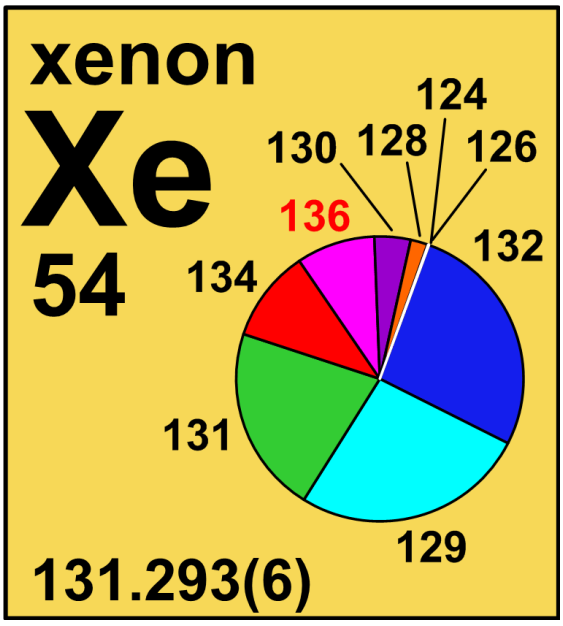
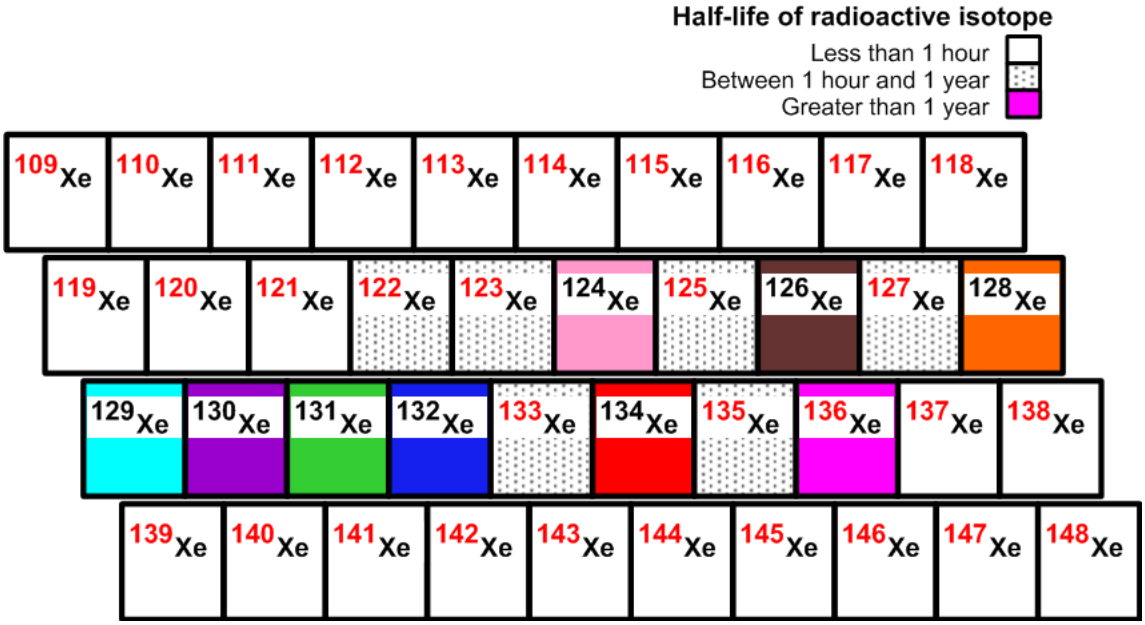
4.54 xenon



Stable isotope	Relative atomic mass	Mole fraction
^{124}Xe	123.905 89	0.000 95
^{126}Xe	125.904 30	0.000 89
^{128}Xe	127.903 531	0.019 10
^{129}Xe	128.904 780 86	0.264 01
^{130}Xe	129.903 5094	0.040 71
^{131}Xe	130.905 084	0.212 32
^{132}Xe	131.904 155 09	0.269 09
^{134}Xe	133.905 395	0.104 36
^{136}Xe†	135.907 214 48	0.088 57

† **Radioactive isotope** having a relatively long **half-life** (2.3×10^{21} 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**.



