12.001 Introduction to Geology
Spring 2008

OXYGEN ISOTOPES – the shortest short story

Oxygen comes in four isotopes:

^{15}O	radioactive: half life of 122.2 sec
^{16}O (99.76%)	stable
^{17}O (0.04%)	stable
^{18}O (0.2%)	stable

The masses of ^{16}O and ^{18}O are sufficiently different to cause them to fractionate in geological processes. For example, if water is vaporized, the water molecules containing the low-mass oxygen atoms vaporize first.

The changes in isotopic ratio are measured in a unit called $\delta^{18}O$, pronounced "delta O 18." Because the initial ratios of ^{16}O and ^{18}O are so low, an equation to calculate their differences has to magnify the small numbers:

$$\delta^{18}O = 1000\left[\frac{\frac{^{18}O}{^{16}O_{sample}} - \frac{^{18}O}{^{16}O_{SMOW}}}{\frac{^{18}O}{^{16}O_{SMOW}}} - 1\right],$$

where SMOW stands for Standard Mean Ocean Water, the "average" against which changes are measured.

Zircons are crystallized out of silicate magmas and are commonly found as tiny accessory minerals in intrusive igneous rocks. If the magma came straight from the mantle, the resulting zircons will have $\delta^{18}O$ values of about +5.3±0.03 per thousand. If the magma was produced by melting surface crustal rocks that had interacted with surface water, the $\delta^{18}O$ values rise; beyond 6.3 per thousand the magma must have had a wet crustal rock component.

AND, for those of you interested in climate change:
Most commonly oxygen isotopes are used as a temperature proxy in ice cores: the weight of ^{18}O requires more energy to vaporize, and water containing ^{18}O freezes faster than water containing ^{16}O. Water vapor in the atmosphere is therefore depleted in heavy molecules and enriched in light molecules. As the air cools, heavier water molecules preferentially condense, and precipitation is molecularly heavier than the vapor left in the air. If temperatures continue to fall, then condensation and in turn precipitation will contain decreasing fractions of heavy molecules, resulting in a depletion of ^{18}O relative to precipitation in a warmer environment. Ice core produced in a cold climate therefore has low ^{18}O values compared to ice core produced in hot climates.

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