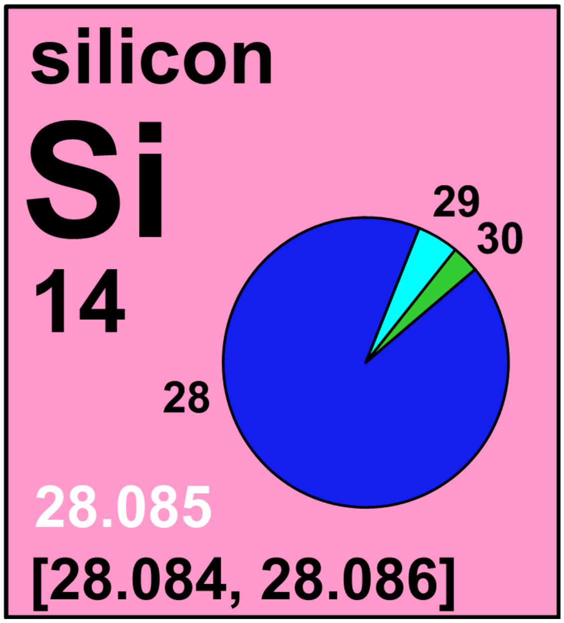
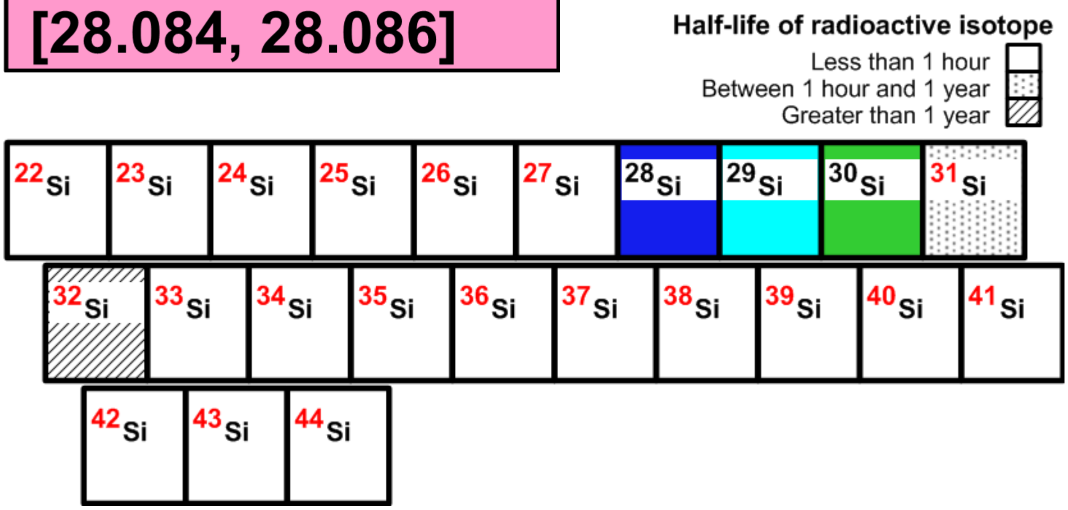
4.14 silicon



Stable isotope	Relative atomic mass	Mole fraction
^{28}Si	27.976 926 535	[0.921 91, 0.923 18]
^{29}Si	28.976 494 665	[0.046 45, 0.046 99]
^{30}Si	29.973 7701	[0.030 37, 0.031 10]



4.14.1 Silicon isotopes in Earth/planetary science

Because molecules, atoms, and ions of the **stable isotopes** of silicon 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 silicon in natural terrestrial materials (Figure 4.14.1). These variations are useful in investigating the origin of substances and studying environmental, hydrological, and geological processes [10, 14]. Diatoms, a major group of algae, need silicon to build up their opaline shells and prefer ^{28}Si while taking up $Si(OH)_4$, which is the biologically available form of silicon in the marine environment. This progressively enriches surface waters with ^{29}Si and ^{30}Si [120]. ^{32}Si-labeled silicic acid of high specific radioactivity is used to measure uptake rates of Si and estimate marine sedimentation of biogenic (created by living organisms) silica (by diatoms and sea shells). By performing uptake kinetic experiments, the ^{32}Si activity can be measured as ^{32}P using counting of Cherenkov radiation (radiation produced by charged particles passing through a medium at a speed greater than that of light through the same medium—after Soviet physicist Pavel A. Cherenkov) with a liquid scintillation analyzer (measuring **ionizing** radiation using the interaction of radiation on a material and counting the resulting **photon** emissions).

