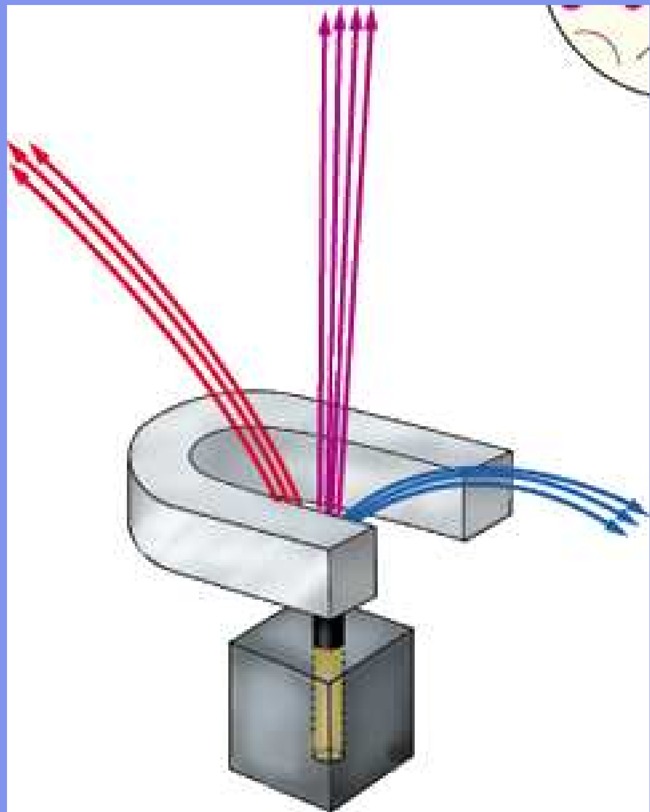
