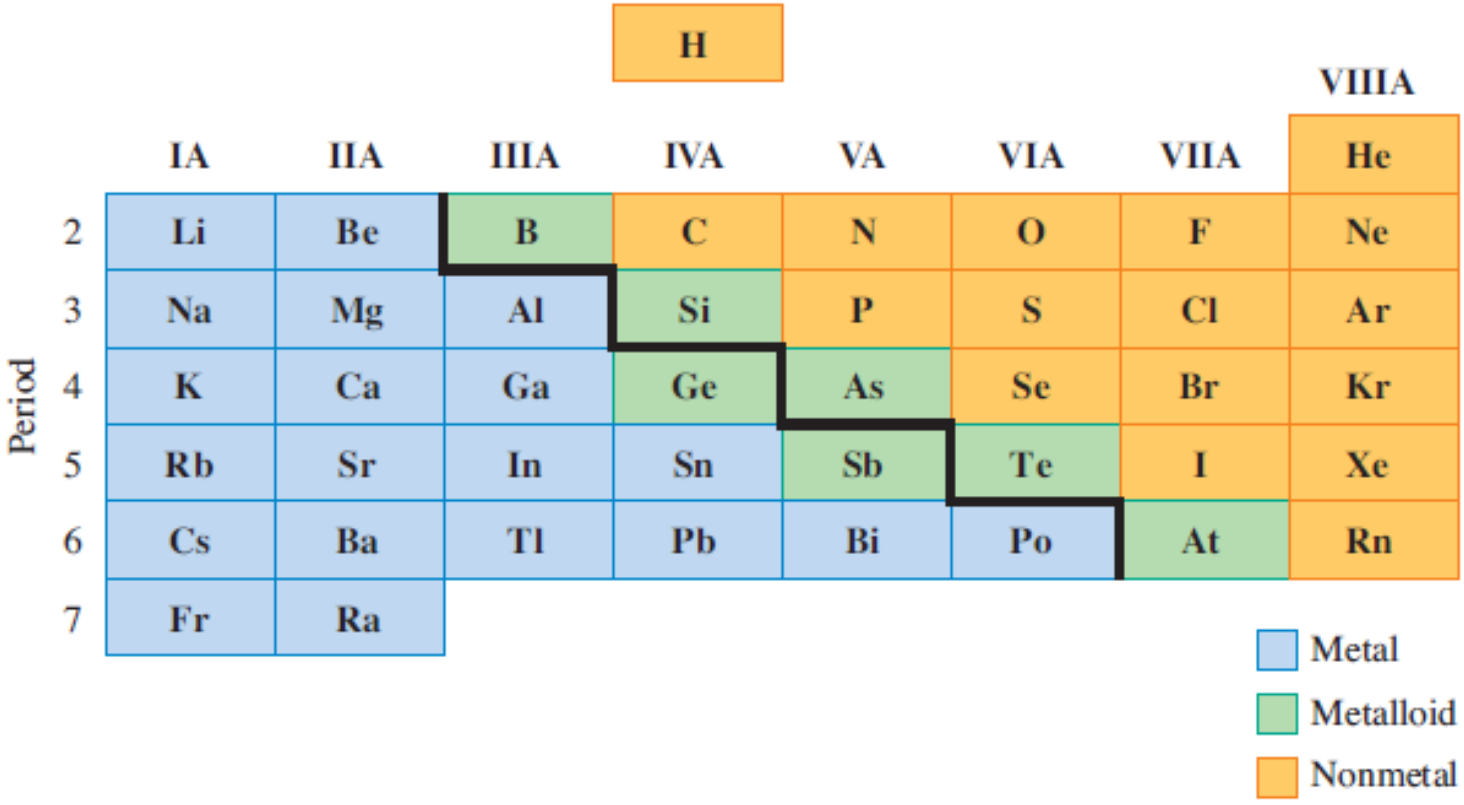
GENERAL CHEMISTRY

Chemistry of the Main-Group Elements

An abridged periodic table showing the main-group elements



Elements to the left of the heavy staircase line are largely metallic in character; those to the right are largely nonmetallic

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General Observations About the Main-Group Elements

Comparison of Metallic and Nonmetallic Elements

Metals	Nonmetals
Lustrous	Nonlustrous
Solids at 20°C (except Hg, which is a liquid)	Solids or gases at 20°C (except Br_2, which is a liquid)
Solids are malleable and ductile	Solids are usually hard and brittle
Conductors of heat and electricity	Nonconductors of heat and electricity (except graphite, an allotrope of C)
Low ionization energies	Moderate to high ionization energies
Low electronegativities	Moderate to high electronegativities
Form cations	Form monatomic anions or oxoanions
Oxides are basic (unless metal is in a high oxidation state)	Oxides are acidic