4.54.1 Xenon isotopes in forensic science and anthropology

Radiogenic xenon **isotopes** are produced by nuclear reactions in atomic bombs and nuclear reactors. For example, ^{131}Xe, ^{133}Xe, and ^{135}Xe are some of the **fission** products of ^{235}U and ^{239}Pu, and finding these isotopes would be evidence of a nuclear bomb reaction. Measurements of

xenon isotopes (e.g., in the atmosphere or the subsurface) have been used to identify contamination from these sources, for example, to detect faults in nuclear reactors or to monitor compliance with nuclear test bans (Figure 4.54.1) [393].

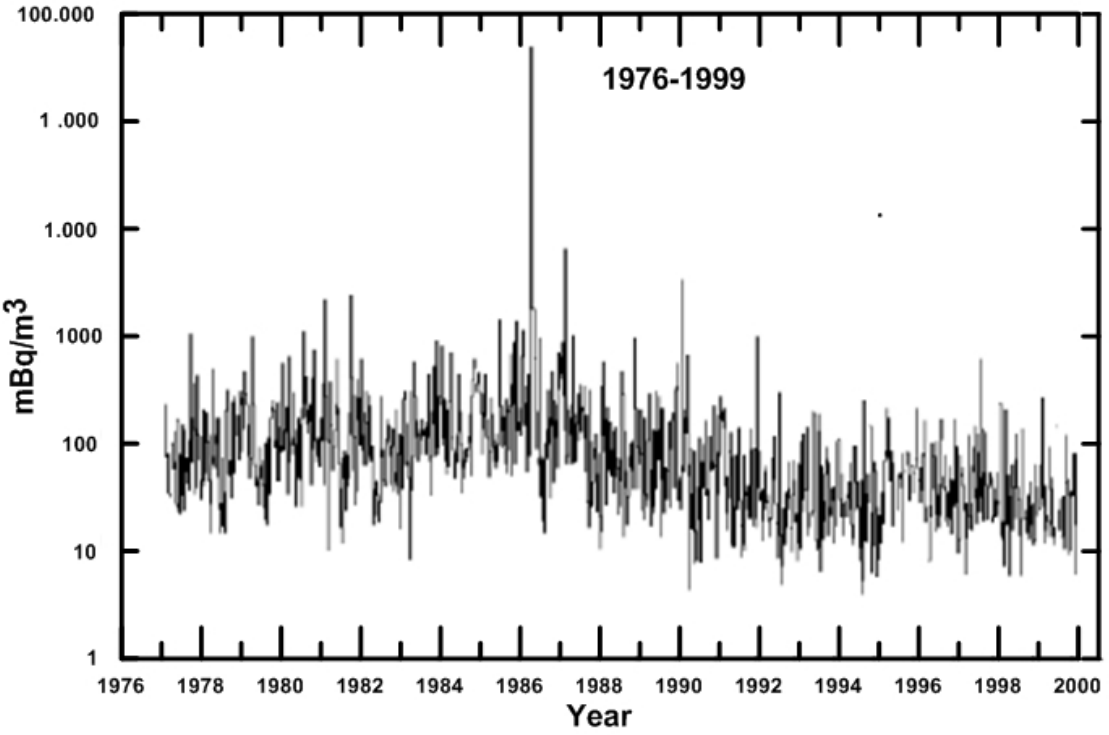


Fig. 4.54.1: The ^{133}Xe time series in air at Freiburg, Germany, between 1976 and 1999. The record indicates persistent low levels of **anthropogenic** ^{133}Xe that are generally attributable to normal acceptable releases from nuclear power plants with variability related in part to multiple sources and changing wind patterns. A major spike occurred in 1986 during the Chernobyl reactor accident in the Ukraine region of the former USSR. The **half-life** of ^{133}Xe (5.2 days) is sufficiently long for it to escape from its source and be distributed in air near the source, but sufficiently short that long-term background levels are very low. Records such as this also can be used to detect undocumented nuclear explosions. (Modified from [393]).

