2.7: Toepassing 2: Radio-aktiewe verval (bl 73)

2.7: Application 2: Radioactive decay (p 73)

2.7: Toepassing 2: Radio-aktiewe verval (bl 73)

Probleem: Skat die ouderdom van 'n dokument, 'n stukkie versteende hout, of 'n dinosaurus fossiel

2.7: Application 2: Radioactive decay (p 73)

Problem: Estimate the age of a document, a piece of fossilized wood, or a dinosaur fossil

2.7: Toepassing 2: Radio-aktiewe verval (bl 73)

Probleem: Skat die ouderdom van 'n dokument, 'n stukkie versteende hout, of 'n dinosaurus fossiel

(1) Aanname:
- Tempo van verval direk eweredig aan aantal radio-aktiewe atome teenwoordig

2.7: Application 2: Radioactive decay (p 73)

Problem: Estimate the age of a document, a piece of fossilized wood, or a dinosaur fossil

(1) Assumption:
- Rate of decay directly proportional to number of radioactive atoms present

(2) Wiskundige formulering

(2) Mathematical formulation

Laat $N = N(t)$ **die aantal radio-aktiewe atome op tydstip** t **wees**

Let $N = N(t)$ *be the number of radioactive atoms at time* t

$$\frac{dN}{dt} = -\lambda N \quad \textbf{met} \ / \textit{with} \quad \lambda > 0$$

$\lambda \equiv$ **vervalkonstante** */ decay constant* **en** */ and* $N(0) = N_0$

(2) Wiskundige formulering

(2) Mathematical formulation

Laat $N = N(t)$ die aantal radio-aktiewe atome op tydstip t wees

Let $N = N(t)$ be the number of radioactive atoms at time t

$$\frac{dN}{dt} = -\lambda N \quad \textbf{met /}\textit{with} \quad \lambda > 0$$

$$\lambda \equiv \textbf{vervalkonstante /}\textit{decay constant} \quad \textbf{en /}\textit{and} \quad N(0) = N_0$$

Halveertyd (halfleeftyd) $t_{1/2}$ (uit vorige werk):

Halving time (half-life) $t_{1/2}$ (from previous work):

$$t_{1/2} = \frac{\ln 2}{\lambda} \quad \textbf{of /}\textit{or} \quad \lambda = \frac{\ln 2}{t_{1/2}}$$

(2) Wiskundige formulering

(2) Mathematical formulation

Laat $N = N(t)$ **die aantal radio-aktiewe atome op tydstip** t **wees**

Let $N = N(t)$ *be the number of radioactive atoms at time* t

$$\frac{dN}{dt} = -\lambda N \quad \textbf{met /}\textit{with} \quad \lambda > 0$$

$\lambda \equiv$ **vervalkonstante /***decay constant* **en /***and* $N(0) = N_0$

Halveertyd (halfleeftyd) $t_{1/2}$ **(uit vorige werk):**

Halving time (half-life) $t_{1/2}$ *(from previous work):*

$$t_{1/2} = \frac{\ln 2}{\lambda} \quad \textbf{of /}\textit{or} \quad \lambda = \frac{\ln 2}{t_{1/2}}$$

(3) Verkry oplossings$\rightarrow$ $N(t) = N_0 \left(\frac{1}{2}\right)^{t/t_{1/2}}$ $\leftarrow$ *(3) Obtain solutions*

- $\mathrm{C}^{14} \rightarrow \mathrm{N}^{14}$**:** $t_{1/2} = 5600$ **jaar** / *years* **(C-14 toets** / *test***)**
- $\mathrm{Ra}^{226} \rightarrow \mathrm{Rn}^{222}$**:** $t_{1/2} = 1700$ **jaar** / *years*
- $\mathrm{U}^{238} \rightarrow \mathrm{Pb}^{206}$**:** $t_{1/2} = 4.5$ **biljoen jaar!** / *billion years!*

- $\mathrm{C}^{14} \rightarrow \mathrm{N}^{14}$: $t_{1/2} = 5600$ **jaar** / *years* **(C-14 toets** / *test***)**
- $\mathrm{Ra}^{226} \rightarrow \mathrm{Rn}^{222}$: $t_{1/2} = 1700$ **jaar** / *years*
- $\mathrm{U}^{238} \rightarrow \mathrm{Pb}^{206}$: $t_{1/2} = 4.5$ **biljoen jaar!** / *billion years!*

(Radio-aktief $\rightarrow$ Nie) Groot $t_{1/2} \Rightarrow$ Stabiele isotoop

(Radioactive $\rightarrow$ Not) Large $t_{1/2} \Rightarrow$ Stable isotope

- $\mathrm{C}^{14} \rightarrow \mathrm{N}^{14}$: $t_{1/2} = 5600$ **jaar** / *years* **(C-14 toets** / *test***)**
- $\mathrm{Ra}^{226} \rightarrow \mathrm{Rn}^{222}$: $t_{1/2} = 1700$ **jaar** / *years*
- $\mathrm{U}^{238} \rightarrow \mathrm{Pb}^{206}$: $t_{1/2} = 4.5$ **biljoen jaar!** / *billion years!*

(Radio-aktief $\rightarrow$ Nie) Groot $t_{1/2} \Rightarrow$ Stabiele isotoop

(Radioactive $\rightarrow$ Not) Large $t_{1/2} \Rightarrow$ Stable isotope

C-14 toets / *test ("Radiocarbon dating"):*

- $\mathrm{C}^{14} \rightarrow \mathrm{N}^{14}$: $t_{1/2} = 5600$ **jaar** / *years* **(C-14 toets** / *test***)**
- $\mathrm{Ra}^{226} \rightarrow \mathrm{Rn}^{222}$: $t_{1/2} = 1700$ **jaar** / *years*
- $\mathrm{U}^{238} \rightarrow \mathrm{Pb}^{206}$: $t_{1/2} = 4.5$ **biljoen jaar!** / *billion years!*

