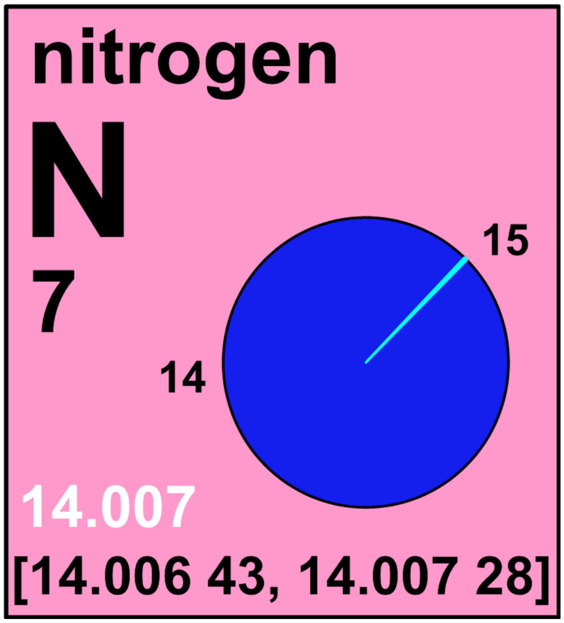
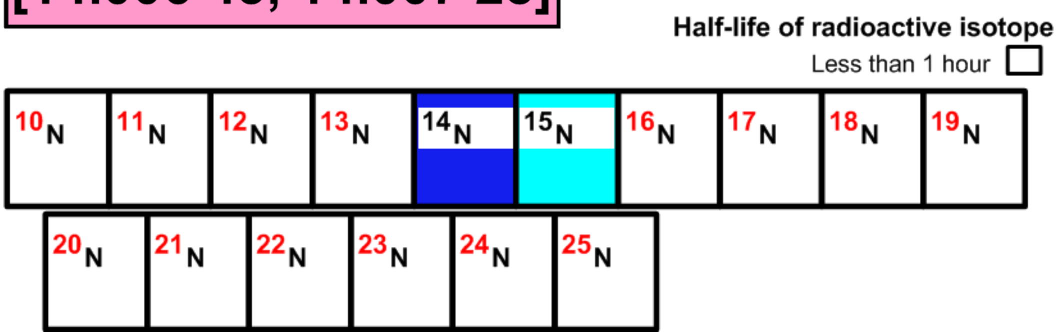
4.7 nitrogen



Stable isotope	Relative atomic mass	Mole fraction
^{14}N	14.003 074 004	[0.995 78, 0.996 63]
^{15}N	15.000 108 899	[0.003 37, 0.004 22]



4.7.1 Nitrogen isotopes in biology

Isotopic fractionation can cause the **isotope-amount ratio** $n(^{15}N)/n(^{14}N)$ to increase systematically through food chains through assimilation of nitrogen compounds in biomolecules such as proteins. When lower-order organisms are ingested by higher-order organisms, ^{15}N may be selectively retained and ^{14}N may be selectively excreted such that higher-order organisms tend to have higher $n(^{15}N)/n(^{14}N)$ ratios than their food sources. Isotopic fractionation occurs as a result of assimilation, storage, and **excretion** of proteins and other nitrogen compounds. Biologists can use isotope-amount ratio $n(^{15}N)/n(^{14}N)$ measurements to test hypotheses about predator-prey relations and detect disruptions to trophic structure of ecosystems that might be caused by toxic contaminants, invasive species, or harvesting of organisms. Similar principles are used to detect differences in diets among animals, including humans, both today and in the distant past [76-78].

Artificially enriched ^{15}N **tracers** are used to study movement and transformation of nitrogen in biological and environmental systems, such as the uptake and loss of nitrogen fertilizers by crops (Figure 4.7.1). A common experiment involves introducing an **isotopically**

labeled compound into the environment and then analyzing various samples taken from the environment for the presence of the enriched **isotope** to determine where the labeled compound moved and whether it transformed into other compounds (Figure 4.7.2). Artificially enriched ^{15}N is used to study uptake and dispersal of nitrogen in feed supplies used in food production industries such as aquaculture [79].

Fig. 4.7.1: Variation in nitrogen **stable isotopes** has been used to track fertilizer nitrogen into plants, soils, and infiltrating groundwater in experiments to improve agricultural efficiency and reduce impacts on the environment. This aerial photograph shows experimental agricultural fields where different amounts of excess nitrogen from fertilizer and plant residues can be found in groundwater. (Photo Source: Böhlke, J.K., U.S. Geological Survey).

Fig. 4.7.2: Tracer experiments with the **stable isotope** ^{15}N have been used to track excess dissolved nitrate in groundwater and streams and to determine to what extent the dissolved nitrate is removed by natural processes, such as conversion to harmless N_2 gas before entering nitrogen-sensitive ecosystems [80]. (Photo Source: Böhlke, J.K., U.S. Geological Survey).

