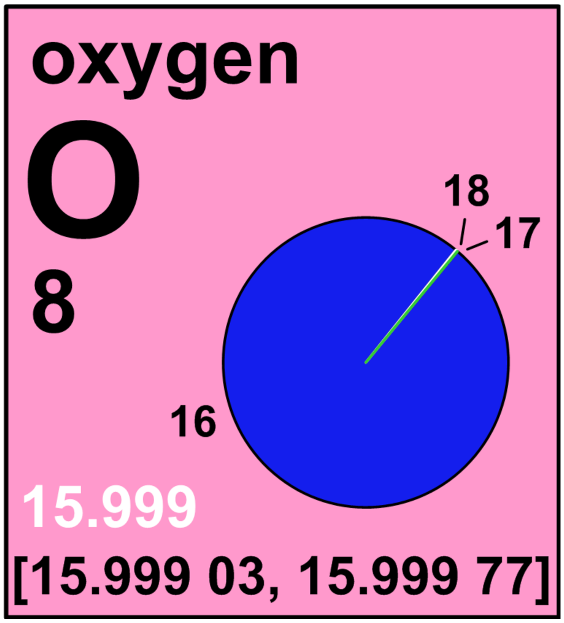
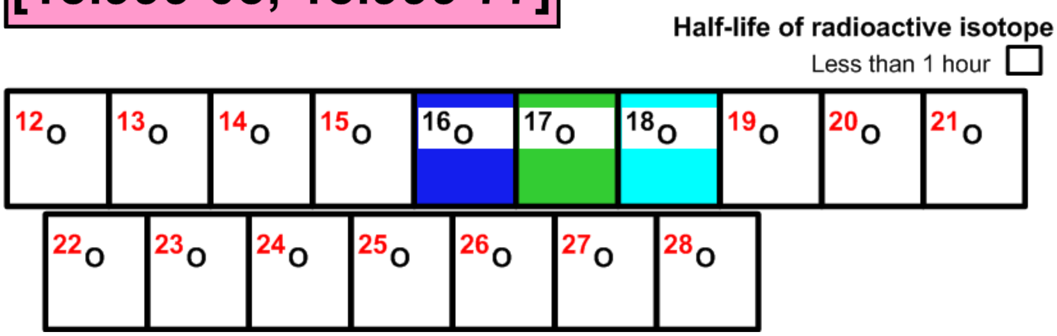
4.8 oxygen



Stable isotope	Relative atomic mass	Mole fraction
^{16}O	15.994 914 620	[0.997 38, 0.997 76]
^{17}O	16.999 131 757	[0.000 367, 0.000 400]
^{18}O	17.999 159 613	[0.001 87, 0.002 22]



4.8.1 Oxygen isotopes in Earth/planetary science

Molecules, atoms, and ions of the **stable isotopes** of oxygen possess slightly different physical and chemical properties, and they commonly will be fractionated during physical, chemical, and biological processes, giving rise to variations in **isotopic abundances** and in **atomic weights**. There are substantial variations in the isotopic abundances of oxygen in natural terrestrial materials (Figure 4.8.1). These variations are useful in investigating the origin of substances and studying environmental, hydrological, and geological processes [10].

A primary use of stable oxygen **isotopes** is in isotope hydrology. Although the evolution of the stable hydrogen and oxygen **isotopic composition** of precipitation begins with evaporation of water from the oceans, their local and global relationship arises primarily from equilibrium **isotopic fractionation** of heavier (^{2}H and ^{18}O) and lighter isotopes (^{1}H and ^{16}O) of hydrogen and oxygen during condensation as a **tropospheric** vapor mass follows a trajectory to higher latitudes and over continents [11, 12]. As a consequence, the isotopic composition and atomic weight of oxygen in precipitation, rivers, and tap waters varies with elevation, season, and distance from the ocean-continent boundary. Figure 4.8.2 shows the variation in stable oxygen isotopic composition of water from rivers across the United States. These variations in oxygen isotopic composition of environmental water are often combined with hydrogen isotopic compositions and have been used to identify the origin of water and to investigate the interaction between groundwater and surface water (e.g., lakes, streams, and rivers) [13].