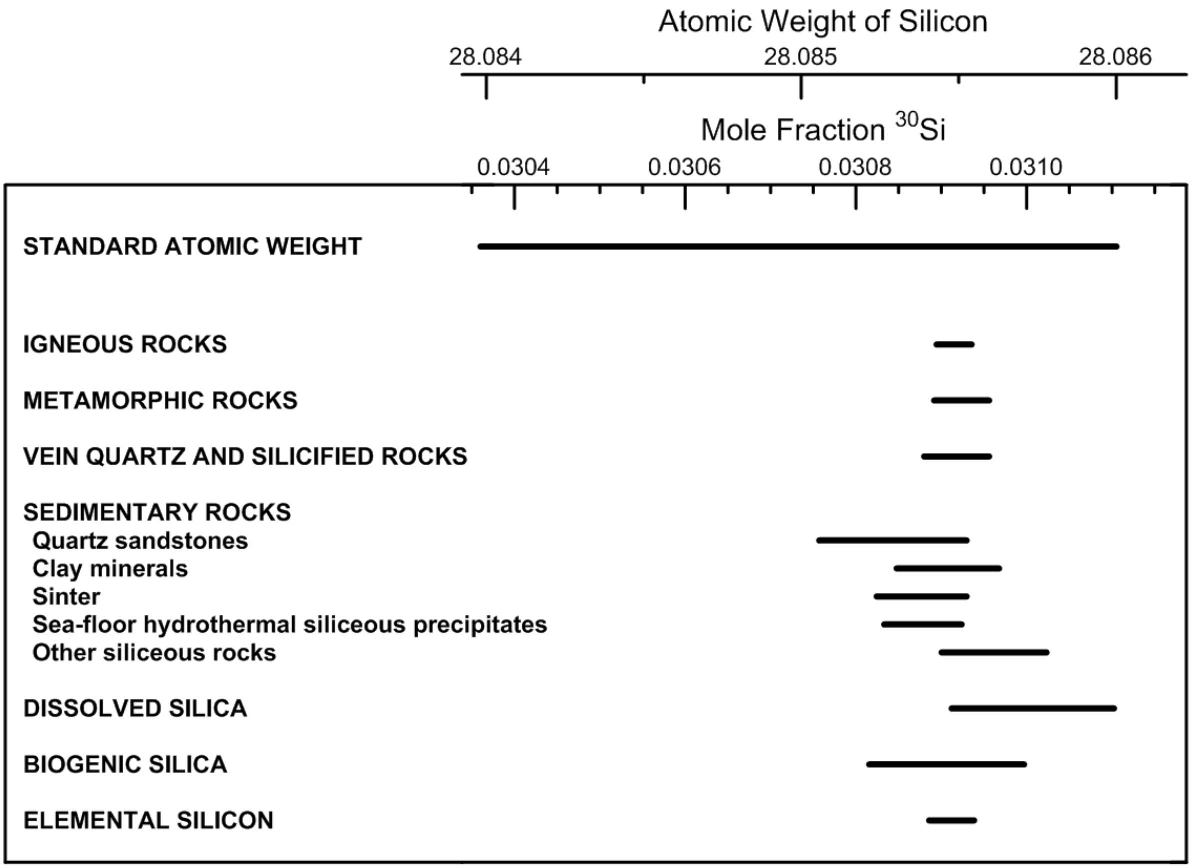


Fig. 4.14.1: Variation in **atomic weight** with **isotopic composition** of selected silicon-bearing materials (modified from [10, 14]).

