

# UBC Physics 102

## Lecture 2

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## Outline

- ▷ Radioactivity
- ▷ Alpha decay
- ▷ Beta decay
- ▷ Gamma decay
- ▷ Rate of decay
- ▷ Half-life
- ▷ Activity
- ▷ Radioactive dating
- ▷ End



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## Radioactivity [Text: Sect. 42-3]

- **Definition: Radioactivity**
  - Decay of an unstable nucleus.
- **Discussion: 3 common types of decay**

Type	Particle emitted	Charge	Mass
$\alpha$ (alpha)	${}^4\text{He}$ (2 p + 2 n)	+2	heavy
$\beta$ (beta)	electron	-1	light
$\gamma$ (gamma)	photon	none	very light

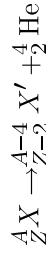


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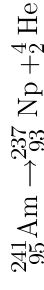
## Alpha decay [Text: Sect. 42-4]

- **Definition:  $\alpha$  decay**



- $\alpha = {}^4_2\text{He}$  (helium nucleus).
- Mass ( $A$ ) and charge ( $Z$ ) conserved.

- **Example: Smoke detectors**



- Emitted  $\alpha$  particle used to generate current between two plates.
- Smoke interrupts current to trip alarm.

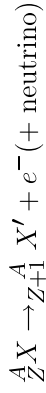


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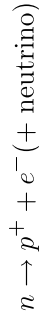
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## Beta decay [Text: Sect. 42-5]

- **Definition:**  $\beta$  decay



- $\beta = e^{-}$  (electron).
- Mass ( $A$ ) and charge ( $Z$ ) conserved.
- Electron comes from nucleus, not orbit.
- Produced by decay of neutron:



## Rate of decay [Text: Sect. 42-8]

- **Derivation: Radioactive decay law**
- Radioactive decay is unpredictable, quantum process.
- Average rate of decay is proportional to amount present,
- $\lambda$  (lambda) is proportionality constant that sets rate.
- Can integrate to find how much material remains after time  $t$ ,

$$N(t) = N_0 e^{-\lambda t}.$$



## Gamma decay [Text: Sect. 42-6]

- **Definition:** *Excited state*
- Nucleus with surplus energy (often result of  $\alpha$  or  $\beta$  decay).
- Denoted by  $*$ , as in  ${}^A_Z X^*$ .
- **Definition:**  $\gamma$  decay



- Produces photon ( $\gamma$  particle).
- Mass ( $A$ ) and charge ( $Z$ ) conserved.

- **Interactive Quiz: PRS 02a**



## Half-life [Text: Sect. 42-8]

- **Derivation: Half-life,  $T_{1/2}$**
- The time it takes for half the original amount of isotope to decay. Is solution to

$$\frac{N_0}{2} = N_0 e^{-\lambda T_{1/2}}.$$

- **Interactive Quiz: PRS 02b**
- **Definition:** *Half-life,  $T_{1/2}$*

$$T_{1/2} = \frac{\ln 2}{\lambda}$$



## Activity [Text: Sect. 42-8]

- Definition: Activity,**  $\left| \frac{dN}{dt} \right|$
- Rate of decay, or number of decays per second of a sample.

$$\left| \frac{dN}{dt} \right| = \lambda N.$$

- Example:**

- $^{31}\text{Si}$  has a half-life of 2.62 hr. What will the activity of a 1 g sample be after 1 week?



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## Activity, contd

- Solution:**

- We know  $N(t) = N_0 e^{-\lambda t}$ . Then

$$\left| \frac{dN}{dt} \right| = \lambda N_0 e^{-\lambda t}.$$

- Need to calculate  $N_0$ ,  $\lambda$ , and  $t$ . First,  $t$  (in hours) is  $t = 1 \text{ wk} = 168 \text{ hr}$ .

- Now, use half-life,  $T_{1/2} = \frac{\ln 2}{\lambda}$  to get  $\lambda$ ,

$$\begin{aligned} \lambda &= \frac{\ln 2}{T_{1/2}} = \frac{0.693}{2.62 \text{ hr}} \\ &= 0.265 \text{ hr}^{-1}. \end{aligned}$$



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## Activity, contd

- Solution: contd**
- Finally, need to find number of particles,  $N_0$ .
- Use atomic mass, 1 particle = 31 u,

$$\begin{aligned} N_0 &= 10^{-3} \text{ kg} \times \frac{1 \text{ u}}{1.66 \times 10^{-27} \text{ kg}} \times \frac{1 \text{ particle}}{31 \text{ u}} \\ &= 1.94 \times 10^{22} \text{ particles.} \end{aligned}$$

- So activity is

$$\begin{aligned} \left| \frac{dN}{dt} \right| &= \lambda N_0 e^{-\lambda t} \\ &= (0.265 \text{ hr}^{-1})(1.94 \times 10^{22} \text{ part.}) e^{-(0.265 \text{ hr}^{-1})(168 \text{ hr})} \\ &= 238 \text{ particles/hr.} \quad \square \end{aligned}$$



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## Radioactive dating [Text: Sect. 42-10]

- Discussion: Carbon dating**
- Unstable  $^{14}\text{C}$  isotope occurs naturally.
- About  $1.3 \times 10^{-10}\%$  of carbon in the environment is  $^{14}\text{C}$ .
- Absorbed during life (eating, breathing, etc.).
- No longer absorbed after death so  $^{14}\text{C}$  decays.
- Can estimate how long ago specimen died by using

$N(t) = N_0 e^{-\lambda t}$  to determine time needed to get  $N$  down to current value,

$$t = \frac{1}{\lambda} \ln \frac{N_0}{N}.$$

- Need to know  $\lambda$ ,  $N_0$ , and current  $N$ .



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## Radioactive dating, contd

- **Discussion: Carbon dating, contd**
- $\lambda$  can be calculated from half-life,  $T_{1/2} = 5730$  yr.
- $N_0$  can be determined from total number of carbon atoms in sample.
- Measure activity to get current  $N$ , from  $\left| \frac{dN}{dt} \right| = \lambda N$ .



## End

- **Practice Problems:**
- Ch. 42: Q. 7, 13, 19, 21, 25
- Ch. 42: Pr. 35, 37, 39, 43, 45, 47, 49, 55, 63, 65
- **Interactive Quiz: Feedback**
- **Tutorial Question: tut02**