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Oxidation States in Compounds of the Main-Group Elements

	Group						
Period	IA	IIA	IIIA	IVA	VA	VIA	VIIA
2	Li +1	Be +2	B +3	C +4 +2 −4	N +5 +4 +3 +2 +1 −3	O −1 −2	F −1
3	Na +1	Mg +2	Al +3	Si +4 −4	P +5 +3 −3	S +6 +4 +2 −2	Cl +7 +5 +3 +1 −1
4	K +1	Ca +2	Ga +3	Ge +4 +2	As +5 +3 −3	Se +6 +4 −2	Br +7 +5 +1 −1
5	Rb +1	Sr +2	In +3 +1	Sn +4 +2	Sb +5 +3 −3	Te +6 +4 −2	I +7 +5 +1 −1
6	Cs +1	Ba +2	Tl +3 +1	Pb +4 +2	Bi +5 +3	Po +4 +2	At +5 −1

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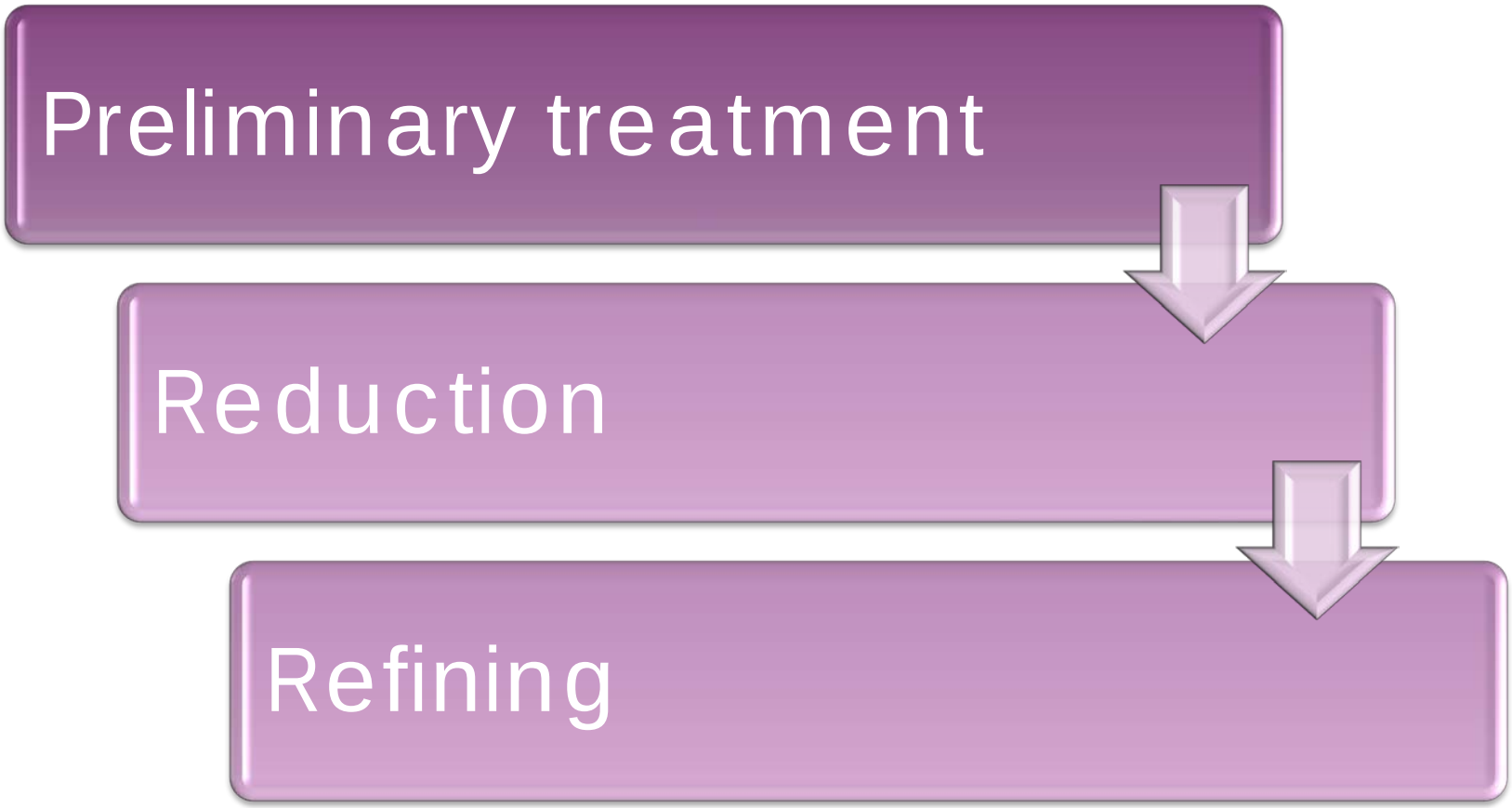
Metals: Characteristics and Production

