

## Nuclear Decay

Reading Assignment:  
pp. 965-980

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## Nuclear Stability

- ◆ **Strong Nuclear Force** depends on maintaining a delicate balance between the number of protons and the number of neutrons in a nucleus.
- ◆ The higher the atomic number, the larger the neutron:proton ratio must be in order to remain stable
- ◆ Difference of +/- 1 neutron can result in an unstable nucleus

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## Natural Radioactive Decay

- ◆ For all decay, two properties must remain constant: **total charge** and **total mass** before the decay to after the decay
- ◆ **Daughter Product** → the atom that is created as a result of nuclear decay
- ◆ **Parent Nuclei** → the unstable atom that is undergoing nuclear decay

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## Types of Decay

- ◆ **Alpha Decay ( $\alpha$  emission)**
  - Alpha particle is emitted from the nucleus
  - Atomic number decreases by 2
- ◆ For example: Uranium-232 decays by alpha emission. What is its daughter product?




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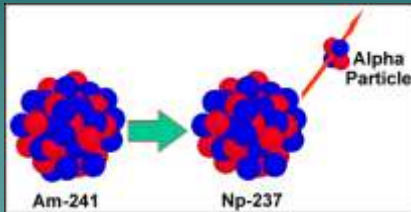
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## Types of Decay

- ◆ **Alpha Decay ( $\alpha$  emission)**




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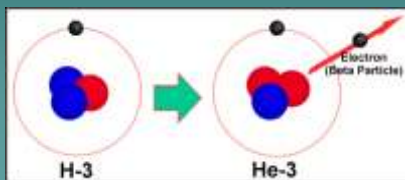
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## Types of Decay

- ◆ **Beta Decay**
  - Beta minus ( $\beta^-$ )  $\rightarrow$  an electron is emitted from the nucleus
  - ◆ Atomic number increases by 1




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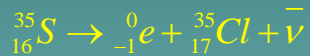
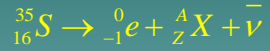
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## Types of Decay

### ◆ Beta Decay—example

– Sulfur-35 emits  $\beta^-$  particles when it decays radioactively. What is its daughter product?




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## Types of Decay

### ◆ Beta Decay

– Beta plus ( $\beta^+$ ) → a positron (positive electron) is emitted from the nucleus

- ◆ Atomic number decreases by 1
- ◆ Not as common as beta-minus

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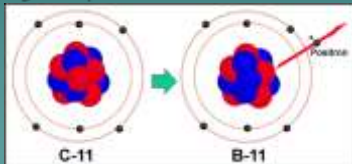
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## Types of Decay

### ◆ Beta Decay—example

– Carbon-11 emits  $\beta^+$  particles when it decays radioactively. What is its daughter product?




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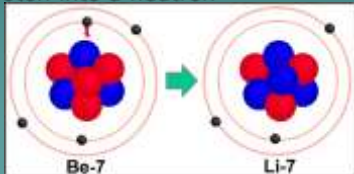
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## Types of Decay

### ◆ Electron Capture

- Essentially the same result as positron emission
- An electron from the lowest energy level is "captured" by the nucleus, turning a proton into a neutron




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## Types of Decay

### ◆ Gamma Decay

- Occurs when there is an unstable amount of internal energy in the nucleus
- Energy is released, returning the nucleus to a more stable state, in the form of a gamma ray (photon energy)




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## Products of sequential nuclear decays

- ◆ When an atom undergoes alpha or beta decay, it often has a daughter product that is also unstable...and therefore will decay. (anything with  $Z > 83$  are naturally radioactive)
- ◆ A series of decays occur, starting with the parent nuclei, and result in a series of different radioactive particle emissions until the original parent nuclei has finally decayed into a stable atom (i.e. Lead)

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## Decay Series Example:

- ◆ Uranium-238 → alpha decay into Thorium-234
- ◆ Thorium-234 → beta(-) into Palladium 234
- ◆ Palladium 234 → beta (-) into Uranium-234
- ◆ Uranium-234 → goes through 4 separate alpha decays into Thorium-230, then Radium-226, then Radon-222, and then Polonium-218
- ◆ Polonium-218 → several possible combinations of alpha and beta decays until the final product, Lead-206

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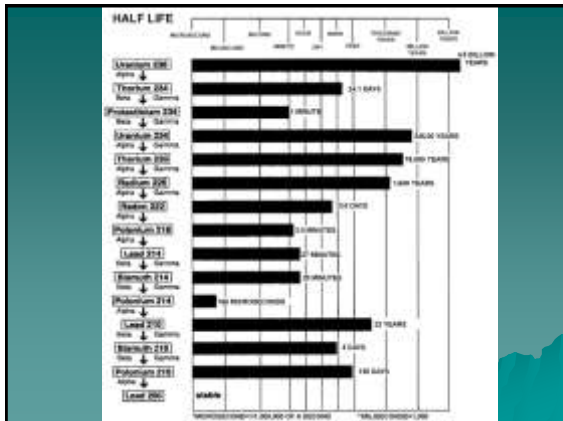
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## Half-Life

- ◆ Radioactive decay is a **random process!**
  - It is impossible to predict exactly when a specific nucleus will decay
- ◆ For a given isotope, however, there is a 50% chance that a nucleus will decay during a particular time period
- ◆ **Half-Life** = the time it takes for 50% of the remaining unstable nuclei to decay

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## Determining Half-Life

- ◆ Decay Curve options:
  - ◆ Number of parent nuclei vs. time
  - ◆ Rate of decay (decays per second) vs. time
- ◆ The half life is the amount of time (x-axis) that passes by before the number of parent nuclei OR the rate of decay has decreased by 50%

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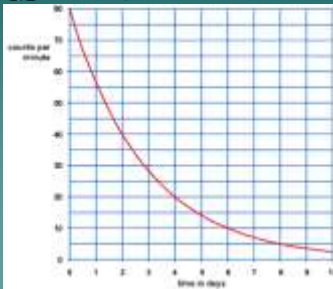
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## Half-Life

- ◆ Decay Curve for a Radioactive Sample with  $t_{1/2} = 2$  days




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## Determining Half-Life

- ◆ Simple Calculation:

$$N = N_0 \left(\frac{1}{2}\right)^n$$

$N$  = number (mass) of parent nuclei remaining

$N_0$  = original number (mass) of parent nuclei

$n$  = # of half-lives that have passed by

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