Group III

The elements of Group III are:

	symbol	electron configuration
boron	B	$[He]2s^2 2p^1$
aluminium	Al	$[Ne]3s^2 3p^1$
gallium	Ga	$[Ar]3d^{10} 4s^2 4p^1$
indium	In	$[Kr]4d^{10} 5s^2 5p^1$
thallium	Tl	$[Xe]4f^{14} 5d^{10} 6s^2 6p^1$

Appearance

Boron is a non-metallic grey powder, and all the other members of Group III are soft, silvery metals. Thallium develops a bluish tinge on oxidation.

General Reactivity

The general trend down Group III is from non-metallic to metallic character. Boron is a non-metal with a covalent network structure. The other elements are considerably larger than boron and consequently are more ionic and metallic in character. Aluminium has a close-packed metallic structure but is on the borderline between ionic and covalent character in its compounds. The remainder of Group III are generally considered to be metals, although some compounds exhibit covalent characteristics.

Occurrence and Extraction

These elements are not found free in nature, but are all present in various minerals and ores. The most important aluminium-containing minerals are bauxite and cryolite.

Aluminium is the most widely used element in this Group. It is obtained by the electrolysis of aluminium oxide, which is purified from bauxite. The melting point of the aluminium oxide is too high for electrolysis of the melt, so instead it is dissolved in molten cryolite.

Physical Properties

The influence of the non-metallic character in this Group is reflected by the softness of the metals. The melting points of all the elements are high, but the melting point of boron is much higher than that of beryllium in Group II, whereas the melting point of aluminium is similar to that of magnesium in Group II. The densities of all the Group III elements are higher than those of Group II elements.

The ionic radii are much smaller than the atomic radii. This is because the atom contains 3 electrons in a quantum level relatively far from the nucleus, and when they are removed to form the ion the remaining electrons are in levels closer to the nucleus. In addition, the increased effective nuclear charge attracts the electrons towards the nucleus and decreases the size of the ion.

Chemical Properties

The chemical properties of Group III elements reflect the increasingly metallic character of descending members of the Group. Here only boron and aluminium will be considered.

Boron is chemically unreactive except at high temperatures. Aluminium is a highly reactive metal which is readily oxidised in air. This oxide coating is resistant to acids but is moderately soluble in alkalis. Aluminium can therefore reduce strong alkalis, a product being the tetrahydroxoaluminate ion, $Al(OH)_4^-$. Aluminium also reacts violently with iron (III) oxide to produce iron in the Thermit process:

$2Al(s) + Fe_2O_3 \rightarrow 2Fe(s) + Al_2O_3(s)$

Oxides

Boron oxide, B_2O_3, is an insoluble white solid with a very high boiling point (over 2000K) because of its extended covalently-bonded network structure. Aluminium oxide, Al_2O_3, is amphoteric.

Halides

The most important halide of boron is boron trifluoride, which is a gas. Aluminium chloride, $AlCl_3$, is a volatile solid which sublimes at 458K. The vapour formed on sublimation consists of an equilibrium mixture of monomers ($AlCl_3$) and dimers (Al_2Cl_6). It is used to prepare the powerful and versatile reducing agent lithium tetrahydridoaluminate, $LiAlH_4$.

Both boron chloride and aluminium chloride act as Lewis acids to a wide range of electron-pair donors, and this has led to their widespread use as catalysts. Aluminium chloride is used in the important Friedel-Crafts reaction.

Hydrides

Boron forms an extensive and interesting series of hydrides, the boranes. The simplest of these is not BH_3 as expected, but its dimer B_2H_6.

Oxidation States and Ionisation Energies

Boron and aluminium occur only with oxidation number +3 in their compounds, and with a few exceptions their compounds are best described as ionic. The electron configuration shows 3 electrons outside a noble gas configuration, 2 in an s shell and 1 in a p shell. The outermost p electron is easy to remove as it is furthest from the nucleus and well shielded from the effective nuclear charge. The next 2 s electrons are also relatively easy to remove. Removal of any further electrons disturbs a filled quantum shell so is difficult. This is reflected in the ionisation energies. The first 3 ionisation energies are low, and the fourth very much higher.

Industrial Information

Boron has limited uses, but is used in flares to provide a highly visible green colour. Boron filaments are now used extensively in the aerospace industry as a light weight yet strong matenal. Boracic acid is used as a mild antiseptic, and borax as a water softener in washing powders. Borosilicate glass contains boron compounds.

Aluminium is one of the most industrially important materials. It is light, non-toxic, has a high thermal conductivity, can be easily worked and does not corrode due to its oxide coating, which is very effective although only 10nm thick. It has several domestic uses such as cooking utensils, aluminium foil and bottle tops, and is widely used in the building industry where a strong, light, easily-constructed material is required. These properties also make it invaluable in the building of aeroplanes and spacecraft.

Further Information

For further information look up the individual elements.

Data

	Atomic Number	Relative Atomic Mass	Melting Point/K	Density/kg m^{-3}
B	5	10.81	2573	2340
Al	13	26.98	933.52	2698
Ga	31	69.72	302.9	5907
In	49	114.82	429.32	7310
Tl	81	204.38	576.7	11850

Ionisation Energies/kJ mol^{-1}

	1st	2nd	3rd	4th
B	800.6	2427	3660	25025
Al	577.4	1816.6	2744.6	11575
Ga	578.8	1979	2963	6200
In	558.3	1820.6	2704	5200
Tl	589.3	1971	2878	4900

	Atomic Radius/nm	Ionic Radius/nm (M^{3+})
B	0.0790	
Al	0.1431	0.057
Ga	0.1221	0.062
In	0.1626	0.092
Tl	0.1704	0.105