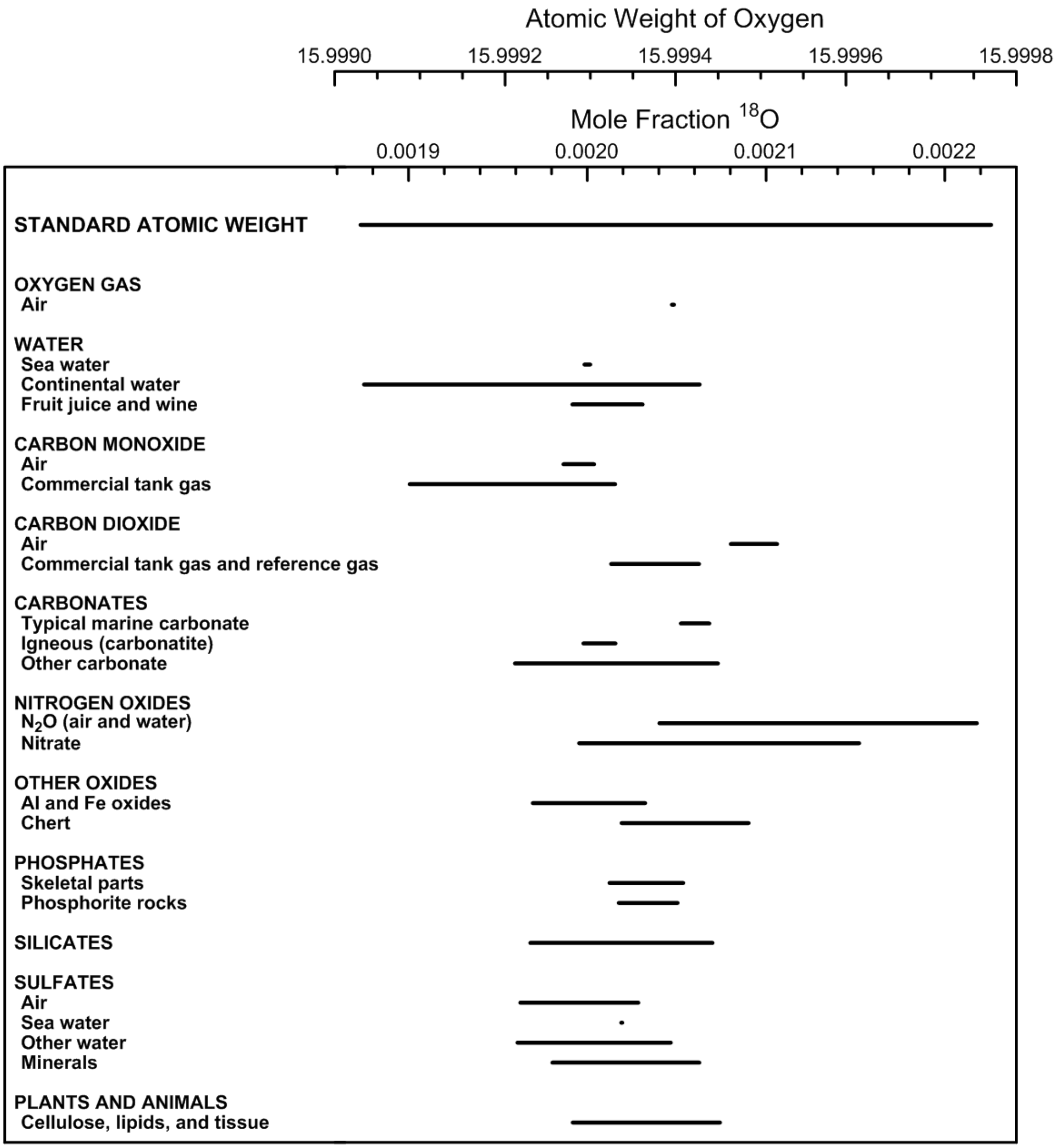


Fig. 4.8.1: Variation in **atomic weight** with **isotopic composition** of selected oxygen-bearing materials (modified from [10, 14]).