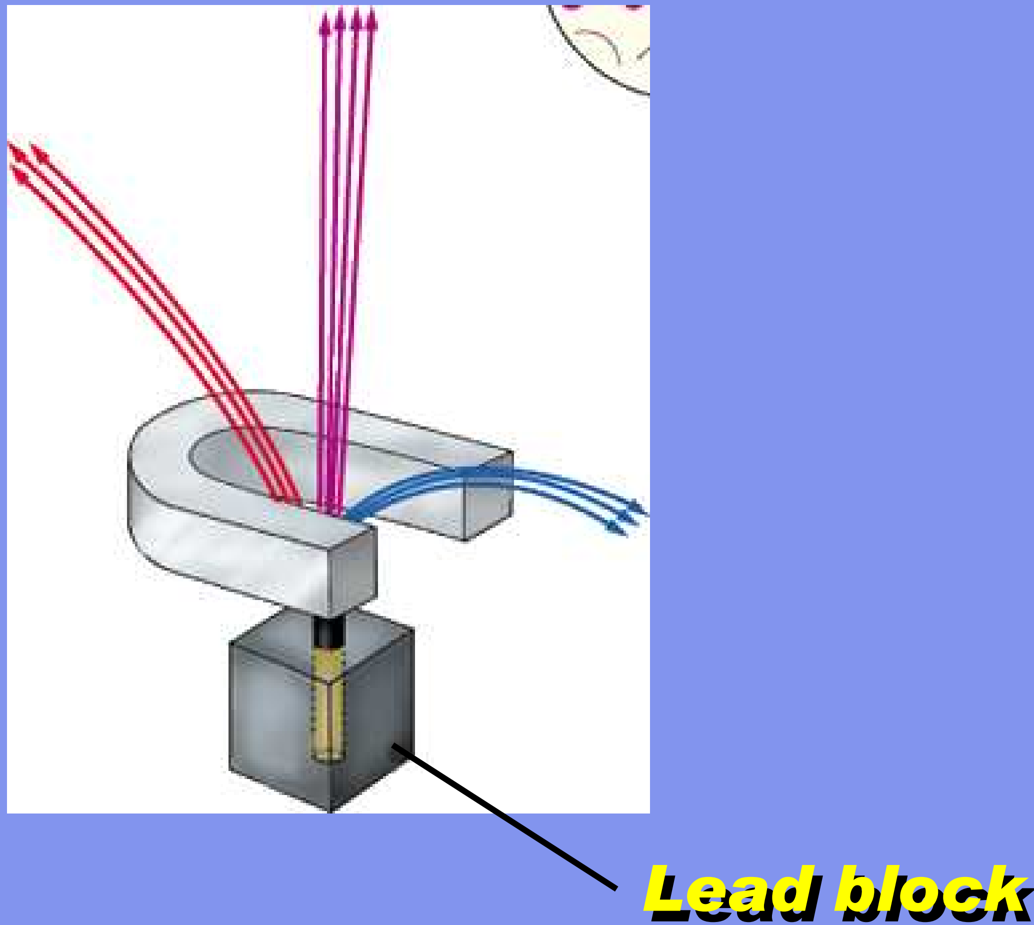
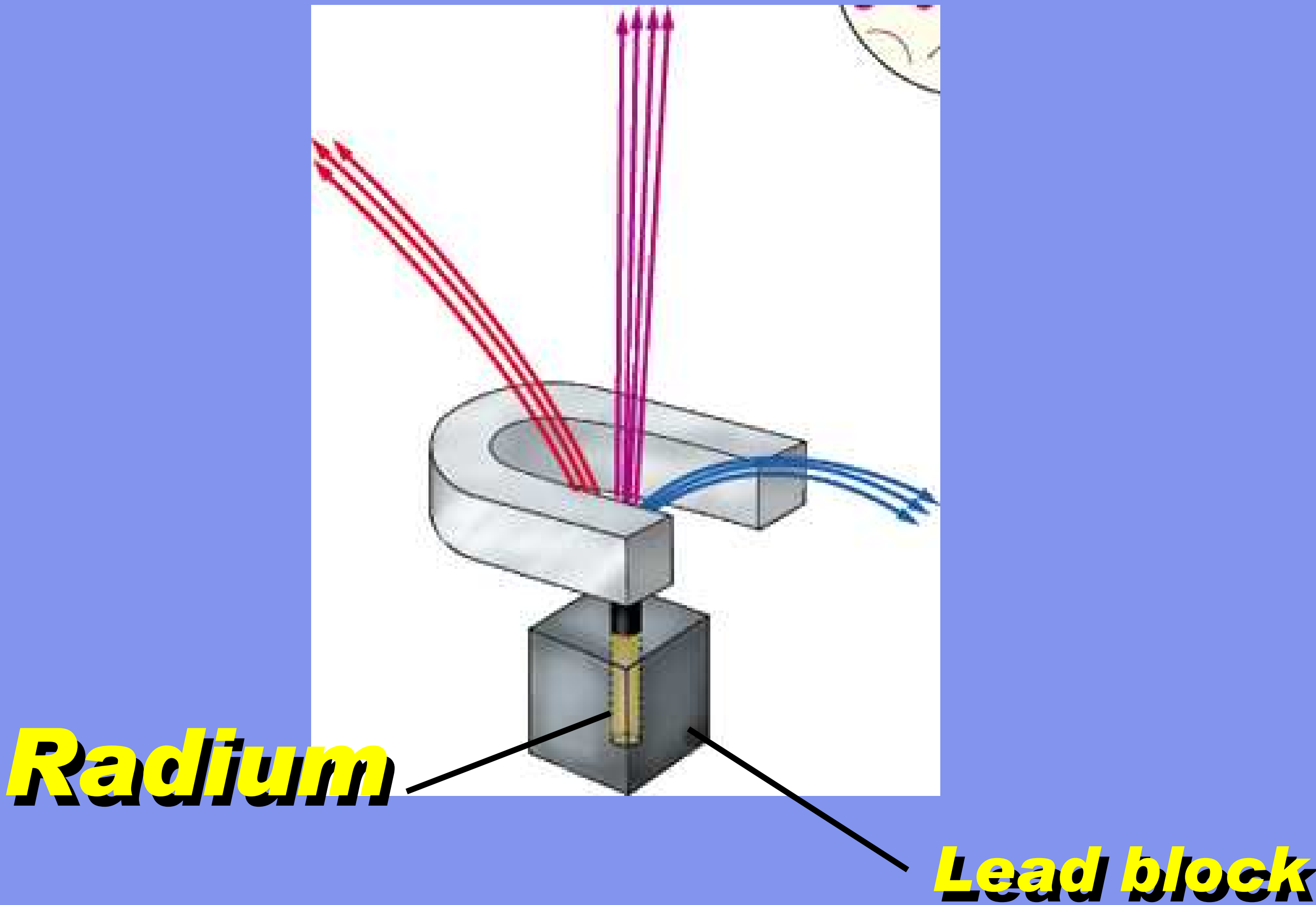