Sources of Metals

Ruby is aluminum oxide, Al_2O_3, containing a small percentage of chromium(III) oxide, Cr_2O_3.

Metallurgy

The basic steps in the production of a metal



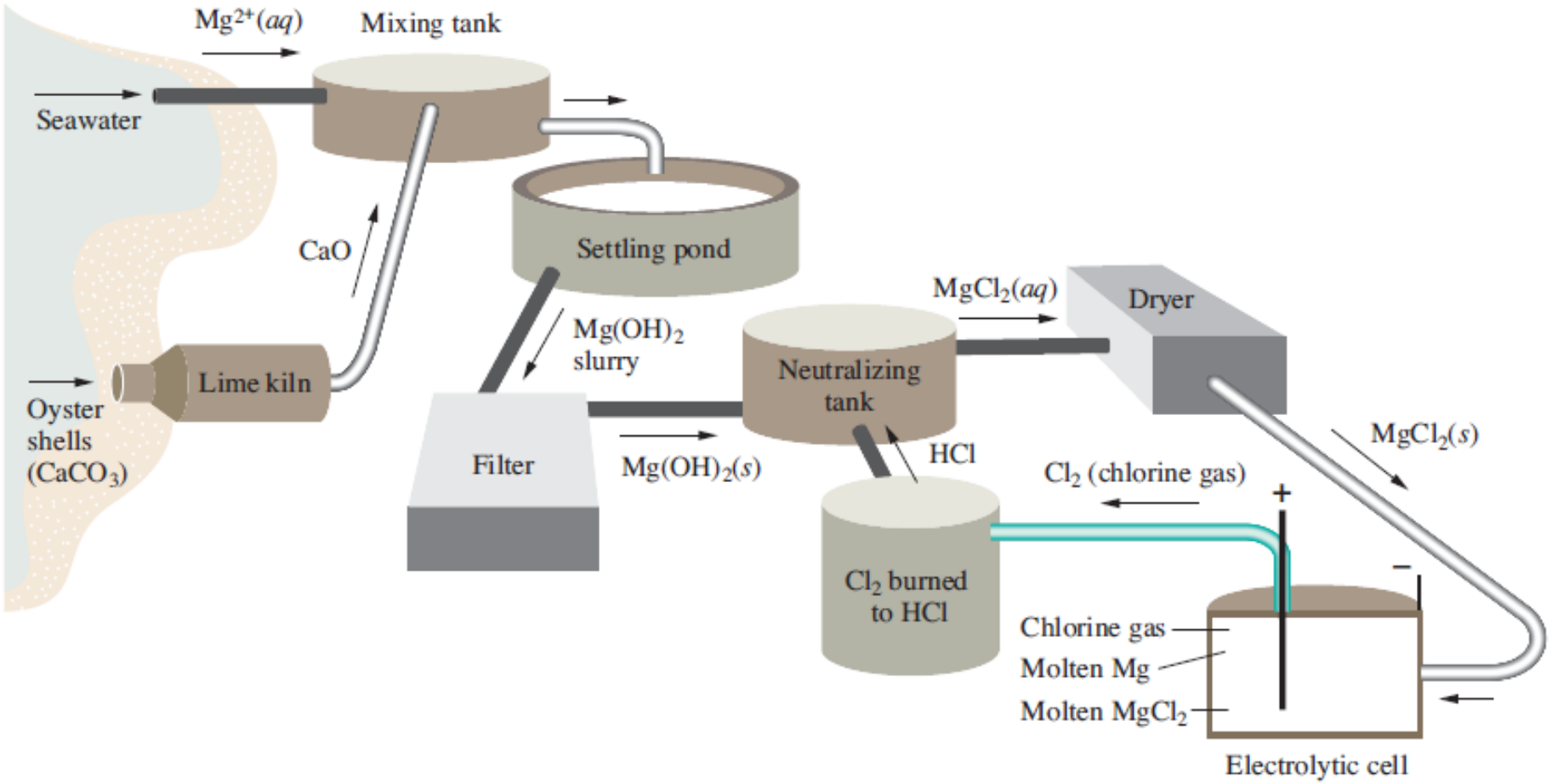
Preliminary Treatment

Precipitation of aluminum hydroxide by acidifying an aluminate ion solution

Left: Carbon dioxide gas is bubbled into a solution of aluminate ion, $Al(OH)_4^-$, containing aluminon dye. *Right:* Aluminum hydroxide, $Al(OH)_3$, precipitates from the acidic solution. The precipitate is normally white but adsorbs the dye to form a pink-colored precipitate