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Chemistry: A Molecular Approach, Global Edition | (4th Edition)

Problem

A meteor has a Pb-206:U-238 mass ratio of 0.855:1.00. What is the age of the meteor? (Assume that the meteor did not contain any Pb-206 at the time of its formation.)

Step-by-step solution

Step 1 of 5

Given, that the mass ratio of Pb-206: U-238 in the meteor is 0.855:1.00.

$\therefore\ m_{\text{U-238}} = 1.00\,\text{g}$

$m_{\text{Pb-206}} = 0.855\,\text{g}$

Comment

Step 2 of 5

U-238 decays into Pb-206 with a half life of 4.5×10^{9} years. This decay reaction follows the first order kinetics.

The integrated rate law for the reaction is

$$\ln\frac{N_t}{N_0} = -kt$$

Comment

Step 3 of 5

The rate constant for the decay of U-238 to Pb-206 can be determined from the half life expression

$$k = \frac{0.693}{t_{1/2}}$$

$$k = \frac{0.693}{4.5\times10^{9}\ \text{years}}$$

$$k = 1.54\times10^{-10}\,\text{yr}^{-1}$$

Comment

Step 4 of 5

The mass in grams of U-238 that would have been required to form the given mass of Pb-206

$$0.855\,\text{g Pb}-206\times\frac{1\,\text{mol Pb}-206}{206\,\text{g Pb}}\times\frac{1\,\text{mol U}-238}{1\,\text{mol Pb}-206}\times\frac{238\,\text{g U}-238}{1\,\text{mol U}-238}=0.9878\,\text{g U}-238$$

The initial mass, N_0 of U–238 is the current mass plus the mass that has decayed into Pb-206.

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Step 5 of 5

Substituting all these values in the integrated rate law,

$$\ln\frac{N_t}{N_0} = -kt$$

$$t = -\frac{\ln\frac{N_t}{N_0}}{k}$$

$$t = -\frac{\ln\frac{1.00\,g}{(1.00+0.9878)\,g}}{1.54\times10^{-10}\,yr^{-}}$$

$$t = 4.5\times10^{9}\ yr$$

The age of the meteor is $4.5\times10^{9}\,yr$.

Comment

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Chapter 20, Problem 15E

Explain the main concepts behind the technique of radiocarbon dating. How can radiocarbon dating be corrected for changes in atmospheric concentrations of C-14? What range of ages can be reliably determined by C-14 dating?

See solution

Chapter 20, Problem 65E

If 1.0 g of matter were converted to energy, how much energy would be formed?

See solution

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