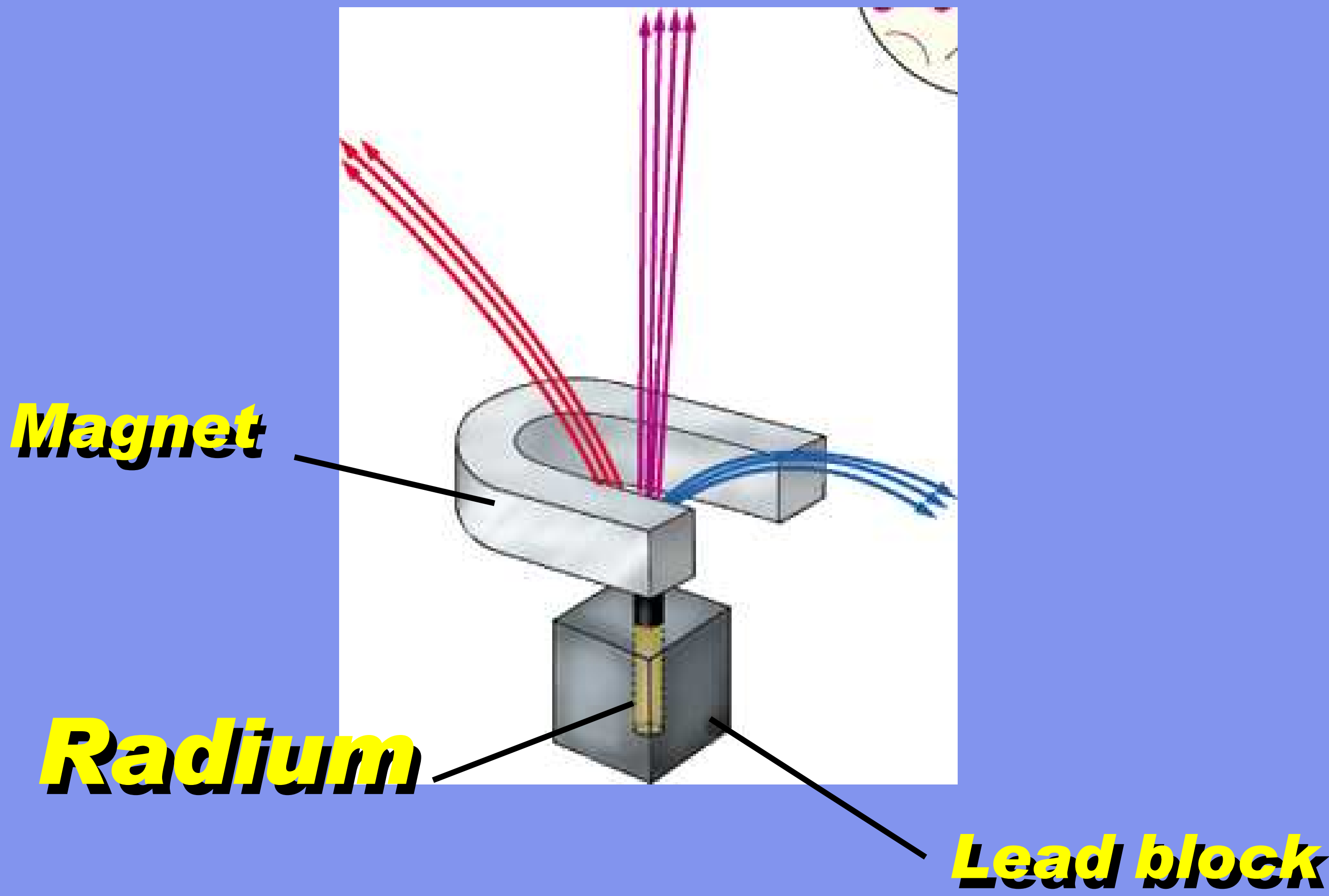
The Atomic Nucleus

