	F_2	Cl_2	Br_2	I_2
Color	pale yellow	yellow/ green	red	violet
M.P.	-218	-101	-7	+113
B.P.	-188	-35	+59	+183
State	gas	gas	liquid	solid
Bond energy	(155)	243	193	151
	HF	HCl	HBr	HI

London forces hold together
Size increases going down the group
Electronegativity increases going up the group
Ionic bond energies going to up the group
F_2 has a weaker bond energy because of the repulsion of non bonding electrons

Group 18 Noble Gases (VIIIA)

Until 1962 no compound of these elements was known not truly inert but still very low reactivity
No compound of He, Ne, Ar have been made

Element	B.P.
He	-269
Ne	-246
Ar	-186
Kr	-153
Xe	-107
Rn	-62

Size increases going down this group
Larger size, larger electron cloud, and larger London forces of attraction

Have the highest ionization energies so don't tend to lose electrons and they have filled orbitals so don't tend to gain electrons.

Compound	M.P.	
XeF_2	129	
XeF_4	117	Colorless crystal
XeF_6	50	
XeO_4		Gas

About 30 compounds that have been made from noble gases

EXTRA MATERIAL – NOT COVERED IN CLASS

Hydrogen

Production – Industry

Steam reformer process:

$$CH_4\ (g) + 2\ H_2O\ (g) \xrightarrow[Ni\ (900°C)]{} CO_2\ (g) + 4\ H_2\ (g)$$

Can remove CO2 by passing through cold water under pressure, CO2 is soluble in water

Water Gas Reaction:

$$C\ (s) + H_2O\ (g) \xrightarrow[1000°C]{} CO\ (g) + H_2\ (g)$$

Coke in pure carbon — water gas

Can separate liquefying CO
Both CO and H2 will burn water gas used as fuel

Electrolysis of Water with Sulfuric acid added:

$$2\ H_2O \xrightarrow{Electroylysis} 2H_2\ (g) + O_2\ (g)$$

Very pure hydrogen

Boron

Found in several different crystal modifications in pure form
High mp, low electrical conductivity, brittleness, hardness

Reacts with halogens at high Temp.

BF_3, BCl_3 → gases
BBr_3 → liquid
BI_3 → solid

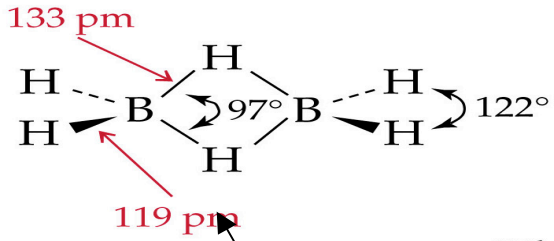
Boric acid

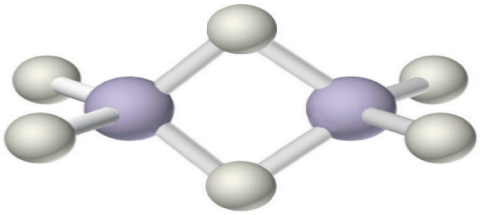
H_3BO_3 pure form, white crystal

$$H_2O + B(OH)_3\,(aq) \Leftrightarrow H^+\,(aq) + B(OH)_4^-\,(aq)$$

Other Compounds:

Diborane (gas under ordinary conditions)





Diborane

Unusual 3 center bonds
Involves 2 e-

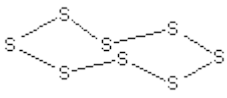
http://wps.prenhall.com/wps/media/objects/602/616516/Chapter_19.html

Unusual three center bonds involve 2 electrons

2 (B 3e-) = 6e-
2 (H 1e-) = 6e-
12 e-

Group 14

Need atom that will form 4 bonds



http://msds.pcd.go.th/searchName.asp?vID=1406

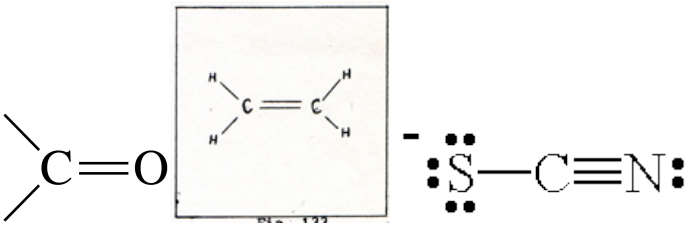
nothing left over

Then why C and not Si or Ge?