4.7.2 Nitrogen isotopes in Earth/planetary science

The **stable isotopes** of nitrogen are subject to isotopic fractionation by physical, chemical, and biological processes. Variations in the isotope-amount ratio $n(^{15}N)/n(^{14}N)$ are substantial (Figure 4.7.3) and commonly are used to study Earth-system processes, especially those related to biology because nitrogen is a major nutrient for growth [81]. For example, isotope fractionation occurs when dissolved solutes, such as nitrate (NO_3^-), are transformed to more reduced compounds (*i.e.*, nitrogen gas) because nitrate with higher ^{14}N abundances tends to be more readily broken down. This leaves the residual unreacted nitrate with a higher $n(^{15}N)/n(^{14}N)$ ratio than the initial ratio prior to reaction. Changes in the **isotopic composition** of biologically reactive compounds can be used to detect such reactions in aquatic environments, which are important mechanisms for removing reactive contaminants like nitrate [82, 83].

Variations in the isotope-amount ratio $n(^{15}N)/n(^{14}N)$ are used to determine sources of nitrogen contamination in the atmosphere, oceans, groundwater, and rivers, where the isotopic composition of a contaminant molecule preserves evidence of the nitrogen sources and processes involved in its creation. An example is nitrate derived from artificial fertilizer, manure, power-plant emissions, or natural sources [84-86].

Artificially enriched ^{15}N tracers have been used to determine rates of movement and natural remediation of nitrogen-bearing contaminants in aquifers and rivers [80, 87].

4.7.3 Nitrogen isotopes in forensic science and anthropology

Stable hydrogen, carbon, and nitrogen isotopic compositions are used to determine the origin of pseudoephedrine from seized methyl-amphetamine made from the pseudoephedrine (drug used as a nasal decongestant or as a stimulant) [88].

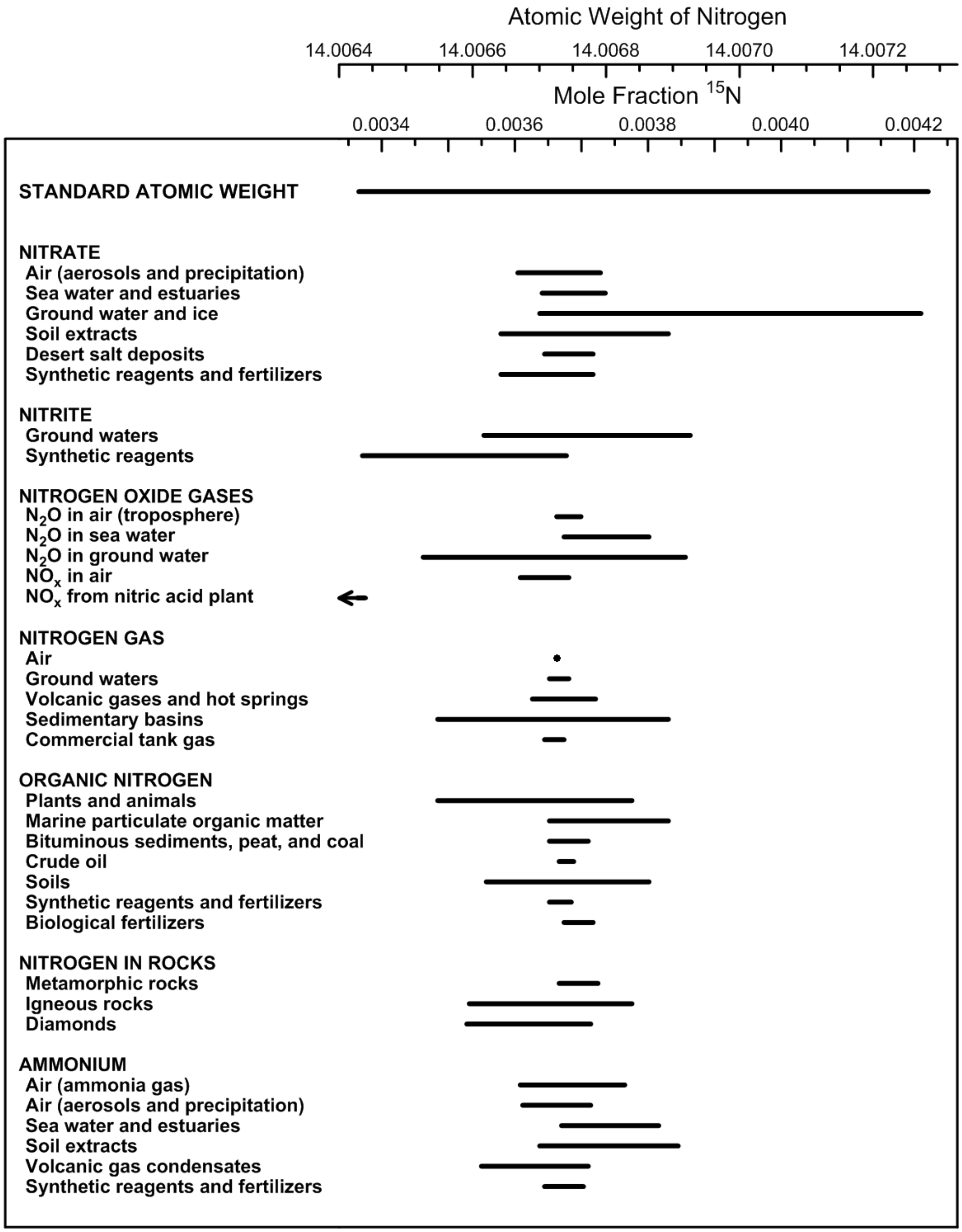


Fig. 4.7.3: Variation in **atomic weight** with **isotopic composition** of selected nitrogen-bearing materials (modified from [10, 14]).