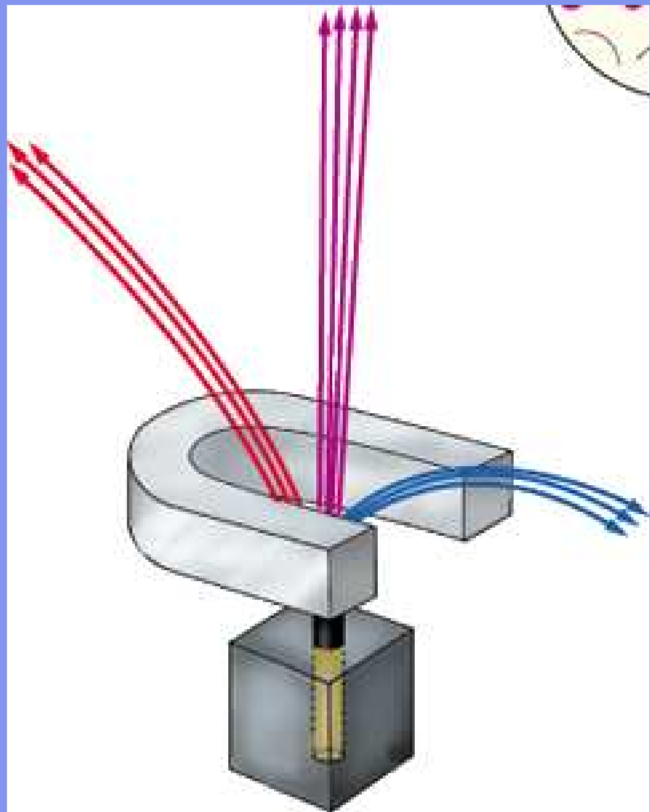
Discovery of Radioactivity

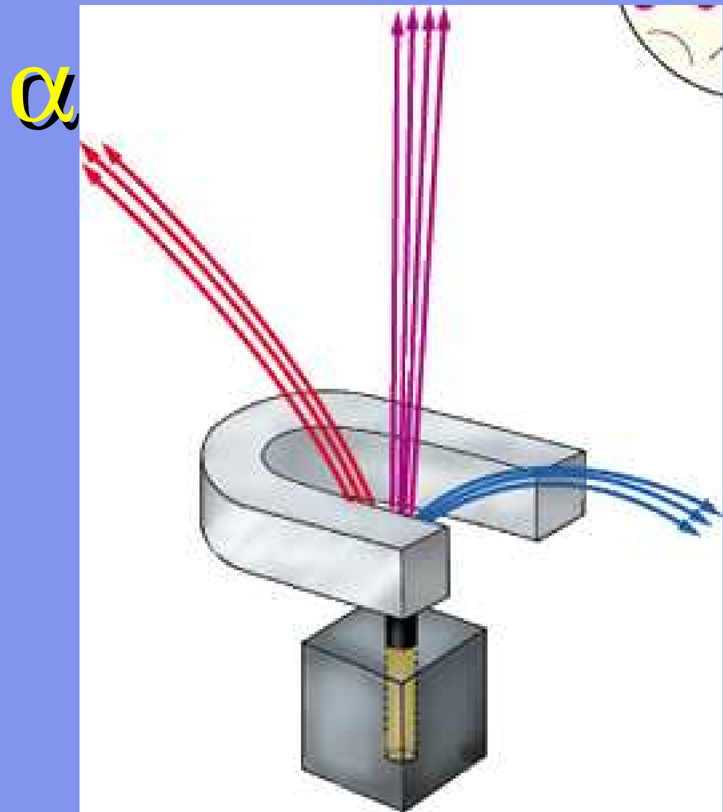



Lead block

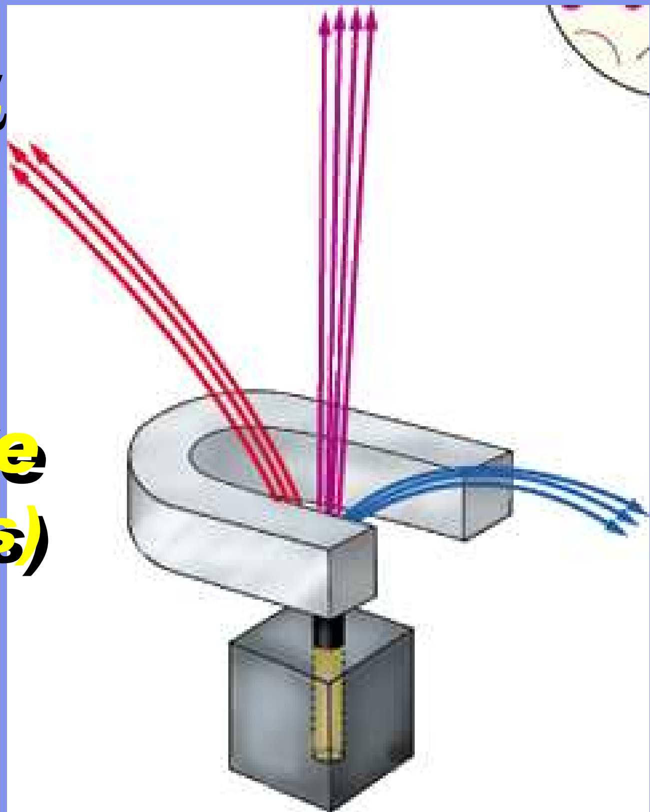

