

GEOCHEMICAL BEHAVIOUR OF ELEMENTS – ALUMINIUM

Most common form: Al^{3-}

Ionic radius: 0.39 Å (tetrahedral) and 0.54 Å (octahedral)

Stable isotope: 27 (100%)

Atomic weight: 26.982

Condensation temperature: 1650 K

Aluminum is the sixth most abundant element in the Earth. Al is a highly refractory lithophile element. The radioactive isotope ^{26}Al quickly decayed into ^{26}Mg in the very first millions of years of the Solar System's evolution. It provided substantial heating to the early planets, and the isotopic composition of Mg is one of the most widely used chronometer based on extinct radioactivities. It is unlikely that Al enters in large proportions in the core, but Al is in many major minerals at any depth in the mantle and in the crust. In the mantle, it enters plagioclase up to pressure of about 1 GPa, spinel to 2 GPa, and garnet beyond. At these high pressure, Al also enters clinopyroxene in large proportions: garnet and clinopyroxene dissolve into each other to form majorite, an essential mineral phase of the mantle above the 660 km discontinuity. At higher pressure, Al is hosted in a perovskite structure, but its precise behavior is still largely unknown. The major plagioclase occurs in basalts, while plagioclase and alkali feldspar may occur together in felsic rocks. Biotite mica may occur in both types of rocks but normally accounts for a small part of the Al inventory. In sedimentary rocks, Al is hosted in clay minerals such as kaolinite and illite and, occasionally, in detrital feldspars. In metamorphic gneisses and schists, Al largely resides in feldspars and micas.

Aluminum can be tetrahedrally coordinated and in this coordination it replaces Si in the center of oxygen tetrahedra. It can also be octahedrally coordinated and form solid solutions with elements such as Ca, Mg, and Fe. During melting, the Al-rich minerals (feldspar, spinel, garnet) quickly dissolve into the melt and Al therefore behaves as a moderately incompatible element. During low-pressure fractionation of basalts, Al is removed by plagioclase precipitation. At higher pressure, plagioclase solubility in silicate melts increases, and this mineral does not precipitate until a late stage in the magmatic differentiation. Aluminum is therefore useful in assessing the depth of differentiation of basaltic series. In mid-ocean ridge and continental flood basalts, Al concentrations do not vary much with fractionation because they are buffered by plagioclase removal: these lavas are differentiated at low pressure in the plagioclase stability field. In contrast, Al concentrations increase steadily with fractionation of Hawaiian basalts: these rocks evolve at higher pressure in the absence of plagioclase.

Typical concentrations of Al_2O_3 in basaltic and granitic melts average 15 wt %. Aluminum solubility in hydrous fluids is low, except at very high temperature and high pH. This solubility is controlled by the stability of different complexes with the hydroxyl ion OH^- and the solubility of clay minerals in equilibrium with the solution, e.g. kaolinite. The minimum in solubility at $pH \approx 6$ reflects the amphoteric character of this element. During weathering, Al solubility is controlled by kaolinite reactions of alkalinity production (6.15). The destruction of feldspars by CO_2 -rich fresh water leaves Al in clays: this element is most efficiently transported by rivers to the sea in the suspended load. In seawater, Al solubility is controlled by the input of airborne clay particles transported from deserts.