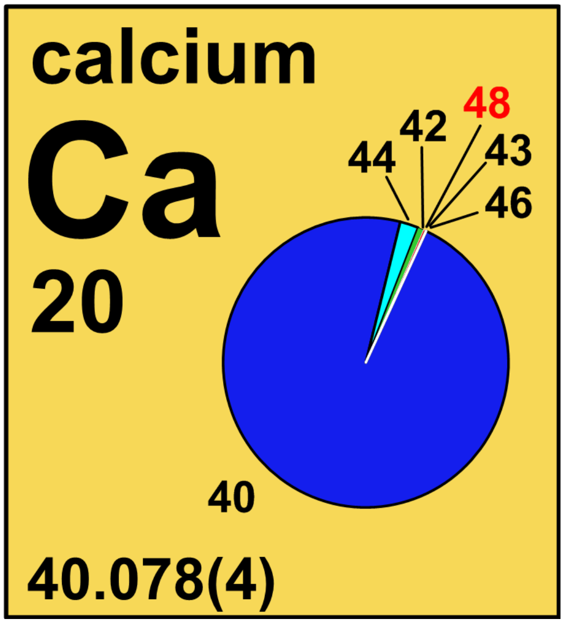
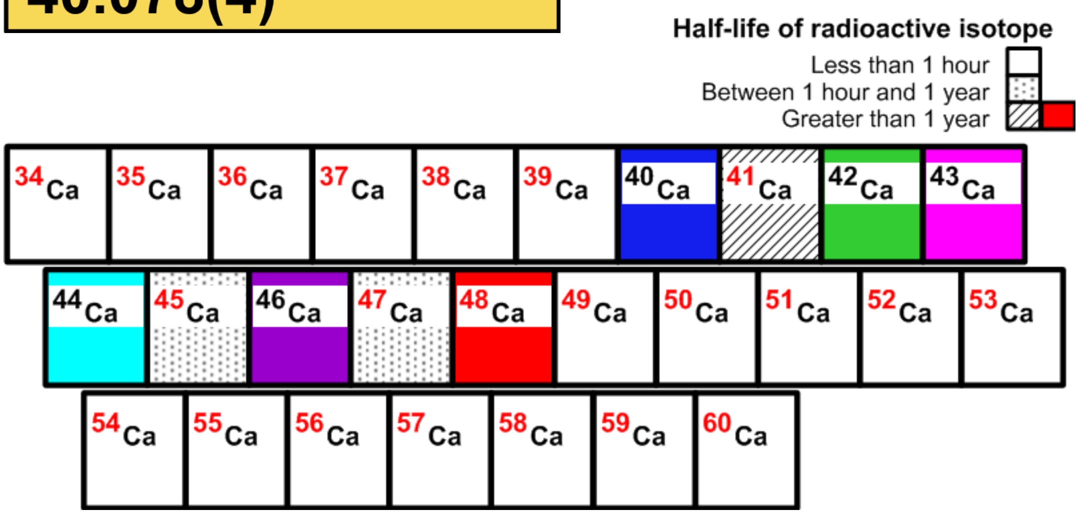
4.20 calcium



Stable isotope	Relative atomic mass	Mole fraction
^{40}Ca	39.962 5909	0.969 41
^{42}Ca	41.958 618	0.006 47
^{43}Ca	42.958 766	0.001 35
^{44}Ca	43.955 482	0.020 86
^{46}Ca	45.953 69	0.000 04
^{48}Ca†	47.952 5228	0.001 87

† **Radioactive isotope** having a very long **half-life** (4×10^{19} years) and a characteristic terrestrial **isotopic composition** that contributes significantly and reproducibly to the determination of the **standard atomic weight** of the **element** in **normal materials**.



4.20.1 Calcium isotopes in Earth/planetary science

Molecules, atoms, and ions of the **stable isotopes** of calcium possess slightly different physical and chemical properties, and they commonly will be fractionated during physical, chemical, and biological processes, giving rise to variations in **isotopic abundances** and in **atomic weights** (Figure 4.20.1). The **isotope-amount ratio** $n(^{44}\text{Ca})/n(^{40}\text{Ca})$ is used to quantify the calcium cycle (sources and sinks of calcium) in the ocean. Calcium **isotopes** fractionate (separate) in terrestrial and marine environments owing to biological and inorganic processes, which discriminate against heavy calcium isotopes. The calcification process controls the removal of calcium from the ocean, which is mostly balanced by hydrothermal and riverine calcium input. Calcium has a long **residence time** in seawater ($\tau_{Ca} \approx$ 1 to 2 million years) relative to the short mixing time of the global ocean (~1000 years), which has allowed the calcium **isotopic composition** of modern seawater to homogenize globally. This was likely the case in the geological past as well, which makes the $n(^{44}Ca)/n(^{40}Ca)$ ratio useful when quantifying the oceanic calcium cycle [179, 180]. The isotope-amount ratio $n(^{44}Ca)/n(^{40}Ca)$ has been used to trace sources of calcium in soil and river water [181]. The isotope-amount ratio $n(^{44}Ca)/n(^{40}Ca)$ ratio of calcium carbonate may serve as a paleothermometer to determine seawater temperatures in the past, making use of the temperature-dependent **isotopic fractionation** between ^{40}Ca and ^{44}Ca [182, 183].