called a *lake*. A standard test for aluminum ion is its precipitation as the hydroxide in the presence of aluminon dye to form this lake.

Reduction

Dow process for producing magnesium from sea water



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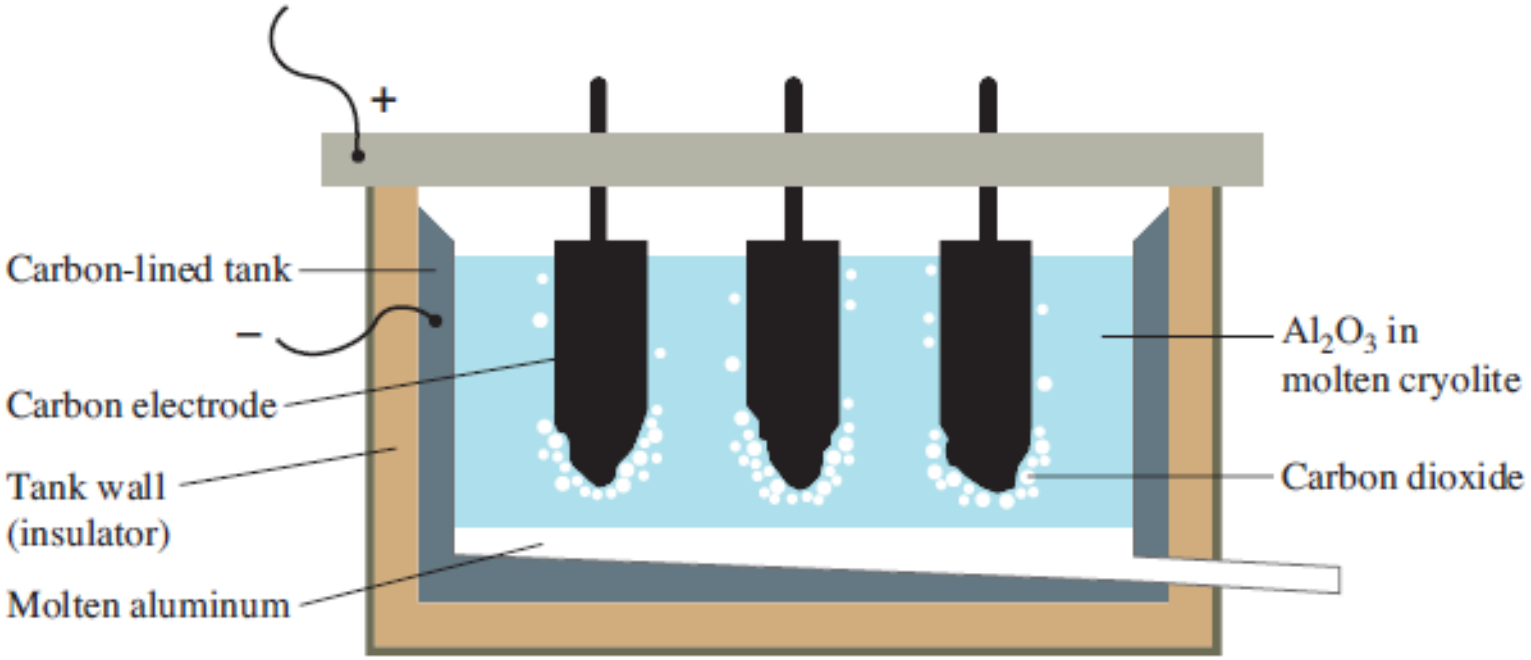
Hall–Héroult cell for the production of aluminum



$$2Al_2O_3(s) + 3C(s) \xrightarrow{\text{electrolysis}} 4Al(l) + 3CO_2(g)$$

Aluminum oxide is electrolyzed in molten cryolite (the electrolyte). Molten aluminum forms at the negative electrode (tank lining), where it is periodically withdrawn.