4.54.2 Xenon isotopes in geochronology

The **stable isotopes** of xenon hold many clues about the formation of the **elements**, solar-system history, and Earth processes [26, 98]. For example, ^{129}Xe has been used as a detector of "extinct" **radionuclides**. Some ^{129}Xe is radiogenic as a result of being produced by the **radioactive decay** of ^{129}I (**half-life** = 1.7×10^7 years). Because the half-life of ^{129}I is much smaller than the age of the Earth, **primordial** ^{129}I (i.e., that which was present at the beginning of Earth's history) is essentially gone after it decayed to ^{129}Xe over geologic time. This means that radiogenic ^{129}Xe could be a marker of the former existence of the "extinct" isotope ^{129}I. Because primordial ^{129}I

was produced largely in **supernovae**, detection of radiogenic ^{129}Xe in **meteorites** and terrestrial samples also implies that the time elapsed between ^{129}I **supernova nucleosynthesis** and planetary condensation was short compared to the subsequent history of the Solar System. The many isotopes and reaction mechanisms of xenon have contributed numerous insights into Earth processes through the study of "xenology" (xenon isotopic variations used as geodynamic **tracers** to study the dynamics of the Earth) [394].

4.54.3 Xenon isotopes in medicine

Xenon isotopes are used in numerous ways to investigate the movement of inhaled gases in lungs and other parts of the body. If **radioactive isotopes** of xenon [^{127}Xe (with a half-life of 0.1 year), ^{133}Xe, and hyperpolarized (having non-equilibrium alignment of nuclear spins, suitable for magnetic resonance) ^{129}Xe] are inhaled, they can be tracked throughout the body by externally monitoring their **decay products** using magnetic resonance microscopy (high resolution magnetic resonance imaging (MRI) at microscopic [nanometer] levels) (Figure 4.54.2). This imaging technique is used to assess how well oxygen is taken up and transported by the blood [395].

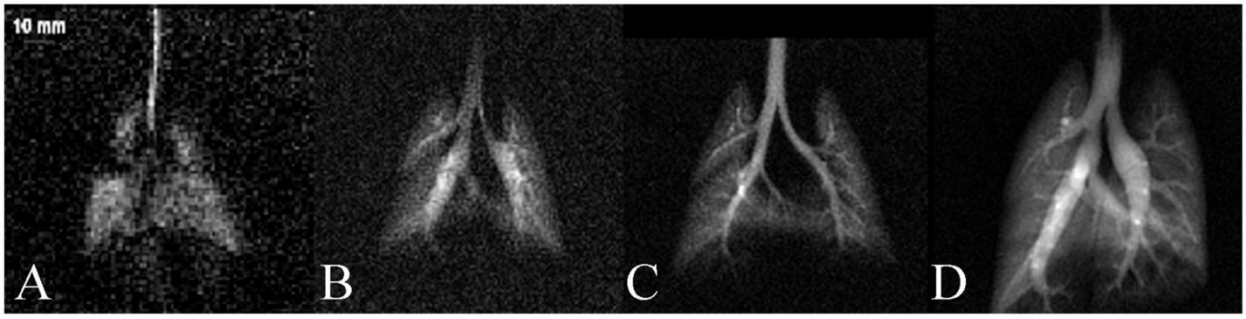


Fig. 4.54.2: Xenon ventilation imaging has progressed greatly since first being used in 1998. One of the first ^{129}Xe images (A) has been enhanced by improving polarization, gas delivery technology, and magnetic resonance (MR) acquisition strategies. The standard ^{129}Xe image (D) is further improved in image quality through improving polarization, gas delivery technology, and MR acquisition strategies. (Image source: Driehuys and Hedlund, 2007, © Sage Publications) [395].

4.54.4 Xenon isotopes used as a source of radioactive isotope(s)

^{124}Xe is used in the production of **radioisotopes** ^{123}I and ^{125}I (with half-lives of 0.55 day and 59 days, respectively) via the reactions ^{124}Xe (n, n p) ^{123}I and ^{124}Xe (n, γ) ^{125}I, respectively, which are used in diagnostic procedures and cancer treatment, respectively [395].