Group I - *The Alkali Metals*

The elements of Group I, the Alkali metals, are:

	symbol	electron configuration
lithium	Li	$[He]2s^1$
sodium	Na	$[Ne]3s^1$
potassium	K	$[Ar]4s^1$
rubidium	Rb	$[Kr]5s^1$
caesium	Cs	$[Xe]6s^1$
francium	Fr	$[Rn]7s^1$

In each element the valence electron configuration is ns^1, where n is the Period number. The last element, francium, is radioactive and will not be considered here.

Appearance

All the Group I elements are silvery-coloured metals. They are soft, and can be easily cut with a knife to expose a shiny surface which dulls on oxidation.

General Reactivity

These elements are highly reactive metals. The reactivity increases on descending the Group from lithium to caesium. There is a closer similarity between the elements of this Group than in any other Group of the Periodic Table.

Occurrence and Extraction

These elements are too reactive to be found free in nature. Sodium occurs mainly as NaCl (salt) in sea-water and dried-up sea beds. Potassium is more widely distributed in minerals such as sylvite, KCl, but is also extracted from sea-water. The alkali metals are so reactive they cannot be displaced by another element, so are isolated by electrolysis of their molten salts.

Physical Properties

The alkali metals differ from other metals in several ways. They are soft, with low melting and boiling temperatures. They have low densities - Li, Na and K are less dense than water. They have low standard enthalpies of melting and vaporization. They show relatively weak metallic bonding as only one electron is available from each atom.

Alkali metals colour flames. When the element is placed in a flame the heat provides sufficient energy to promote the outermost electron to a higher energy level. On returning to ground level, energy is emitted and this energy has a wavelength in the visible region:

Li red	Na yellow	K lilac	Rb red	Cs blue

The ionic radii of the alkali metals are all much smaller than the corresponding atomic radii. This is because the atom contains 1 electron in an s level relatively far from the nucleus in a new quantum shell, and when it is 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 alkali metals are strong reducing agents. The standard electrode potentials all lie between -2.7V and -3.0V, indicating a strong tendency to form cations in solution. They can reduce oxygen, chlorine, ammonia and hydrogen. The reaction with oxygen tarnishes the metals in air, so they are stored under oil. They cannot be stored under water because they react with it to produce hydrogen and alkali hydroxides:

$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$

This reaction illustrates the increasing reactivity on descending the Group. Li dissolves steadily in water with effervescence; sodium reacts more violently and can burn with an orange flame; K ignites on contact with water and burns with a lilac flame; Cs sinks in water, and the rapid generation of hydrogen gas under water produces a shock wave that can shatter a glass container.

Na dissolves in liquid ammonia to give a deep blue solution of sodium cations and solvated electrons. This solution is used as a reducing agent. At higher concentrations the colour of the solution changes to bronze and it conducts electricity like a metal.

The chemistry of Li shows some anomalies, as the cation Li^+ is so small it polarises anions and so introduces a covalent character to its compounds. Li has a diagonal relationship with magnesium.

Oxides

The alkali metals form ionic solid oxides of compostion M_2O when burnt in air. However, Na also forms the peroxide Na_2O_2 as the main product, and K forms the superoxide KO_2, also as the main product.

Hydroxides

Alkali metal hydroxides are white ionic crystalline solids of formula MOH, and are soluble in water. They are all deliquescent except LiOH. The aqueous solutions are all strongly alkaline (hence the name of this Group) and therefore dangerous to handle. They neutralise acids to form salts, eg:

$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$

Halides

Alkali metal halides are white ionic crystalline solids. They are all soluble in water except LiF, which has a very high lattice enthalpy arising from the strong electrostatic interaction of the small Li^+ and F^- ions.

Oxidation States and Ionisation Energies

Alkali metals have oxidation states of 0 and +1. All the common compounds are based on the M^+ ion. This is because the first ionisation energy of these elements is low, and the second ionisation energy much higher. The outermost electron is well shielded from the attractive nuclear charge by filled inner electron levels and so is relatively easy to remove. The next electron is much more difficult to remove as it is part of a full level and is also closer to the nucleus.

Ionisation energy decreases down the Group because the outermost electron is progressively further from the nucleus and so is easier to remove.

Industrial Information

Sodium hydroxide, chloride and carbonate are among the most important industrial chemicals associated with this Group. Sodium hydroxide is produced by the electrolysis of saturated brine in a cell with steel cathodes and titanium anodes. Sodium carbonate is made by the Solvay Process, in which soluble sodium chloride is converted into insoluble sodium hydrogencarbonate and filtered off, then heated to produce the carbonate. However, the principal by-product of this process is calcium chloride, and its deposition in rivers causes environmental concern. The Solvay Process is therefore gradually being replaced by the purification of sodium carbonate from minerals.

Further Information

For further information look up the individual elements.

Data

	Atomic Number	Relative Atomic Mass	Melting Point/K	Density/kg m^{-3}
Li	3	6.94	453.7	534
Na	11	22.99	371.0	971
K	19	39.10	336.8	862
Rb	37	85.47	312.2	1532
Cs	55	132.91	301.6	1873

Ionisation Energies/kJ mol^{-1}

	1st	2nd	3rd
Li	513.3	7298.0	11814.8
Na	495.8	4562.4	6912.0
K	418.8	3051.4	4411.0
Rb	403.0	2632.0	3900.0
Cs	375.7	2420.0	3400.0

	Atomic Radius/nm	Ionic Radius/nm	Standard Electrode Potentials/V
Li	0.152	0.068	-3.04
Na	0.185	0.098	-2.71
K	0.227	0.133	-2.92
Rb	0.247	0.148	-2.92
Cs	0.265	0.167	-2.92