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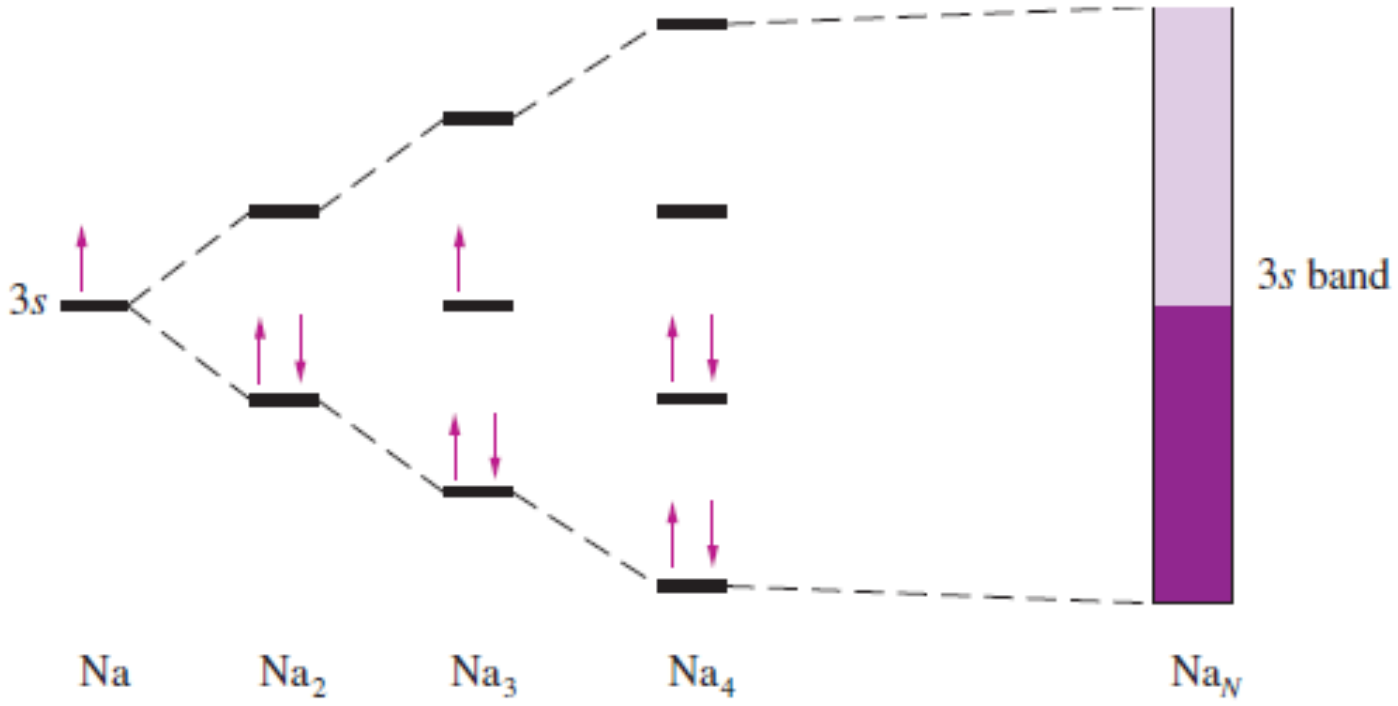
Bonding in Metals