Bond	Bond strength
C-C	347
C-O	335
C-H	414
C-Cl	326
Si-Si	236
Si-O	368
Si-H	328
Si-Cl	391

Stronger bond strength means it is a more stable bond

Silicon has a tendency to bond to other elements rather than itself
Carbon is as likely to bond to itself as to other elements – strong C-C bond



(1) (2) (3)

http://cwx.prenhall.com/petrucci/medialib/media_portfolio/27.html
http://philmintz.tripod.com/ThePhilosophyOf/page4.html
http://en.wikipedia.org/wiki/Thiocyanate

Only group 14 elements uses p orbitals to form pi bonds

Preparation

C found in CO_2 of atmosphere
all plants and animals contain
carbonates such as $Ca(CO_3)$ - limestone
hydrocarbons (CH) - oil
allotropes - diamond, graphite, and buckyballs
impure carbon – coal

90+ % of compounds (molecules) contain C atoms (20 million)

Pure Carbon

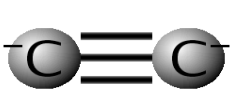
Diamond	Graphite
sp^4 hybrid	sp^3 hybrid
4 bonds for C	3 bonds in a plane
hard	soft black solid
high M.P. , stable	luster
bukyballs/ fullerenes (soccer ball shape)	in plane of layers
3 dimensional network	

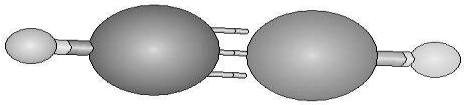
C and Si compounds

Carbides- salt like anions of carbons alone

Calcium carbide

CaC_2 (s) + 2 H_2O → $Ca(OH)_2$ (s) + C_2H_2 (g)





acetylide (1) acetylene – burned for light and heat (2)

(1)http://smid.blueprint.org/pubchem/PCList.php?numrows=7368&fg=alkyne&npp=10&start=80
(2) http://www.oophda.com/hydrocarb/

Silicon carbide- SiC, diamond like tetrahedral structure

Silanes

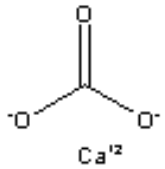
Si $_nH_{2n+2}$ like alkanes but only up to n = 6

Si_2H_6

Oxides

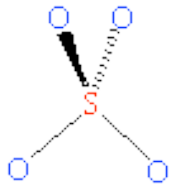
Carbonates

Calcium carbonate- $CaCO_3$, limestone



http://dynamicnutripro.com/resource_html/resource_calcium_detail.asp

A variety of silicates occur in nature
Basic unit or building block



http://www.hull.ac.uk/php/chsajb/concepts/tutorial_sheets/2004_mock_questions_answers.html

Join tetrahedral with bridging oxygens so oxygen atom used for both Si
See figures

Glass fuse silicates and carbonates
SiO_2, Na_2CO_3, $CaCO_3$

Cement is a mixture of limestone $CaCO_3$ and clay $H_4Al_2Si_2O_9$.

Group 15

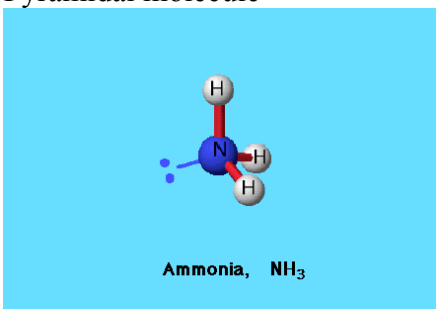
Hydrogen Compounds

Gases at room temperature

NH_3	ammonia
PH_3	phosphine
AsH_3	arsine
SbH_3	stibine
BiH_3	bismuthine

Arsine, stibine, and bismuthine are very poisonous gases.

