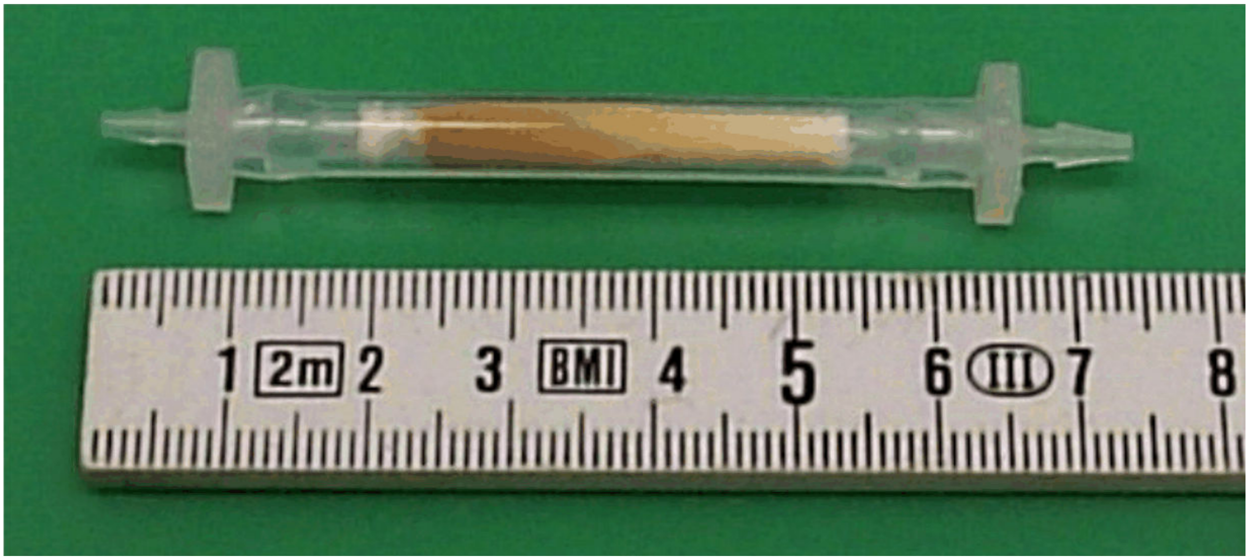
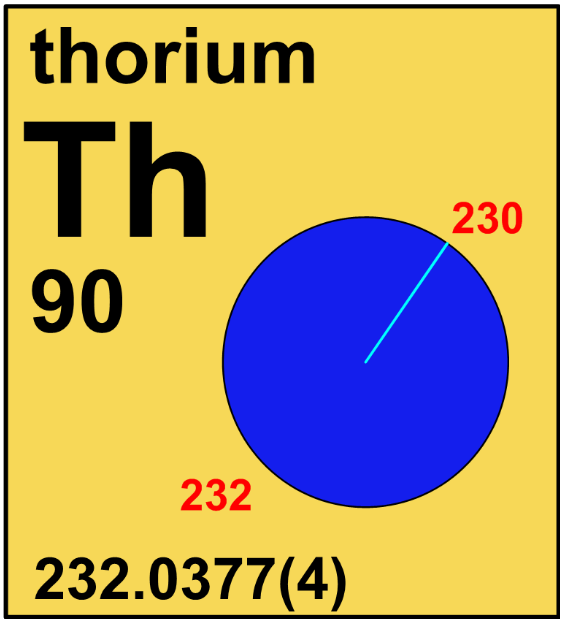