Molecular Orbital Theory of Metals

Formation of an energy band in sodium metal



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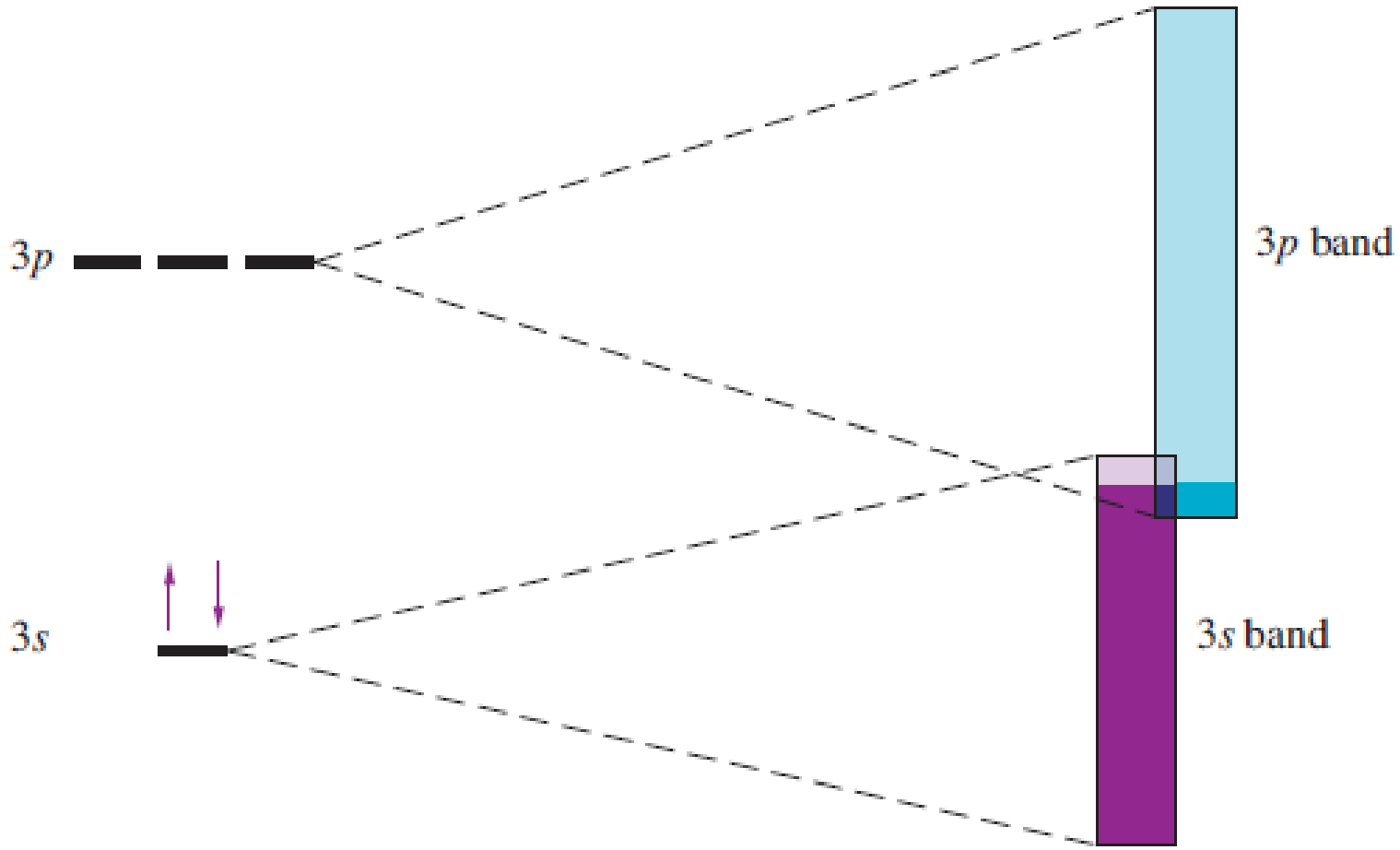
Formation of 3*s* *and 3p bands in* magnesium metal



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Group IA: The Alkali Metals

Cutting of sodium metal

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Uses of Alkali Metal Compounds

Compound	Use
Li_2CO_3	Preparation of porcelain, glazes, special glasses
	Preparation of LiOH
	Treatment of bipolar disorder
LiOH	Manufacture of lithium soaps for lubricating greases
	In air-regeneration systems
LiH	Reducing agent in organic syntheses
$LiNH_2$	Preparation of antihistamines and other pharmaceuticals
NaCl	Source of sodium and sodium compounds
	Condiment and food preservative
	Soap manufacture (precipitates soap from reaction mixture)
NaOH	Pulp and paper industry
	Extraction of aluminum oxide from ore
	Manufacture of viscose rayon
	Petroleum refining
	Manufacture of soap
Na_2CO_3	Manufacture of glass
	In detergents and water softeners
Na_2O_2	Textile bleach
$NaNH_2$	Preparation of indigo dye for denim (blue jeans)
KCl	Fertilizer
	Source of other potassium compounds
KOH	Manufacture of soft soap
	Manufacture of other potassium compounds
K_2CO_3	Manufacture of glass
KNO_3	Fertilizers
	Explosives and fireworks

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Group IIA: The Alkaline Earth Metals

Magnesium and barium metals

Magnesium metal turnings are in the beaker (left). Barium metal (right) is much more reactive than magnesium and must be stored in a bottle of kerosene to exclude moisture and oxygen, with which barium reacts.