Pyramidal molecule



http://www.elmhurst.edu/~chm/onlcourse/chm110/outlines/topic5.html

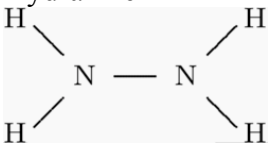
Most important compound ammonia prepared by the Haber process

$$N_2\,(g) + 3\,H_2\,(g) \overset{Fe}{\Leftrightarrow} 2\,NH_3\,(g)$$

Process performed at 500 atm and 500°C with a catalyst (Fe, Fe_3O_4, K_2O, Al_2O)

NH_3 has hydrogen bonding in liquid state

Hydrazine



http://en.wikipedia.org/wiki/Hydrazine

Strong reducing agent used in some rocket fuels.

Production

Source	Production
N_2	in the air distillation of liquefied air
$Ca_3(PO_4)_2$ $(+2)_3(-3)_2$, phosphate rock	heat with sand SiO_2 and coke (carbon)
As As_2S_3	heat with O_2 to produce oxide, then heat oxide with coke (carbon) to produce metal and CO
Sb Sb_2S_3 sulfide ores in Cu_2S	" "
Bi Bi_2S_3	" "

Example 1:

$$Ca_3(PO_4)_2\,(s) + 6\,SiO_2\,(s) \xrightarrow{Heat} 6\,CaSiO_3\,(l) + P_4O_{10}\,(g)$$

$$P_4O_{10}\,(g) + 10\,C\,(s) \xrightarrow{Heat} P_4\,(g) + 10\,CO\,(g)$$

Example 2:

$$2\,Sb_2S_3\,(s) + 9\,O_2\,(g) \rightarrow SbO_6\,(g) + 6\,SO_2\,(g)$$

Example 3:

$$2\,As_2S_3\,(s) + 9\,O_2\,(g) \rightarrow As_4O_6\,(g) + 6\,SO_2\,(g)$$

$$As_4O_6\,(s) + 6\,C\,(s) \rightarrow As_4\,(g) + 6\,CO$$

Nitrides	Phosphides
N^{3-}	P^{3-}

At high temp
Ionic Nitrides Mg_3N_2 magnesium nitride
Will react with a number of metals at high temp.
High M.P., white, crystalline solids

Covalent nitrides BN boron nitride
Network crystal
Others are molecules

Metal with white phosphorous to form metal phosphides
Ca_3P_2

Halogen Compounds

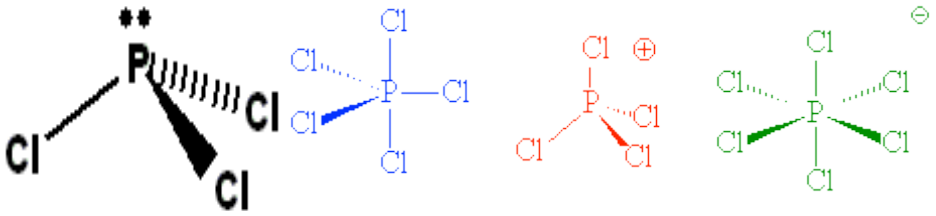
Trihalides and pentahalides (not N) are most important halogen compounds

Tri compounds have been made with F, Cl, Br, and I
All trihalides are covalent compounds except BiF_3 which is ionic

P, As, Sb, and Bi compounds can be prepared by direct combination of the elements

N trihalide from halogenation of ammonia

Structure of PCl_n



PCl_3	PCl_5	PCl_4^+	PCl_6^-
Pyramidal	Trigonal Bipyramidal	Tetrahedral	Octahedral
(1)	(2)`	(2)	(2)

(1) http://www.inchm.bris.ac.uk/schools/vsepr/examples/pcl3.htm
(2) http://www.chm.bris.ac.uk/motm/ascl5/ascl5h.htm