Radium
Lead block


Magnet
Radium
Lead block

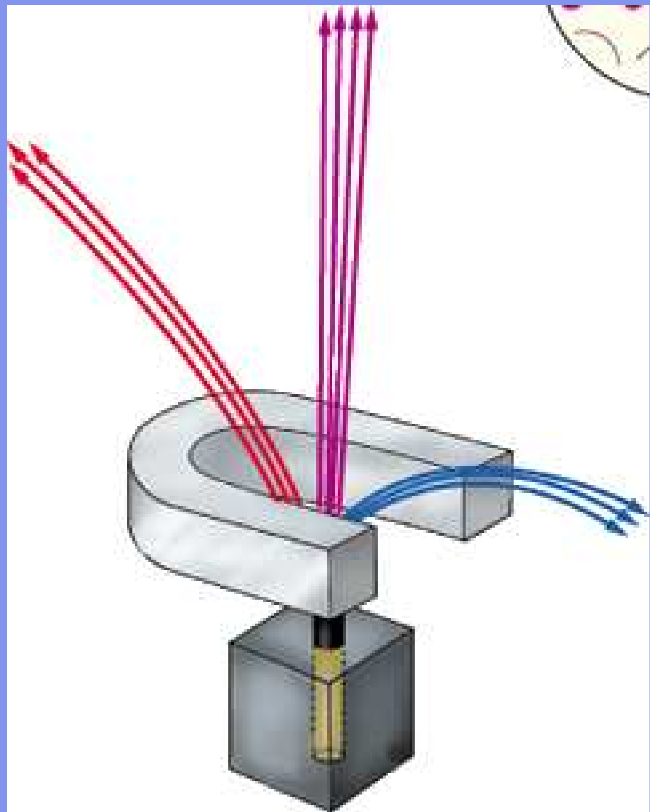



α

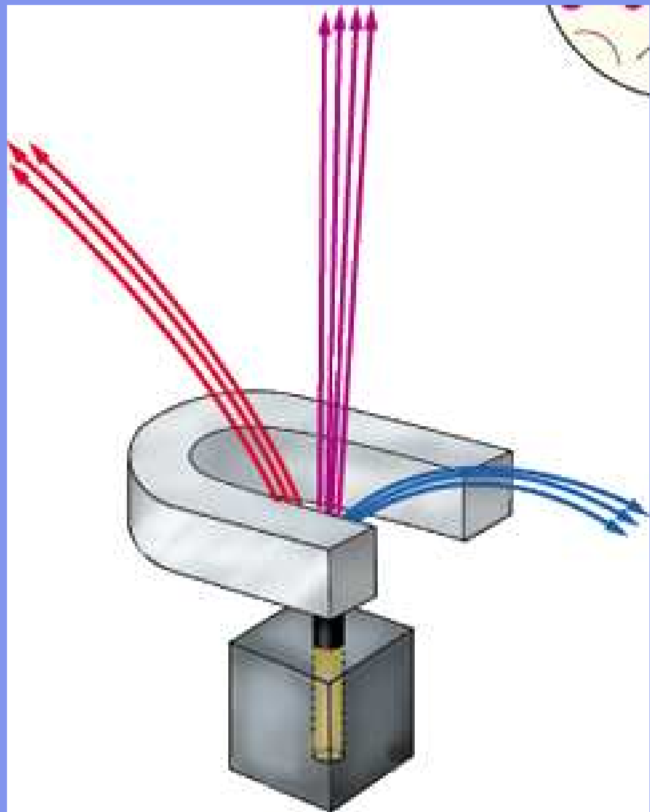
α



Alpha particle
(helium nucleus)



