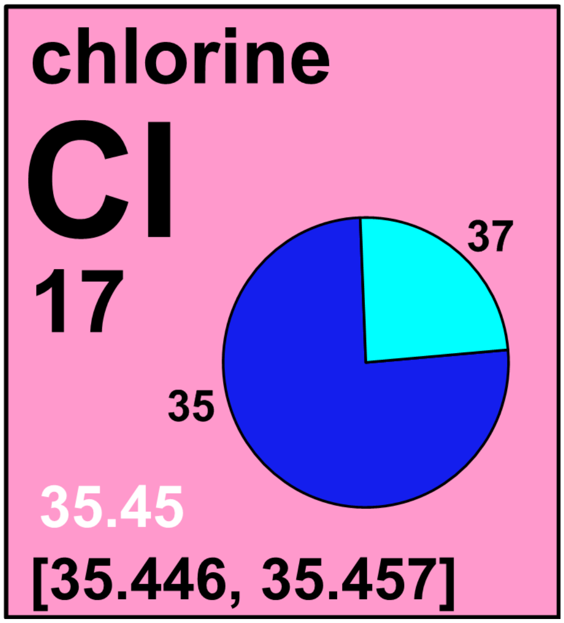
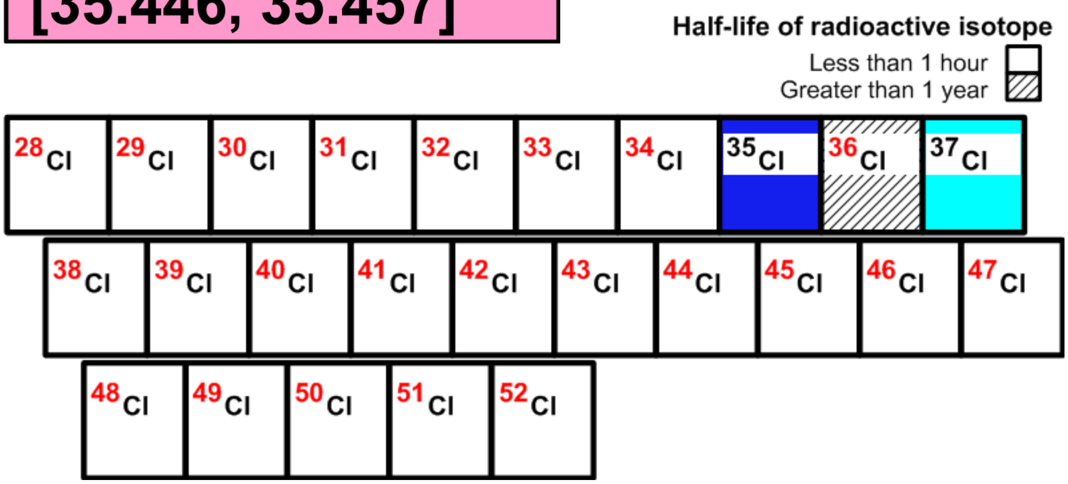
4.17 chlorine



Stable isotope	Relative atomic mass	Mole fraction
^{35}Cl	34.968 8527	[0.755, 0.761]
^{37}Cl	36.965 9026	[0.239, 0.245]



4.17.1 Chlorine isotopes in Earth/planetary science

Because molecules, atoms, and ions of the **stable isotopes** of chlorine possess slightly different physical and chemical properties, they commonly will be fractionated during physical, chemical, and biological processes, giving rise to variations in **isotopic abundances** and in **atomic weights**. There are substantial variations in the isotopic abundances of chlorine in natural terrestrial materials (Figure 4.17.1). These variations are useful for investigating the origin of substances and studying environmental, hydrological, and geological processes. Chlorine is subject to **isotopic fractionation** by physical and chemical processes. Variations in **isotopic compositions** of stable chlorine **isotopes** provide evidence for ultrafiltration and crystallization of brines and indicate sources of chlorine-bearing contaminants, such as solvents and rocket fuels in the environment [148, 149].