Sulfides, selenides, tellurides only with group 1 and 2 metals are truly ionic

Usually oxygen has negative oxidation number except F, S, Se, and Te have +4, +6 with O and Halogens

Oxygen Compounds

N_2O	+1	dinitrogen oxide	(nitrous oxide)
NO	+2	nitrogen oxide	N=O (nitric oxide)
N_2O_3	+3	dinitrogen trioxide	
NO_2	+4	nitrogen dioxide	
N_2O_5	+5	dinitrogen pentoxide	

N_2O – laughing gas, general anesthetic, gas in whipped cream aerosol cans

N_2 (g) + O_2 (g) → 2 NO (g)
3000°C

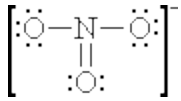
Atmospheric nitrogen converted to NO by lightning

2 NO_2 ⇔ N_2O_4 equilibrium
Brown Colorless
Smog

Oxyacid of nitrogen

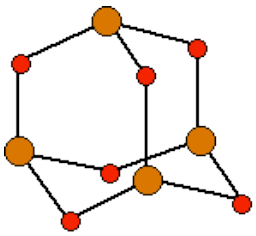
Nitric acid

H_2NO_3 → H^+ (aq) + NO_3^- (aq)
Nitrate



http://members.tripod.com/~EppE/chembond.htm

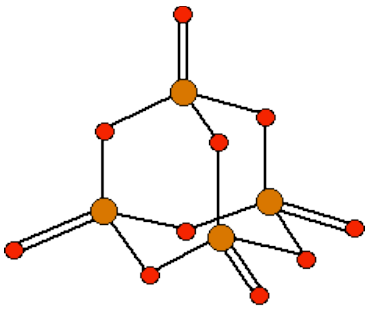
P_4O_6 phosphorous (III) oxide
(+3)(-2)



a P_4O_6 molecule

http://www.chemguide.co.uk/inorganic/period3/oxidesphys.html

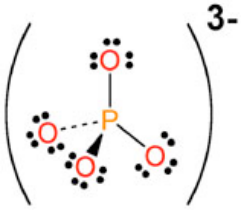
P_4O_{10} phosphorous (V) oxide, used as drying agent
(5)(-2)



a P_4O_{10} molecule

http://www.chemguide.co.uk/inorganic/period3/oxidesphys.html

PO_4 phosphate



http://www.chemistry.wustl.edu/~edudev/LabTutorials/PeriodicProperties/Ions/ions.html

$Ca_3(PO_4)_2$ (s) + 4 HNO_3 (l) → $Ca(H_2PO_4)_2$ (s) + 2 $Ca(NO_3)_2$ (s)
Too insoluble Phosphates nitrates
to be used directly are important in fertilizers

Group 16

Production – Lab

Thermal decomposition of oxygen compounds

2 $KClO_3$ → 2 KCl (s) + 3 O_2 (g)
MnO_2 (catalyst)
Potassium chlorate
Potassium chloride

2 HgO → 2 Hg + O_2 (g)

Reactions

Strong bond energy 494 kJ/mol O=O
Broken at high temp.

Many reactions give off energy exothermic so self sustaining but still at high temp.

Form ionic compounds with metals and form covalent compound with nonmentals

With Metals:

Ions of oxygen

O_2^-	superoxide (large group 1 metals Cs, Rb, K, O_2)
O_2^{2-}	peroxide
O^{2-}	oxide (normally produced and at high temp. favored)

$4\ Mg\ (s) + O_2\ (g) \rightarrow 2\ MgO\ (s)$
$4\ Al\ (s) + 3\ O_2\ (g) \rightarrow 2\ Al_2O_3\ (s)$
$2\ Hg\ (l) + O_2\ (g) \Leftrightarrow 2\ HgO\ (s)$

Many metals can have more than one oxidation state and so different oxides form

FeO low pressure T > 600
(+2)(-2)

Fe_3O_4 T = 300 in air
(+3)

Fe_2O_3 T > 300
(+3)(-2)

With Nonmetals:

Except for noble gases and group17 elements, all nonmetals in elemental state react with O_2.

