7.1: Lanthanoids

The fifteen elements shown in Table 7.1.1 from lanthanum, La ($4f^0$), to lutetium, Lu ($4f^{14}$), are **lanthanoids**. Ln may be used as a general symbol for the lanthanoid elements. Although lanthanoids, scandium, Sc, and yttrium, Y, are sometimes called rare earth elements, they are relatively abundant in the earth's crust. With the exception of promethium, Pm, which does form a stable isotope, even the least abundant thulium, Tm, and lutetium, Lu, are as abundant as iodine. Because lanthanoids have very similar properties and are difficult to separate from one another, they were not useful for basic research and application, and hence they were regarded as rare elements. Since a liquid-liquid solvent extraction method using tributylphosphine oxide became available in the 1960s, lanthanoid elements have been readily available and widely used not only for chemical research but also as materials in alloys, catalysts, lasers, cathode-ray tubes, etc.

Exercise 7.1.1

What is the difference between lanthanoids and lanthanides?

Answer

Fifteen elements La-Lu are lanthanoids and fourteen elements Ce-Lu without lanthanum are lanthanides (meaning the elements similar to lanthanum). Occasionally the names are confused and 15 elements including lanthanum may be called lanthanides.

Table 7.1.1 Properties of lanthanoids

Atomic number	Name	Symbol	Electron configuration	M^{3+} radius (pm)
57	Lanthanum	La	$5d^1 6s^2$	116
58	Cerium	Ce	$4f^1 5d^1 6s^2$	114
59	Praseodymium	Pr	$4f^3 6s^2$	113
60	Neodymium	Nd	$4f^4 6s^2$	111
61	Promethium	Pm	$4f^5 6s^2$	109
62	Samarium	Sm	$4f^6 6s^2$	108
63	Europium	Eu	$4f^7 6s^2$	107
64	Gadolinium	Ge	$4f^7 5d^1 6s^2$	105
65	Terbium	Tb	$4f^9 6s^2$	104
66	Dysprosium	Dy	$4f^{10} 6s^2$	103
67	Holmium	Ho	$4f^{11} 6s^2$	102
68	Erbium	Er	$4f^{12} 6s^2$	100
69	Thurium	Tm	$4f^{13} 6s^2$	99
70	Ytterbium	Yb	$4f^{14} 6s^2$	99
71	Lutetium	Lu	$4f^{14} 5d^1 6s^2$	98

Because the three stages of ionization enthalpy of lanthanoid elements are comparative low, they are positive elements and readily assume trivalent ionic states. Most compounds of lanthano other than Ce^{4+} ($4f^0$), Eu^{2+} ($4f^7$), Yb^{2+} ($4f^{14}$), are usually Ln^{3+} ones. Ln^{3+} species are hard acids, and since f electrons are buried deeply and not used for bonding, they are hardly influenced by ligands. There is a tendency for atomic and ionic radii to decrease with the increase of the atomic number, and this phenomenon is called the **lanthanide contraction**. This contraction is due to small shielding effects of 4 f electrons, which causes the atomic nucleus to draw outer shell electrons strongly with an increase of atomic number.

Complexes of lanthanoid metals are 6 to 12 coordinate and especially many 8 and 9 coordinate compounds are known. Organometallic compounds with cyclopentadienyl ligands of the types Cp_3Ln or Cp_2LnX are also known, all of which are very reactive to oxygen or water.