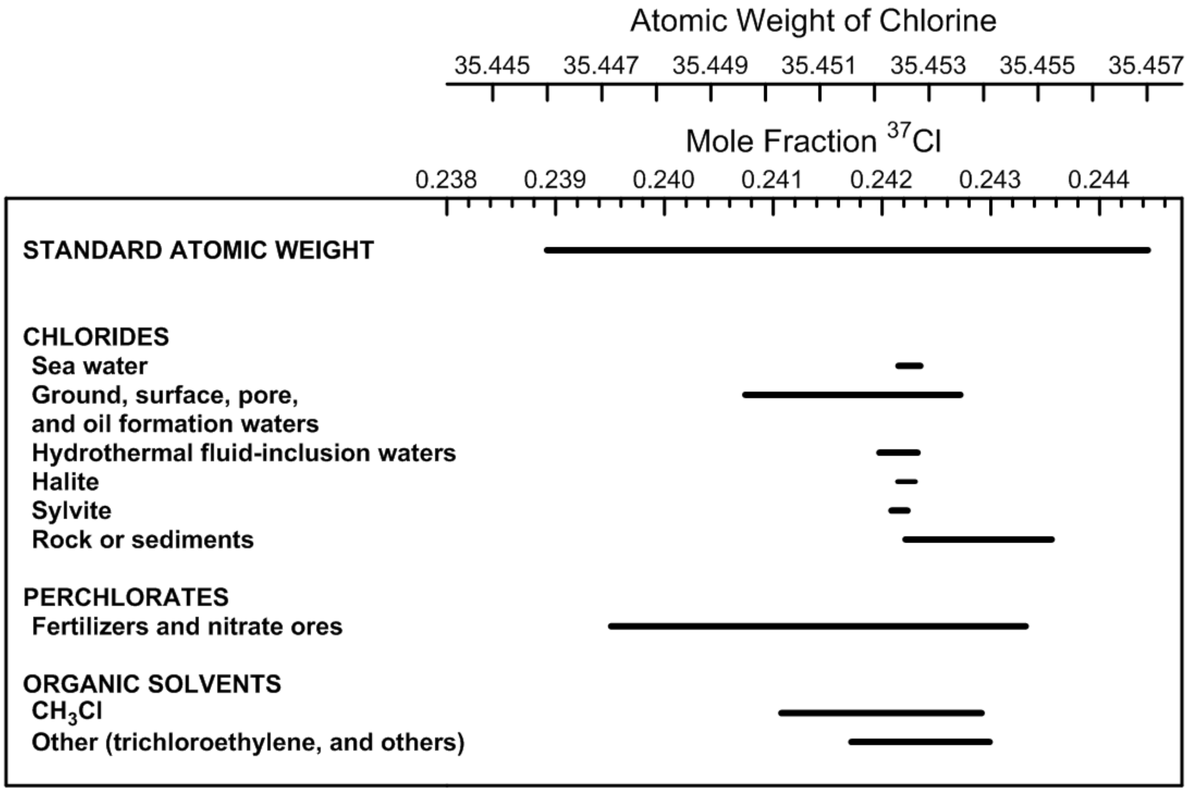


Fig. 4.17.1: Variation in **atomic weight** with **isotopic composition** of selected chlorine-bearing materials (modified from [10, 14]).

4.17.2 Chlorine isotopes in forensic science and anthropology

Analyses of chlorine isotopes and other environmental **tracers** can help to identify whether an environmental contaminant is of **anthropogenic** origin or naturally occurring. For example, perchlorate (ClO_4^-) can be of anthropogenic origin and is also found naturally. Perchlorate is a widespread groundwater contaminant that can interfere with hormone production in the thyroid gland by displacing iodide. Both the stable chlorine **isotope-amount ratio** ($n(^{37}Cl)/n(^{35}Cl)$) and the **mole fraction** of ^{36}Cl ($n(^{36}Cl)/n(Cl)$) can provide useful information about origins of perchlorate in the environment (Figure 4.17.2). Such information may be important for legal reasons and for remediation of contaminated areas [149, 150].