$2\ H_2\ (g) + O_2\ (g) \rightarrow 2\ H_2O\ (g)$
$2\ C\ (s) + O_2\ (g) \rightarrow 2\ CO\ (g)$ Incomplete combustion
$C\ (s) + O_2\ (g) \rightarrow CO_2$
$S\ (s) + O_2\ (g) \rightarrow SO_2\ (g)$
$N_2\ (g) + O_2\ (g) \rightarrow 2\ NO\ (g)$ Very high T, electric arc

Other oxides prepared by other than direct combination of elements.

Most compounds produce same products as if individual elements were used

$2\ H_2S + 3\ O_2 \rightarrow 2\ H_2O\ (g) + 2\ SO_2\ (g)$
$CH_4\ (g) + 2\ O_2 \rightarrow CO_2\ (g) + 2\ H_2O\ (g)$

$3\ O_2\ (g) \xrightarrow{\text{Electrical Discharge}} 2\ O_3\ (g)$

Ozone can decompose to oxygen at room temperature
Ozone can rapidly oxidize metal
More reactive than oxygen

Ozone in upper atmosphere prevents ultraviolet rays (UV – shorter wavelength than visible)

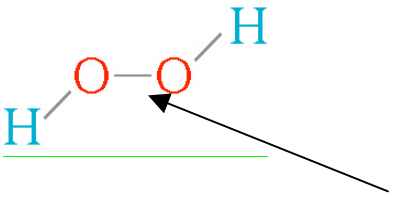
$O_3 \rightarrow O_2 + O$
UV radiation

Converts radiant energy into heat energy

$O + O_2 + M \rightarrow O_3 + M$
M = absorb energy

$E = h\nu * c = \lambda\nu$
$E = hc/\lambda$

Hydrogen Peroxide



peroxide unstable

http://www.chemistry.ohio-state.edu/~grandinetti/teaching/Chem121/lectures/chemical%20bonds/bonds.html

May explode in pure form
Save in solution with water

$BaO_2 + H_2SO_4 \rightarrow BaSO_4 + H_2O_2$

Participates in oxidation reaction at temperature where O_2 slow

$PbS + 4\ H_2O_2 \rightarrow PbSO_4 + 4\ H_2O$
$O_2 \rightarrow$ slow

Oxygen
-1 → -2
Oxidizing agent, it is reduced

Hydrogen Compounds:

Not direct combination because H_2S, H_2Se, H_2Te are unstable at hight Temp.

Use dilute acid on sulfides S^{2-}
selendides Se^{2-}
tellurides Te^{2-}

$Fe\ (s) + 2\ H^+\ (aq) \rightarrow Fe^{2+}\ (aq) + H_2S\ (g)$

H_2S, H_2Se, H_2Te are all unpleasant smelling poisonous gases.
are bent molecules like water
water is liquid due to hydrogen bonding

Hydrogen compounds dissolve in water to give weak acids

$H_2S\ (aq) \Leftrightarrow H^+\ (aq) + HS^-\ (aq)$

Stronger acid and lower electronegativity as go down periodic table and hence gives up H more readily.

Forms of Sulfur	Ox. # of Sulfur
Hydrogen sulfide H_2S	-2
Sulfur dioxide SO_2	+4
Sulfur trioxide SO_3	+6
Sulfuric acid H_2SO_4	+6
Pyrosulfuric acid $H_2S_2O_7$	+6

Production of Sulfuric Acid

(4+ oxidation state of S
(6+ preparation of H_2SO_4, sulfuric acid)

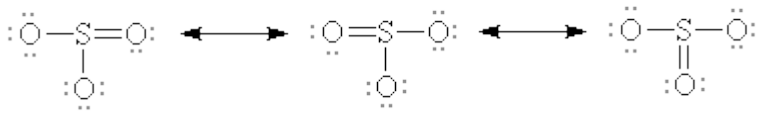
Sulfur dioxide SO_2

Burn sulfur $S\ (s) + O_2 \rightarrow SO_2\ (g)$
Roasting sulfides $Ca_2S + O_2 \rightarrow 2\ Cu + SO_2\ (g)$