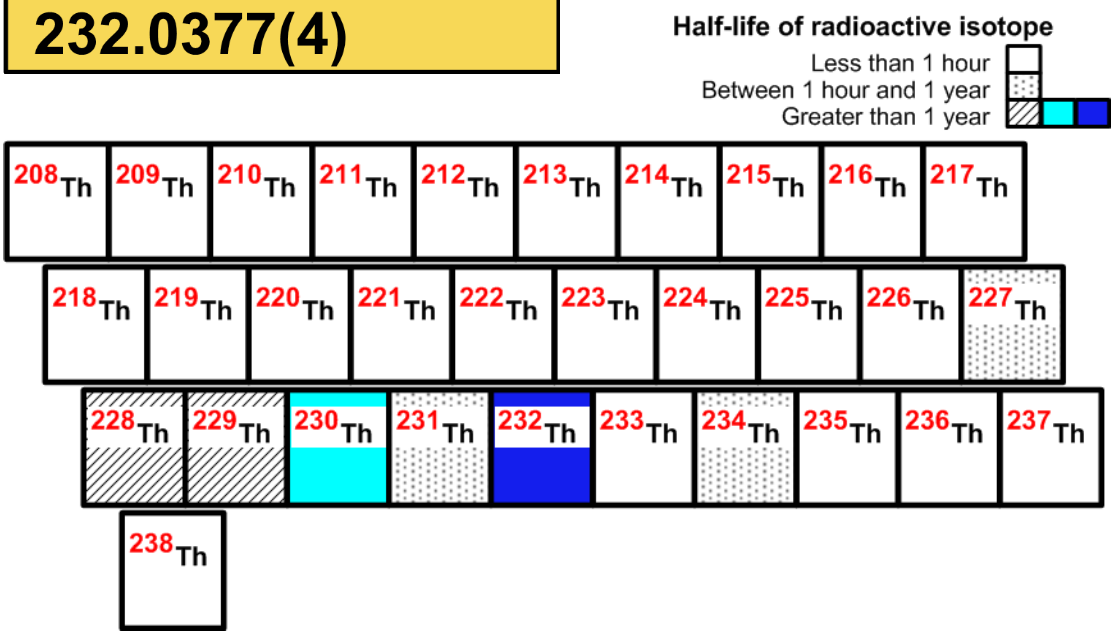

**Fig. 4.89.2:** Institute for Transuranium Elements (ITU) Standard $^{225}Ac/^{213}Bi$ Radionuclide Generator. Image kindly provided by Dr. Alfred Morgenstern, European Commission, Joint Research Centre – Institute for Transuranium Elements, Karlsruhe, Germany.

## 4.90 thorium




| Stable isotope | Relative atomic mass | Mole fraction |
|---|---|---|
| $^{230}Th^{\dagger}$ | 230.033 13 | 0.0002 |
| $^{232}Th^{\dagger}$ | 232.038 06 | 0.9998 |

† **Radioactive isotope** having a relatively long **half-life** 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**. Half-lives of $^{230}$Th and $^{232}$Th are $7.56 \times 10^4$ years and $1.40 \times 10^{10}$ years, respectively.




### 4.90.1 Thorium isotopes in Earth/planetary science

$^{234}$Th (with a half-life of 24 days) has been used as a **tracer** for estimating the flux of organic carbon in the ocean (Figure 4.90.1) [586, 587]. $^{234}$Th has been used for estimating the **residence time** of suspended particulate matter (SPM) in water columns [586].