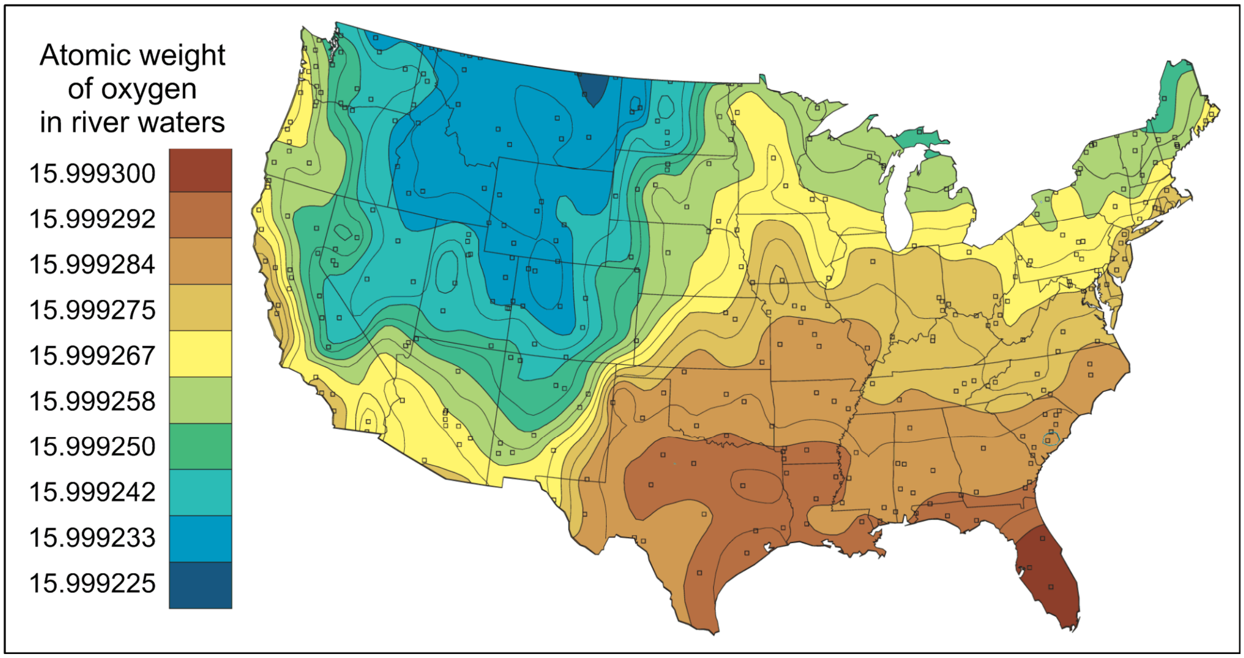


Fig. 4.8.2: Variation in atomic weight of oxygen in river waters across the continental United States (modified from [13]). Blue color indicates waters most depleted in ^{18}O (resulting in lower atomic weight of oxygen) and brown color indicates those most enriched in ^{18}O (resulting in higher atomic weight of oxygen).

4.8.2 Oxygen isotopes in forensic science and anthropology

Measurements of relative ^{18}O abundances have been used to determine the breeding grounds of many species of migrant songbirds. These species of songbirds only grow their feathers before migration, and they grow them on or close to their breeding grounds. Therefore, the isotopic composition of a bird's feathers correlates to the isotopic signature of the growing season's precipitation [16, 17].

Measurements of relative ^{18}O abundances of human hair or nail samples collected at archeological sites have been used to determine the geographic region in which a subject lived based on the oxygen isotopic composition of the water they drank (Figure 4.8.3). This is possible because hair stores a daily record of oxygen isotopic composition of intake water, which correlates to local **meteoric water** [89].