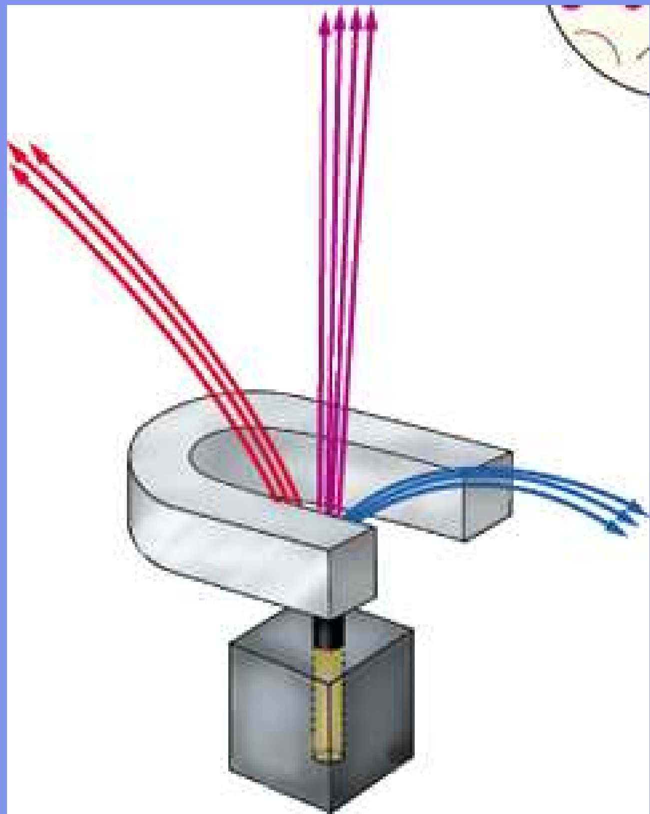
β

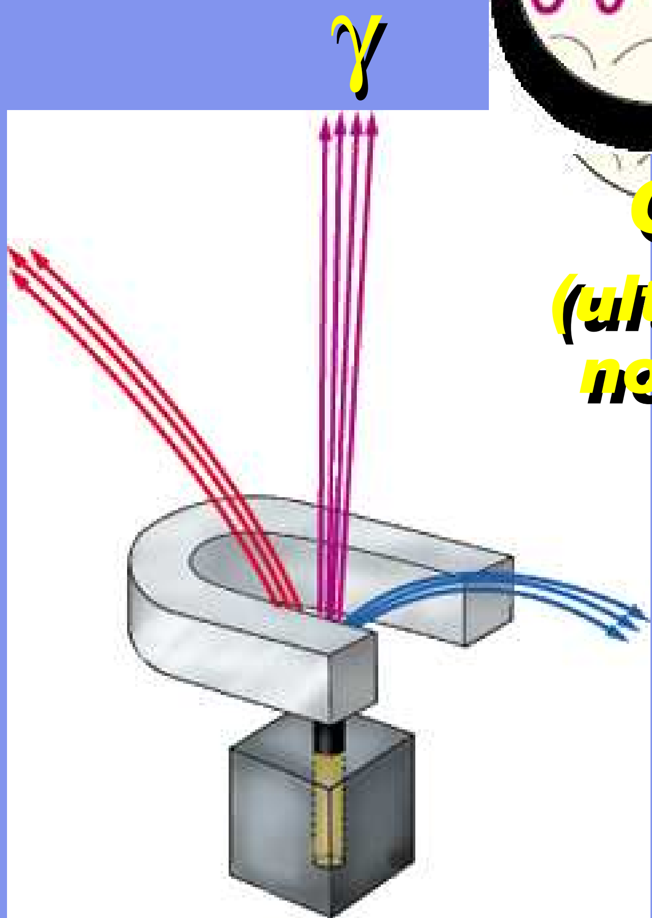


β

Beta particle
(electron)