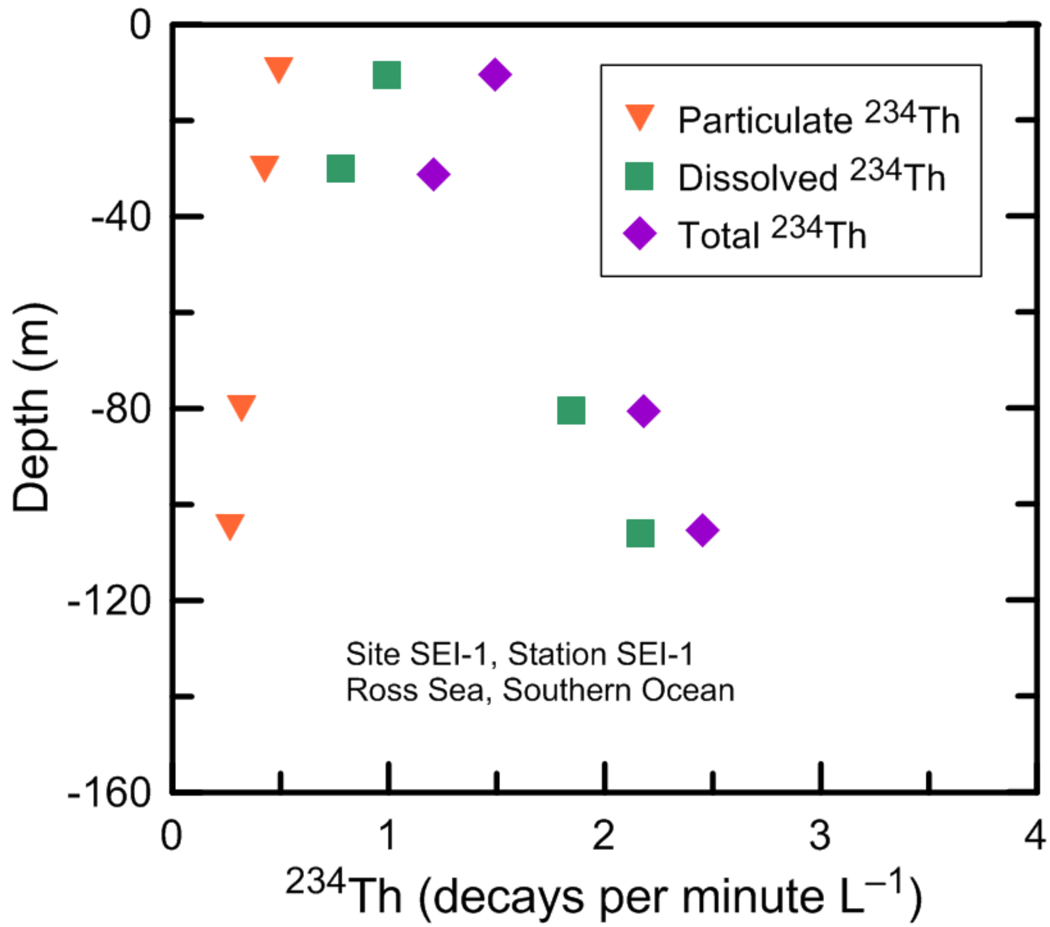



**Fig. 4.90.1:** Particulate, dissolved and total $^{234}$Th in water column profiles in the Ross Sea, Southern Ocean (modified from [587]).

### 4.90.2 Thorium isotopes in geochronology

The decay of $^{232}$Th to $^{208}$Pb is used to date rocks based on the accumulation of the stable **daughter product** $^{208}$Pb. The half-lives of the **isotopes** between the **parent radionuclide** $^{232}$Th and stable endpoint $^{208}$Pb all have much shorter half-lives than thorium. Therefore, the amount of $^{208}$Pb that accumulates in a sample is determined primarily by the amount of $^{232}$Th parent radionuclide present when the mineral was formed and the time that has elapsed since the mineral solidified [588].

Another dating method, the $^{230}$Th/$^{234}$U method, is based on the hypothesis that the sample contains uranium, but no $^{230}$Th at the time of its formation. Then, the age of the specimen is determined mainly by the amount of $^{230}$Th in the specimen. Reliable ages with this method range from several thousand to approximately 350 thousand years [289].

### 4.90.3 Thorium isotopes in industry

The most precise time and frequency measurements are performed with optical atomic clocks that use as a frequency standard the optical frequency generated as electrons change energy levels. It has been proposed that a nuclear clock, using a nuclear transition could outperform an electron transition. The **metastable isotope**, $^{229m}Th$, with a half-life of 13.9 hours, has been confirmed as a possible candidate for a nuclear clock [589]. The further development of a nuclear frequency standard will require more precise determinations of the energy and **half-life** of the isomer.