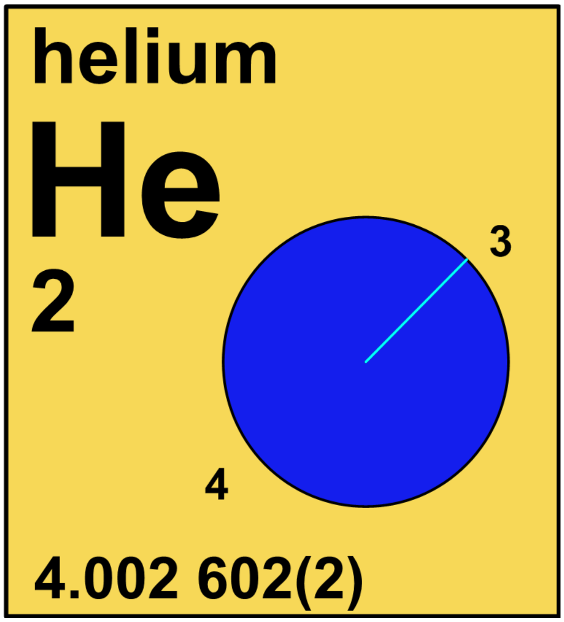
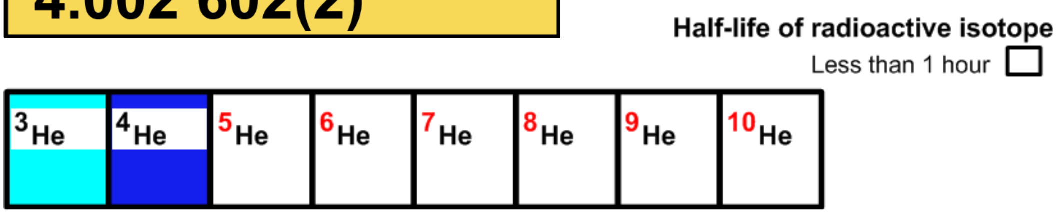
4.2 helium



Stable isotope	Relative atomic mass	Mole fraction
^{3}He	3.016 029 32	0.000 002
^{4}He	4.002 603 2541	0.999 998



4.2.1 Helium isotopes in geochronology

^{3}He is a product of **radioactive decay** of ^{3}H (**half-life** of 12.31 years). The relative variations in the **mole ratio** $n(^{3}\text{He})/n(^{3}\text{H})$ can be interpreted in terms of elapsed time. This has been especially useful in aquatic systems including oceans, lakes, and aquifers that received large inputs of ^{3}H from precipitation following **thermonuclear bomb** test periods. ^{3}H-^{3}He dating provides elapsed time since a water mass became isolated from the atmosphere, in the time range from the mid-1950s to the present. Such studies are important for establishing the sustainability of groundwater resources in shallow aquifers [24, 25].

^{4}He is a product of radioactive decay in the uranium and thorium decay series. As a result, ^{4}He concentration is used to estimate the relative ages of minerals and groundwater. In closed systems (systems that do not exchange matter with their surroundings), relative variations in the **mole ratio** $n(^{4}\text{He})/n(\text{U})$ can be interpreted in terms of elapsed time, although other processes can alter the distribution of helium, which is highly mobile in terrestrial environments [26, 27].

^{4}He concentrations commonly increase along groundwater flow paths through cumulative release from aquifer materials. This rate of accumulation is used to estimate the time since groundwater was recharged at the surface. The ^{4}He accumulation method of groundwater dating typically is used in deeper aquifers where groundwater is relatively old and the ^{3}H-^{3}He method cannot be used because of the relatively short half-life of 12.31 years for ^{3}H [27].

4.2.2 Helium isotopes in industry

^{3}He has a large **absorption cross section** for **neutrons**, which makes it especially useful for radioactivity detection [28, 29]. In this application, neutrons produced by radioactive decay of **elements**, such as uranium and plutonium, enter the detector where the reaction ^{3}He (n, p) ^{3}H produces ^{1}H and ^{3}H atoms. This induces further collisions and release of **electrons**, which interact with charged surfaces to generate an electric current. Large amounts of ^{3}He are used to produce neutron detectors in portal monitors for detecting illicit radioactive materials at ports, border crossings, and airports (Figure 4.2.1), but unfortunately, the **isotope** ^{3}He is rare and there is a need to incorporate alternative gases for use in neutron detectors. ^{3}He neutron detectors are also used in devices that determine proportions of water, oil, and gas in wells drilled for energy production. Other important uses of ^{3}He include lasers, gyroscopes used for missile stability and guidance, and cryogenic research (ultra-low temperature, less than 1 K).

The global supply of ^{3}He available for research and practical applications has become severely limited in recent years such that prices have increased substantially and some uses have been curtailed [28, 29]. A major source of ^{3}He is recovered from nuclear weapons containing ^{3}H when the warheads are reconditioned or dismantled. ^{3}He accumulates in such devices as a **radiogenic** product of ^{3}H decay. The annual supply of new ^{3}He has decreased with reductions in nuclear arsenals.

Fig. 4.2.1: Radiation detectors are installed in many areas to screen people, vehicles, and cargo for radioactive materials. ^{3}He detectors are sensitive to **thermal neutrons** and are used to detect isotopes of uranium and plutonium that might be used in nuclear weapons along with other sources that produce **neutrons** by **radioactive decay**. (Image Source: U.S. Government Accountability Office) [30].

4.2.3 Helium isotopes in medicine

^{3}He is used as an inhalant to improve **magnetic resonance imaging** (MRI) of the lungs [31].