SO_2 colorless gas with sharp irritating odor and poisonous
$(+4)(-2)_2$

Sulfur Trioxide

$2\ SO_2\ (g) + O_2\ (g) \rightarrow 2\ SO_3\ (g)$
Pt catalyst
600°C



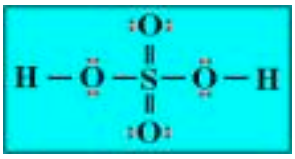
http://www.cartage.org.lb/en/themes/Sciences/Chemistry/Inorganicchemistry/Informationbonding/bondingindex/Resonance/Resonance.htm

Very reactive and strong oxidizing agent

SO_3 (g) + H_2SO_4 (l) → $H_2S_2O_7$ (l)
Pyrosulfuric acid

$H_2S_2O_7$ + H_2O → 2 H_2SO_4 (l)
Add enough pyrosulfuric acid to make desired concentration of sulfuric acid

Sulfuric acid is colorless, oily, liquid,



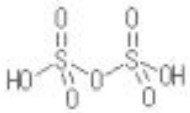
http://www.eou.edu/webshack/404_error.html

Tetrahedral shape

Sulfuric acid – about 40 million tons in U.S., SO_2 ad air through tube with Pt metal and vanadium catalyst
1831 patent to make sulfur trioxide

Suggested SO_3 + H_2O
Used to make fertilizers, chemical,

Pyrosulfuric acid ($H_2S_2O_7$)



http://ja.wikipedia.org/wiki/%E3%83%81%E3%82%AA%E7%A1%AB%E9%85%B8

Group 17

Production- Industry

Sources

F	CaF_2 fluorospar mineral deposits
Cl	Cl^- seawater
Br	Br^- seawater
I	I^- oil well brines

F_2:

CaF_2 (s) + H_2SO_4 (l) → $CaSO_4$ (s) + 2 HF (g)

KF + HF → KHF_2

2 KHF_2 (l) → H_2 (g) + F_2 (g) + 2 KF (l)

heat, electrolysis

K^+ HF_2^- ions

No chemical agent can be used to oxidize F since it is strongest oxidizing agent
Cannot be in water since F- electrolyze water

Cl_2:

2 Na^+ (aq) + 2 Cl^- (aq) + 2H_2O → H_2 (g) + Cl_2 (g) +2 Na^+ (aq) + 2OH^- (aq)

electrolysis

Br_2:

Cl_2 (g) + 2 Br^- (aq) → 2 Cl^- (aq) + Br_2 (l)
Use Cl2 as oxidizing agent

I_2:

Cl_2 (g) + 2 I^- (aq) → 2 Cl^- (aq) + I_2 (s)

Production - Lab

F_2 only by electrolysis
Others need oxidizing agent that will take electron from halide

MnO_2 (s) + 4 H^+ (aq) + 2 Cl^- (aq) → Mn^{2+} (aq) + Cl_2 (g) + 2 H_2O

Reduction Oxidation
Manganese dioxide

Compounds

Interhalogen	X_2	+	X_2' →	2 XX'
Hydrogen Halides	X_2	+	H_2 →	2 HX
Metal Halides	n X_2	+	2 M →	2 MX_n
Oxyacids of the Halogens				

Interhalogen Compounds:

Examples (some combination have not been made)

All	XX'	BrCl, ICl, …. Except IF
	XX_3'	IF_3
	XX_5'	IF_5, Cl_5, BrF_5
	XX_7'	only IF_7 (need to have room around central atom)

Valence Electrons							Pairs	
Central	Outer						Bond	Nonbond
		XX'		BrF	ClF			
7 +	3	XX_3'	IF_3	BrF3	ClF3	Tshaped	3	2
7 +	4	XX_5'	IF_5	BrF_5		Square Pyramid	5	1
7 +	7	XX_7'	IF_7			Pent. Bipyramid	7	

More fluorine atoms around central atom

Hydrogen Halides:

H_2 + X_2 → 2 HX

Reactivity $F_2 > Cl_2 > Br_2 > I_2$

Hydrogen	fluoride	HF
	chloride	HCl
	bromid	HBr
	iodide	HI

All gases at room temperature

Weak acid – Hydrofluoric acid, Hydrochloric acid (stored in placstic, etch glass)
Strong acid - Hydrobromic acid, Hydroiodic acid

Hydrofluoric acid will react with glass

SiO_2 (s) + 6 HF (aq) → 2 H+ + SiF_6^{2-} (aq) + 2 H_2O

Metal Halides:

Made by direct reaction of elements

(Group 1, Group 2, Metal) + Halides = Ionic Bond

(Transition , other metals) + Halides = Somewhat covalent Bond

Ionic character decreases in order F > Cl > Br > I

AlF	Completely ionic
AlCl	semicovalent – layer held together by London forces
Al_2Br_6	Covalent – form molecules in crystal
Al_2I_6	

Oxyacids of chlorine:

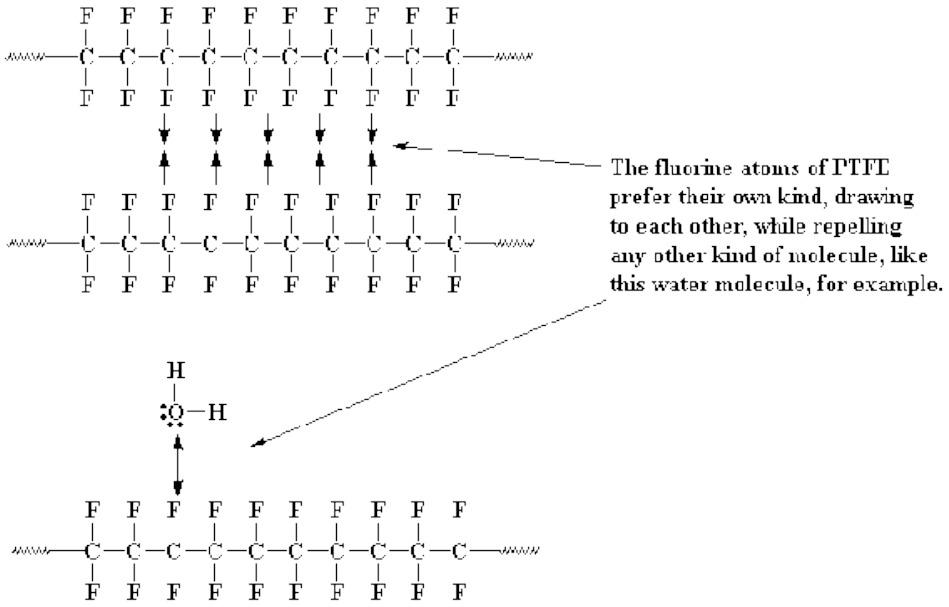
		Cl Ox #	
Hypochlorous	HO-Cl	+1	hypochloride
Chlorous	HO-ClO	+3	chlorite
Chloric	HO-ClO_2	+5	chlorate
Perchloric	HO-ClO_3	+7	perchlorite

Acid strength increases with the higher oxidation number for Cl

Industrial Uses of Halogens
(are used to make other compounds)

F

Freon CCL2F2 fluorochlorocarbons in refrigeration
Teflon



http://webphysics.davidson.edu/faculty/dmb/PY430/Friction/teflon.html

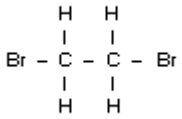
F_2 → UF_6 separate ^{235}U and ^{238}U
NaF prevent tooth decay

Cl

Many organic compounds contain Cl
Pharmaceuticals
Solvents carbon tetrachloride
Pesticides
Dyes
Bleaching chlorox
Polymers PVC plastic

Br

Fumigants (EDB Carcinogen, ethylene dibromide)



http://www.inchem.org/documents/jmpr/jmpmono/v65apr06.htm

Fire proofing agents

I
AgI photography
Some pharmaceuticals