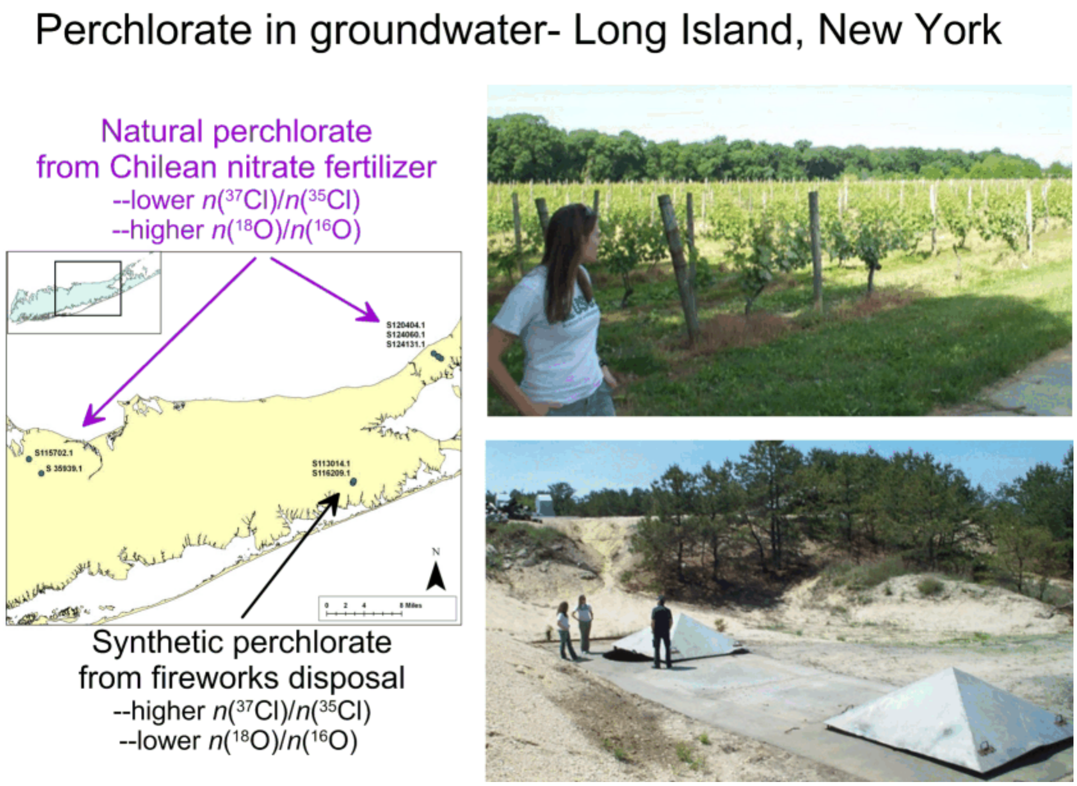


Fig. 4.17.2: By analyzing the **isotopic composition** of chlorine and oxygen in perchlorate in groundwaters of Long Island, NY, sources of perchlorate contamination could be identified [151]. Isotopic compositions indicate that wells in different parts of Long Island were contaminated by different sources. The agriculture source of perchlorate (upper photo) is identified as nitrate fertilizer from Chile, where natural perchlorate-bearing nitrate salt deposits were mined and processed for export. The synthetic source is attributed to contamination from a fireworks disposal area (lower photo). (Image Source: J.K. Böhlke, U.S. Geological Survey).

4.17.3 Chlorine isotopes in geochronology

Radioactive ^{36}Cl provides a useful tool to determine ages in geology and hydrology. Some radioactive ^{36}Cl is **cosmogenic** and enters the terrestrial environment in precipitation. Because of its long **half-life** of 3.01 × 10^5 years, the level of ^{36}Cl in aquifers can be measured and used to estimate ages (on the order of 10^5 to 10^6 years) of old meteoric groundwater (water that was originally precipitation) [152].

Thermonuclear bomb tests in the ocean produced large amounts of ^{36}Cl by **neutron** reactions with ^{35}Cl in seawater. This was especially prevalent in the late 1950s. Large amounts of this anthropogenic ^{36}Cl were distributed throughout the atmosphere, deposited with precipitation, and incorporated into terrestrial soils and groundwater. This enriched ^{36}Cl has been used as a tracer of **meteoric water** from that era [153].