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Uses of Alkaline Earth Compounds

Compound	Use
MgO	Refractory bricks (for furnaces)
	Animal feeds
$Mg(OH)_2$	Source of magnesium for the metal and compounds
	Milk of magnesia (antacid and laxative)
$MgSO_4 \cdot 7H_2O$	Fertilizer
	Medicinal uses (laxative and analgesic)
	Mordant (used in dyeing fabrics)
CaO and $Ca(OH)_2$	Manufacture of steel
	Neutralizer for chemical processing
	Water treatment
	Mortar
	Stack-gas scrubber (to remove H_2S and SO_2)
$CaCO_3$	Paper coating and filter
	Antacids, dentifrices
$CaSO_4$	Plaster, wallboard
	Portland cement
$Ca(H_2PO_4)_2$	Soluble phosphate fertilizer
$BaSO_4$	Oil-well drilling mud
	Gastrointestinal x-ray photography
	Paint pigment

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Reaction of carbon dioxide with calcium hydroxide solution

$$Ca^{2+}(aq) + 2HCO_3^-(aq) + Ca(OH)_2(aq) \longrightarrow 2CaCO_3(s) + 2H_2O(l)$$

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Group IIIA and Group IVA Metals

Chemistry of the Nonmetals

Some nonmetals

Left to right: Sulfur, bromine, white phosphorus, and carbon.

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List of All Elements That Are Nonmetals

So, if we include the nonmetals group, halogens, and noble gases, all of the elements that are nonmetals are:

- ✓ Hydrogen (sometimes)
- ✓ Carbon
- ✓ Nitrogen
- ✓ Oxygen
- ✓ Phosphorus
- ✓ Sulfur
- ✓ Selenium
- ✓ Fluorine
- ✓ Chlorine
- ✓ Bromine
- ✓ Iodine
- ✓ Astatine
- ✓ Tennessine (sometimes considered a halogen, sometimes considered a metalloid)
- ✓ Helium
- ✓ Neon
- ✓ Argon
- ✓ Krypton
- ✓ Xenon
- ✓ Radon
- ✓ Oganesson (possibly behaves as a "noble gas", except it won't be a gas under ordinary conditions)

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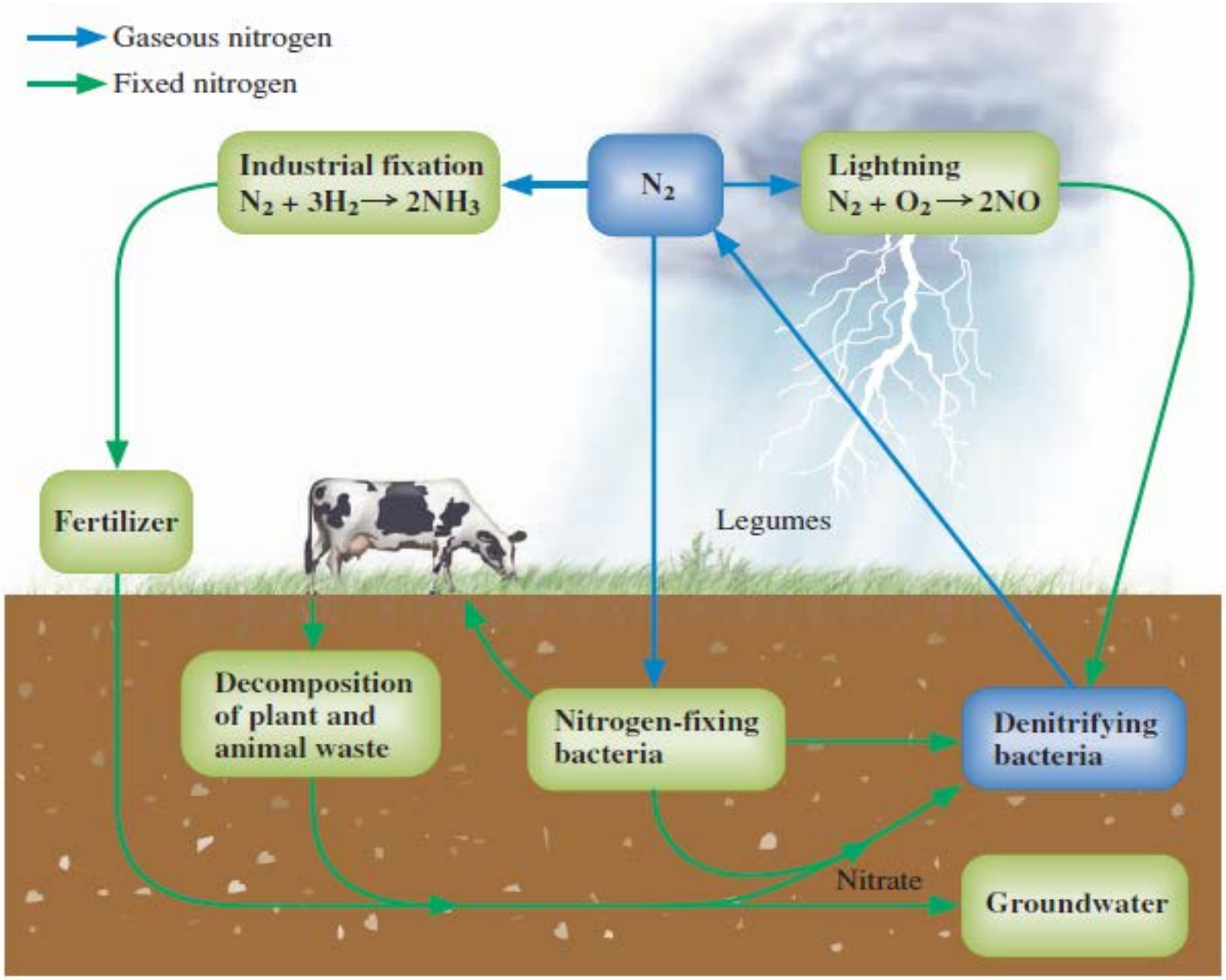
Group IVA: The Carbon Family

