

Nuclear Stability

We can establish a pattern of reactions between protons and neutrons in nuclear reactions



The question is why, for example, some nuclei undergo an alpha decay and not a beta decay. This has to do with the **neutrons to protons ratio** (n/p) in the nuclei. When the nuclei of all 1000 known isotopes are plotted (based on their number of protons and neutrons), a **band (belt) of stability** is obtained (blue region). The nuclei in this region are stable. The isotopes that fall outside of this region (are off-balance) are radioactive and decay spontaneously. Example 11 is the last element on the band of stability, so all nuclei with 84 or more protons are radioactive. The type of radioactivity depends on the n/p

- The nuclei above the band of stability tend to decrease the n/p ratio.
- The nuclei below the band of stability tend to increase the n/p ratio.



Nuclei with the **magic numbers** of 2, 8, 18, 28, 50, or 82 protons or 2, 8, 18, 28, 50, 82, or 126 neutrons, and in general, with even numbers of protons, neutrons are more stable.

Rates of Radioactive Decay

Radioactive decay obeys first-order kinetics laws. And although the half-life of radioactive elements may vary enormously (10^2 second to billions of years), it is independent of the quantity of the element. This advantage is used in **radiocarbon dating** which is used for **estimating the ages of fossils and artifacts**. The technique is based on the rate of ${}^{14}\text{C}$ decay which spreads from the atmosphere to living organisms.



The half-life of carbon-14 decaying to nitrogen by emission of a β^- particle is 5715 years.



The ${}^{14}\text{C} : {}^{12}\text{C}$ ratio is constant in living organisms. However, when a living organism dies, the ${}^{14}\text{C} : {}^{12}\text{C}$ ratio begins to decrease, and so does the decay rate of ${}^{14}\text{C}$. The relationship of the quantity or rates of decay is given by the first-order rate law:

$$\ln \left(\frac{N}{N_0} \right) = -kt \quad \ln \left(\frac{\text{rate}_t}{\text{rate}_0} \right) = -kt$$

Example: A sample of wood from an Egyptian mummy case gives a count of 9.4 counts/g, this is the current decay rate determined experimentally. How old is the wood if its initial decay rate is 15.3 counts/g?

Solution: We are going to use the integrated rate law of first-order reactions. The rates are given, so we need to determine the rate constant of the decay.

The half-life of first-order reactions is $t_{1/2} = 0.693/k$. Therefore, k is:

$$k = \frac{0.693}{t_{1/2}} = \frac{0.693}{5715 \text{ y}} = 1.210 \times 10^{-4} \text{ y}^{-1}$$

$$\ln \left(\frac{9.4}{15.3} \right) = (1.210 \times 10^{-4}) \times t \Rightarrow t = \frac{\ln \left(\frac{9.4}{15.3} \right)}{(1.210 \times 10^{-4})} = 4,829 \text{ years}$$

Energy Changes in Nuclear Reactions

The energies involved with nuclear reactions are extremely large. For example, the energy change in this reaction is $-4.1 \times 10^{12} \text{ J/mol}$



For comparison, the energy change for combustion of 1 mol CH_4 is 890 kJ/mol.

Standard Chemistry Nuclear Study Guide

Lingsheng Yao



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Operating Manual, Qualification Standards for General Schedule Positions United States. Office of Personnel Management, 1994 Self-study Manual on Optical Radiation Measurements Fred Edwin Nicodemus, 1976 **Current Catalog** National Library of Medicine (U.S.), 1985 First multi year cumulation covers six years 1965 70 **Publications** United States. National Bureau of Standards, 1986 **CRC Handbook of Management of Radiation Protection Programs, Second Edition** Kenneth L. Miller, 2020-08-11 CRC Handbook of Management of Radiation Protection Programs 2nd Edition is unique in that it offers practical guidance for managing various aspects of radiation protection programs ranging from the daily operation of a health physics office to the preparation of radiation experts for court appearances as professional witnesses The book also covers such topics as organization and management of nonionizing radiation safety programs with special emphasis on laser safety programs and management of radioactive waste personnel monitoring programs radiation accident victims internal exposure relative radiotoxicity and radiation therapy patients Other chapters discuss handling radiation accidents and education and training requirements for radiation protection Legal aspects covered in the book include the history of radiation court cases legal implications of record keeping and preparation for court appearances CRC Handbook of Management of Radiation Protection Programs 2nd Edition will be a valuable reference resource for medical and health physicists industrial hygienists physicians nuclear engineers radiation protection regulators radiation emergency management agents radiation safety committees and managers of facilities using ionizing and nonionizing radiation sources Catalog of Copyright Entries. Third Series Library of Congress. Copyright Office, 1968 Includes Part 1 Number 1 Books and Pamphlets Including Serials and Contributions to Periodicals January June

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