4.14.2 Silicon isotopes in geochronology

Cosmogenic ^{32}Si has a **half-life** of about 150 years and is produced by **cosmic ray spallation** of argon in the stratosphere and **troposphere** [121]. ^{32}Si in dust is precipitated in snow, making it possible to date dust in snow and glacial ice (Figure 4.14.2). Glaciers are archives for global climate history because they contain a variety of proxies (imprints of past environmental conditions used to interpret paleoclimate) for climate forcing and climate response. Cosmogenic

^{32}Si that is stored in glaciers and ice-core samples can be analyzed using **accelerator mass spectrometry** to date when sections of glaciers formed [122, 123].

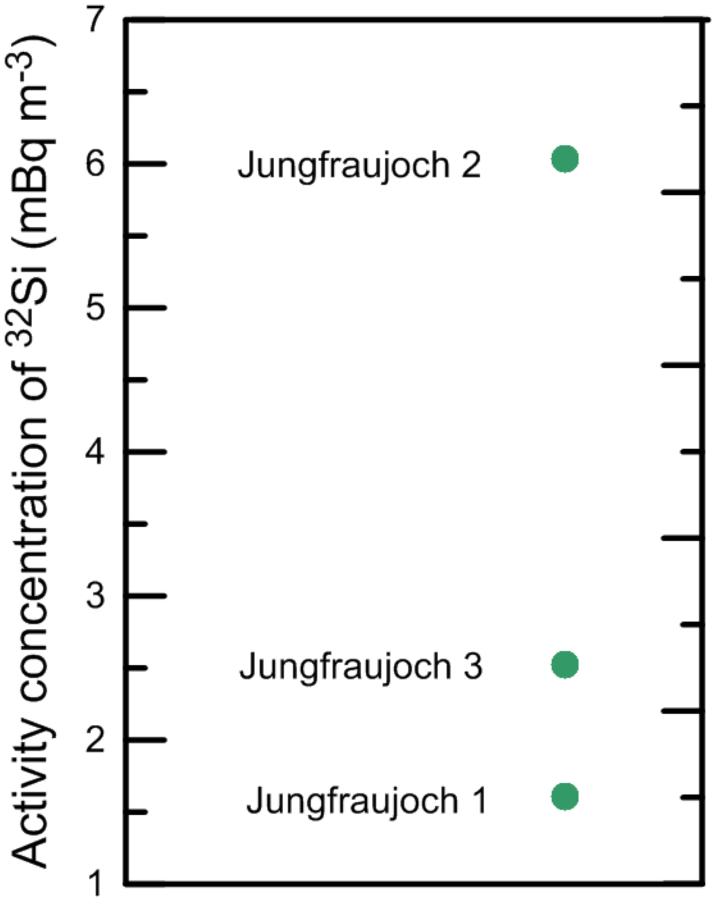


Fig. 4.14.2: ^{32}Si concentrations in three snow samples from Jungfraujoch, a glacial pass in the Bernese Alps at an elevation of approximately 3.5 km above sea level (modified from [124]). Sample Jungfraujoch 2 contains Saharan dust and has a substantially higher concentration of ^{32}Si than snow samples not containing Saharan dust.

4.14.3 Silicon isotopes in industry

At Keio University in Japan, the Itoh Research Group has developed a method that utilizes ^{29}Si to store and process information. The Itoh Research Group focused on manipulating the nanostructure of materials at an atomic level, especially with semiconductors such as silicon. Their manipulations and observations demonstrate that differences in the nuclear spin and mass of an isotope affects the ease of further manipulation of the isotope [125, 126].

Silicon crystals enriched to higher than 99.99 percent purity of ^{28}Si are being used in the Avogadro Project. This project is intended to remeasure the **Avogadro constant** (N_A), which is the proportionality factor between the amount of substance and number of elementary entities [127].