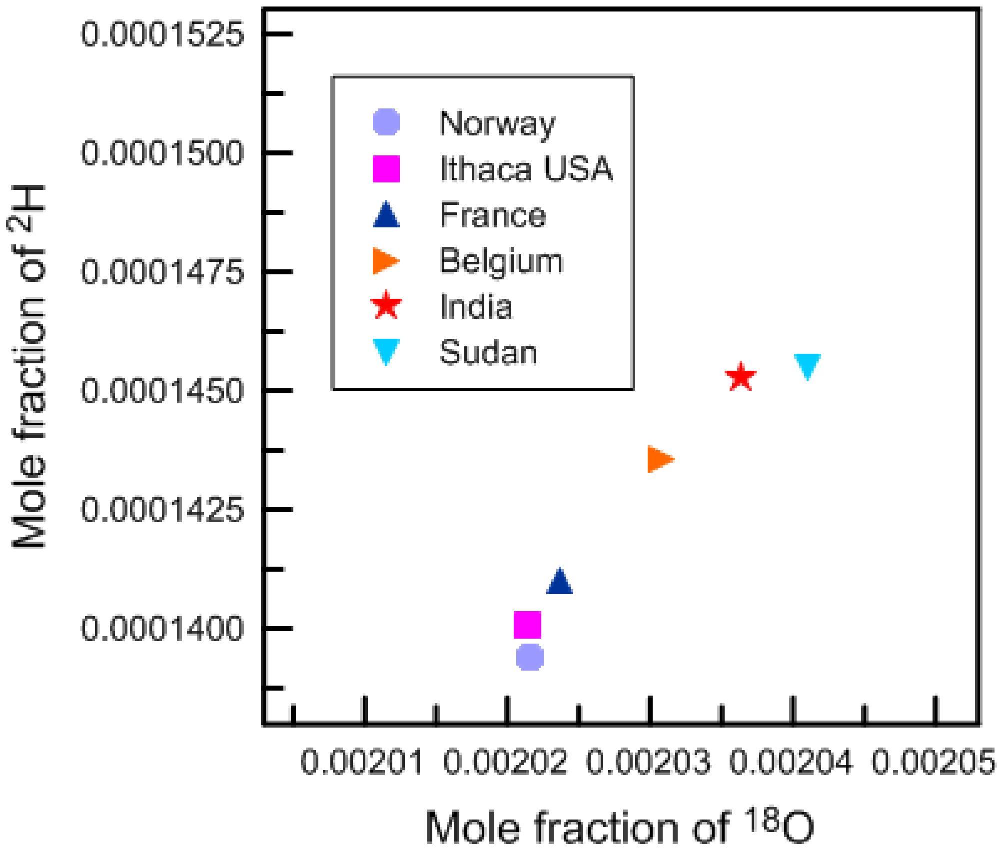


Fig. 4.8.3: Cross plot of **mole fractions** of ^{2}H and ^{18}O of human nail samples from a variety of global sites (modified from [90]). The hydrogen and oxygen **isotopic compositions** reflect the oxygen and hydrogen isotopic compositions of water consumed, and generally they decrease with increasing latitude, increasing elevation, and distance inland from the ocean-continent boundary [11, 12].

4.8.3 Oxygen isotopes in medicine

^{16}O is used to produce radioactive ^{13}N via the ^{16}O (p, ^{4}He) ^{13}N reaction for imaging in **positron emission tomography** (**PET**) and to study blood flow through the heart (myocardial perfusion)[91, 92].

^{17}O has been used as a **tracer** to study cerebral oxygen utilization [93]. Variations in stable oxygen and hydrogen isotopes are used in energy expenditure studies in animals and humans. The subject is administered a dose of doubly labeled water (water enriched in both ^{2}H and ^{18}O). Measurements of the elimination rates of ^{2}H and ^{18}O in the subject over time through regular sampling of body water (by sampling saliva, urine, or blood) provide information on energy expenditure because the hydrogen isotopic composition of body water is affected primarily by water loss (mainly urination), but the oxygen isotopic composition is affected by both respiration and water loss [94].