The **radioactive isotope** ^{45}Ca (half-life of 1.63 days) is used to study calcium behavior in soils, detergents, water-purification systems, and glassy materials. ^{45}Ca is introduced into a system and monitored to measure various types of calcium responses within the system and to investigate how calcium of one matrix may interact with another (*i.e.*, calcium of soil mixing with that of fertilizers). ^{45}Ca has been used to investigate the transport of contaminants in groundwater through the unsaturated zone [184].

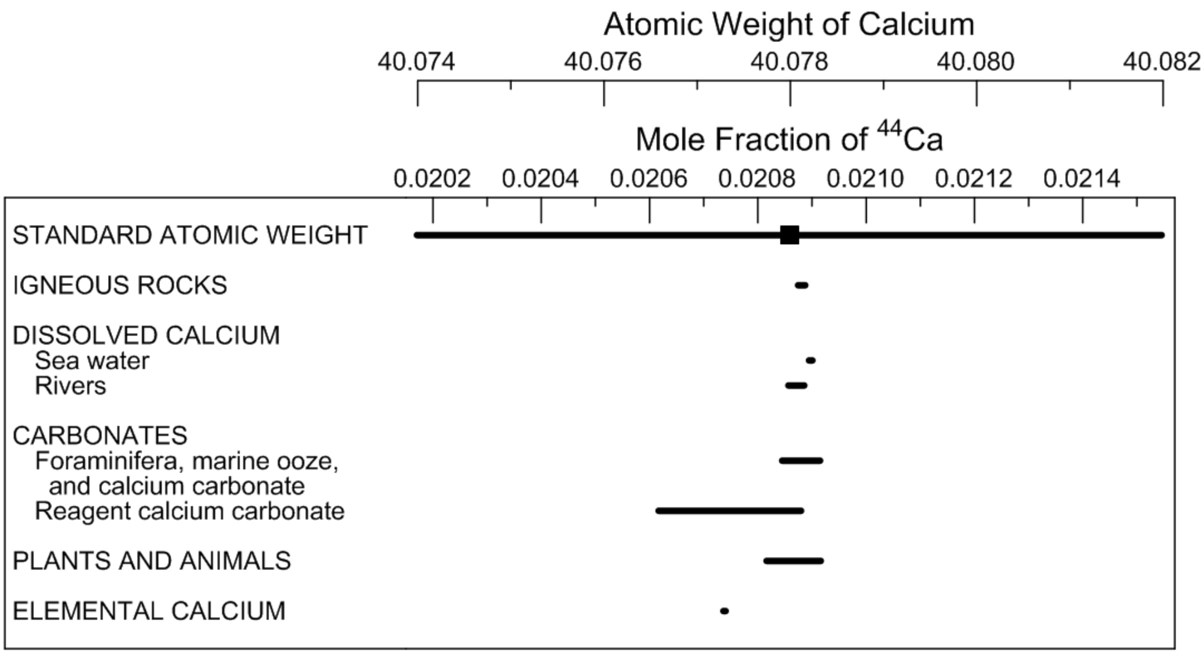


Fig. 4.20.1: Variation in **atomic weight** with **isotopic composition** of selected calcium-bearing materials (modified from [14]).

4.20.2 Calcium isotopes in medicine

Stable isotopes of calcium (^{42}Ca, ^{44}Ca, ^{46}Ca, and ^{48}Ca) and **radioisotopes** of calcium (^{45}Ca, with a half-life of 109 hours, and ^{47}Ca) can be used for tracing calcium uptake, utilization, and **excretion** in the body. For example, most of our knowledge on the efficiency by which calcium is absorbed in the intestine (bioavailability) comes from studies in which calcium in the diet was labeled with stable or radioactive isotopes. In such studies, the isotope-labeled food is ingested and fecal matter tested for the presence and quantity of unabsorbed isotope. When coupling oral ingestion of food labeled with one calcium isotope with an **intravenous** injection of a second calcium isotope, this technique can be used as a means to measure calcium absorption within the body by measuring excretion of both **tracers** in the urine. In a similar fashion, dietary absorption of magnesium and zinc can be studied [181, 185].

Stable and radioactive isotopes are used in biomedical research and clinical practice to study disorders associated with calcium **metabolism**, in particular in relation to bone health and calcium accumulation in body tissues (vascular calcification, kidney stone formation). Stable isotope tracers have been used successfully to study bone calcium balance during space-flight and in-bed-rest studies. A long-living calcium radioisotope (^{41}Ca), with a **half-life** of 9.9×10^4 years, has been used successfully for labeling of bone calcium to measure bone calcium turnover via urinary excretion of the tracer [186].

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