(Radio-aktief $\rightarrow$ Nie) Groot $t_{1/2} \Rightarrow$ Stabiele isotoop

(Radioactive $\rightarrow$ Not) Large $t_{1/2} \Rightarrow$ Stable isotope

C-14 toets / *test ("Radiocarbon dating"):*

- **Klein hoeveelhede radio-aktiewe C^{14} in atmosfeer**
- *Small amounts radioactive C^{14} in atmosphere*

- $\mathrm{C}^{14} \rightarrow \mathrm{N}^{14}$: $t_{1/2} = 5600$ **jaar** / *years* **(C-14 toets** / *test***)**
- $\mathrm{Ra}^{226} \rightarrow \mathrm{Rn}^{222}$: $t_{1/2} = 1700$ **jaar** / *years*
- $\mathrm{U}^{238} \rightarrow \mathrm{Pb}^{206}$: $t_{1/2} = 4.5$ **biljoen jaar!** / *billion years!*

(Radio-aktief $\rightarrow$ Nie) Groot $t_{1/2} \Rightarrow$ Stabiele isotoop

(Radioactive $\rightarrow$ Not) Large $t_{1/2} \Rightarrow$ Stable isotope

C-14 toets / *test ("Radiocarbon dating"):*

- **Klein hoeveelhede radio-aktiewe C^{14} in atmosfeer**
- **Plante/diere neem radio-aktiewe C^{14} op**

- *Small amounts radioactive C^{14} in atmosphere*
- *Plants/animals take up radioactive C^{14}*

- $\mathrm{C}^{14} \rightarrow \mathrm{N}^{14}$: $t_{1/2} = 5600$ **jaar** / *years* **(C-14 toets** / *test***)**
- $\mathrm{Ra}^{226} \rightarrow \mathrm{Rn}^{222}$: $t_{1/2} = 1700$ **jaar** / *years*
- $\mathrm{U}^{238} \rightarrow \mathrm{Pb}^{206}$: $t_{1/2} = 4.5$ **biljoen jaar!** / *billion years!*

(Radio-aktief $\rightarrow$ Nie) Groot $t_{1/2} \Rightarrow$ Stabiele isotoop

(Radioactive $\rightarrow$ Not) Large $t_{1/2} \Rightarrow$ Stable isotope

C-14 toets / *test ("Radiocarbon dating"):*

- **Klein hoeveelhede radio-aktiewe C^{14} in atmosfeer**
- **Plante/diere neem radio-aktiewe C^{14} op**
- **$\Rightarrow$ C^{14} in plante/diere $\approx$ C^{14} in atmosfeer**

- *Small amounts radioactive C^{14} in atmosphere*
- *Plants/animals take up radioactive C^{14}*
- *$\Rightarrow$ C^{14} in plants/animals $\approx$ C^{14} in atmosphere*

- $\mathrm{C}^{14} \rightarrow \mathrm{N}^{14}$: $t_{1/2} = 5600$ **jaar** / *years* **(C-14 toets** / *test***)**
- $\mathrm{Ra}^{226} \rightarrow \mathrm{Rn}^{222}$: $t_{1/2} = 1700$ **jaar** / *years*
- $\mathrm{U}^{238} \rightarrow \mathrm{Pb}^{206}$: $t_{1/2} = 4.5$ **biljoen jaar!** / *billion years!*

(Radio-aktief $\rightarrow$ Nie) Groot $t_{1/2} \Rightarrow$ Stabiele isotoop

(Radioactive $\rightarrow$ Not) Large $t_{1/2} \Rightarrow$ Stable isotope

C-14 toets / *test ("Radiocarbon dating"):*

- **Klein hoeveelhede radio-aktiewe C^{14} in atmosfeer**
- **Plante/diere neem radio-aktiewe C^{14} op**
- **$\Rightarrow$ C^{14} in plante/diere $\approx$ C^{14} in atmosfeer**
- **Plant/dier sterf: C^{14} op-name staak en $\mathrm{C}^{14} \rightarrow \mathrm{N}^{14}$**

- *Small amounts radioactive C^{14} in atmosphere*
- *Plants/animals take up radioac-tive C^{14}*
- *$\Rightarrow$ C^{14} in plants/animals $\approx$ C^{14} in atmosphere*
- *Plant/animal dies: C^{14} uptake stops & $\mathrm{C}^{14} \rightarrow \mathrm{N}^{14}$*

- **Kan nou ouderdom van fossiel (t) afskat met:**

$$\frac{N(t)}{N_0} = \left(\frac{1}{2}\right)^{t/5600}, \quad t \text{ in jare}$$

- N_0 **bekend (soos in atmosfeer)**
- $N(t)$ **gemeet met Geiger-teller**

Net akkuraat tot en met ouderdom van $60\,000$ **jaar**

- *Can now estimate age of fossil (t) with:*

$$\frac{N(t)}{N_0} = \left(\frac{1}{2}\right)^{t/5600}, \quad t \text{ in years}$$

- N_0 *known (as in atmosphere)*
- $N(t)$ *measured with Geiger counter*

Only accurate to age of $60\,000$ *years*

Voorbeeld: 'n Stukkie versteende hout bevat 63% soveel C^{14} as lewendige hout met dieselfde massa. Hou oud is die versteende hout?

Antwoord: 3733 jaar

Example: A piece of fossilized wood contains 63% as much C^{14} as living wood with the same mass. How old is the fossilized wood?

Answer: 3733 years