Group VA: Nitrogen and the Phosphorus Family

The nitrogen cycle



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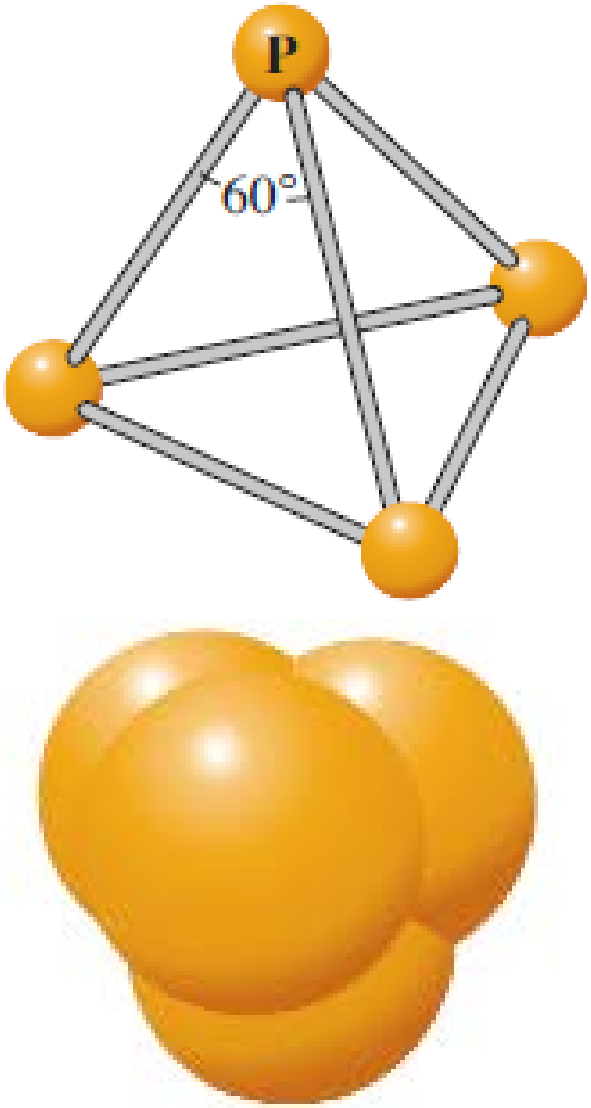
Allotropes of phosphorus and Structure of the phosphorus molecule



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Group VIA: Oxygen and the Sulfur Family

Group VIIA: The Halogens

Uses of Some Halogen Compounds

Compound	Use
AgBr, AgI	Photographic film
CCl_4	Manufacture of fluorocarbons
CH_3Br	Pesticide
$C_2H_4Cl_2$	Manufacture of vinyl chloride (plastics)
HCl	Metal treating
	Food processing
NaClO	Household bleach
	Manufacture of hydrazine for rocket fuel
$NaClO_3$	Paper pulp bleaching (with ClO_2)
KI	Human nutritional and animal feed supplement

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Group VIIIA: The Noble Gases: Helium and the Other Noble Gases

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