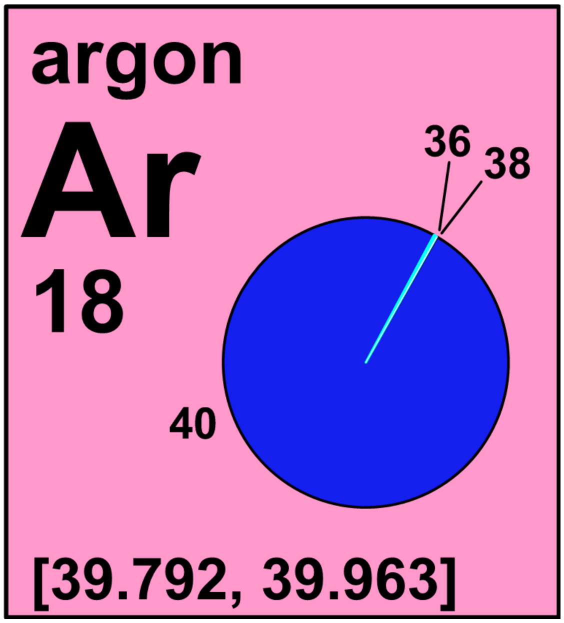
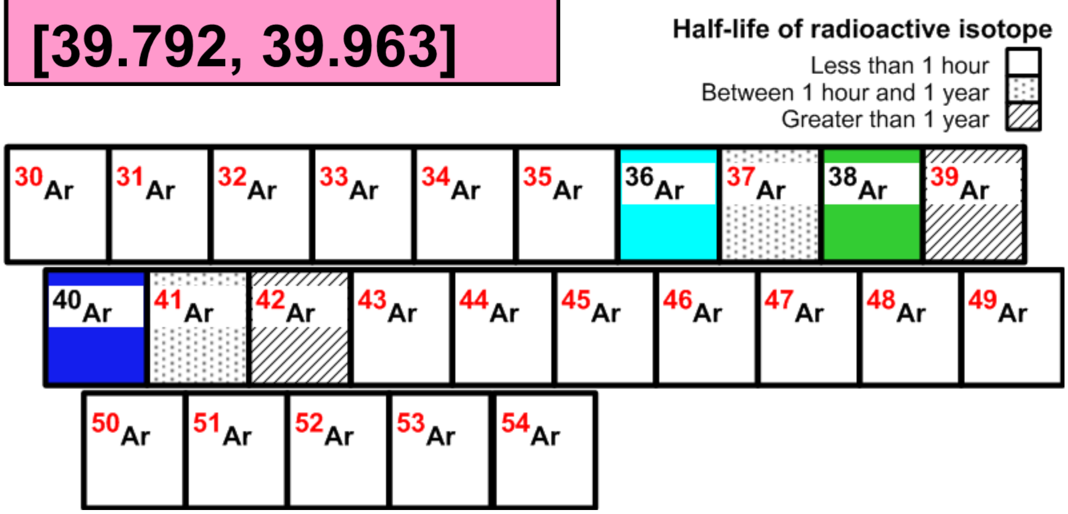
4.18 argon



Stable isotope	Relative atomic mass	Mole fraction
^{36}Ar	35.967 5451	[0.0000, 0.0208]
^{38}Ar	37.962 732	[0.0000, 0.0433]
^{40}Ar	39.962 383 12	[0.936, 1.000]



4.18.1 Argon isotopes in Earth/planetary science

Argon's chemically inert properties and three stable isotopes make it an ideal **tracer** of Earth processes [98, 154-164]. Measurements and models of the **isotope-amount ratio** $n(^{40}\mathrm{Ar})/n(^{36}\mathrm{Ar})$ can provide insights about the evolution of the atmosphere and orogenic (mountain-building) history of the Earth. Comparison of results from the potassium-argon and $n(^{40}\mathrm{Ar})/n(^{39}\mathrm{Ar})$ isotope-amount-ratio dating methods with results from other dating methods has been used to study temperature histories of rocks through differences in apparent ages caused by excess argon or partial argon gas loss. The isotope-amount ratio $n(^{40}\mathrm{Ar})/n(^{36}\mathrm{Ar})$ of dissolved argon in groundwater can provide hydrologic information, such as rates of crustal degassing and relative groundwater age. ^{38}Ar produced by **cosmic-ray** bombardment of rocks and soils at Earth's surface can provide information about surface exposure history and erosion rate.

4.18.2 Argon isotopes in geochronology

Argon **isotopes** are used to date rock samples, especially volcanic rocks, using two related techniques (Figure 4.18.1) [98, 165-167].

a. The first technique is potassium-argon dating (K-Ar), which is based on the decay of radioactive ^{40}K to stable ^{40}Ar. By comparing the concentrations of potassium and ^{40}Ar in a sample, it is possible to determine how long the sample has been accumulating **radiogenic** ^{40}Ar to determine the "age" of the sample. The **half-life** of ^{40}K is approximately 1.25×10^9 years, making this a useful tool for dating rocks range in age from about 10^6 to 10^9 years.
b. A modification of the potassium-argon dating technique is the $n(^{40}Ar)/n(^{39}Ar)$ isotope-amount-ratio technique, in which a sample is irradiated in a nuclear reactor to produce ^{39}Ar from ^{39}K. The isotope-amount ratio $n(^{40}Ar)/n(^{39}Ar)$ is then determined, and from this, the approximate age of the rock can be calculated (Figure 4.18.2).

The study of ^{37}Ar (half-life of 35 days), ^{39}Ar (half-life of 268 years), and ^{40}Ar concentrations in groundwater can provide information about the production and release of these isotopes from rocks and other sources into groundwater and the relative ages of different groundwaters [156, 161, 162, 168-170].

Fig. 4.18.1: Studying the ratios of argon isotopes can provide insight into the origins and movement of magma and the ages of volcanic rock. ^{40}Ar begins increasing in concentration once lava has solidified. (Image Source: U.S. Geological Survey Hawaiian Volcano Observatory, Kilauea) [171].

Fig. 4.18.2: The U. S. Geological Survey $^{40}Ar/^{39}Ar$ geochronology laboratory in Denver, Colorado uses a custom-built argon extraction line connected to a Mass Analyzer Products (MAP) 215-50 **mass spectrometer** with a differentially pumped dual laser setup. (U.S. Geological Survey $^{40}Ar/^{39}Ar$ Geochronology Laboratory) [172].

4.18.3 Argon isotopes in industry

^{38}K (half-life of 7.6 minutes), which is produced by the reactions ^{38}Ar (p, n) ^{38}K and ^{40}Ar (n, 3n) ^{38}K, is a widely used blood-flow tracer. Because ^{38}Ar is more expensive, ^{40}Ar, which also offers many additional advantages as a target, is more commonly used to produce ^{38}K for medical purposes [173, 174]. ^{41}Ar (half-life of 1.82 hours) is used as an industrial gas-flow tracer to help track the movement of gases because its inert properties, half-life, and **gamma radiation** make it well suited for this purpose [174].