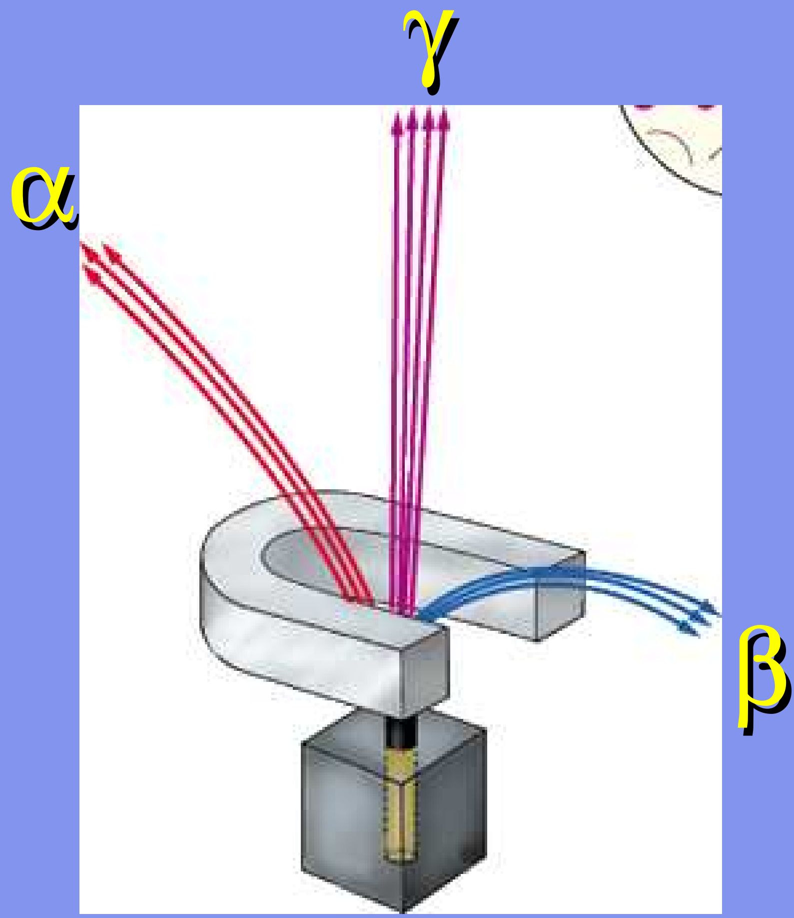
γ



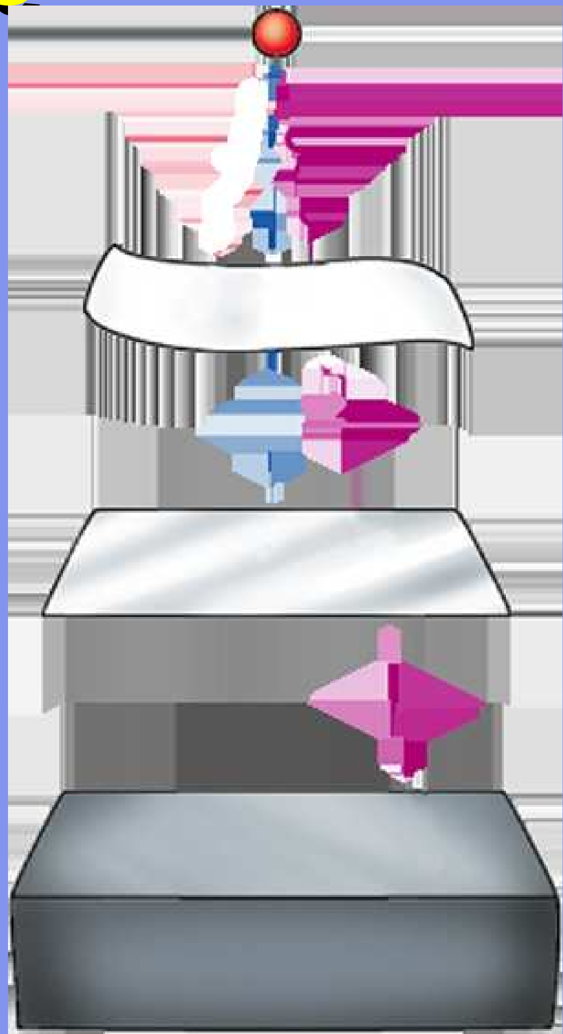


Gamma ray

(ultra-high energy nonvisible light)


γ
α
β

Radioactive Source

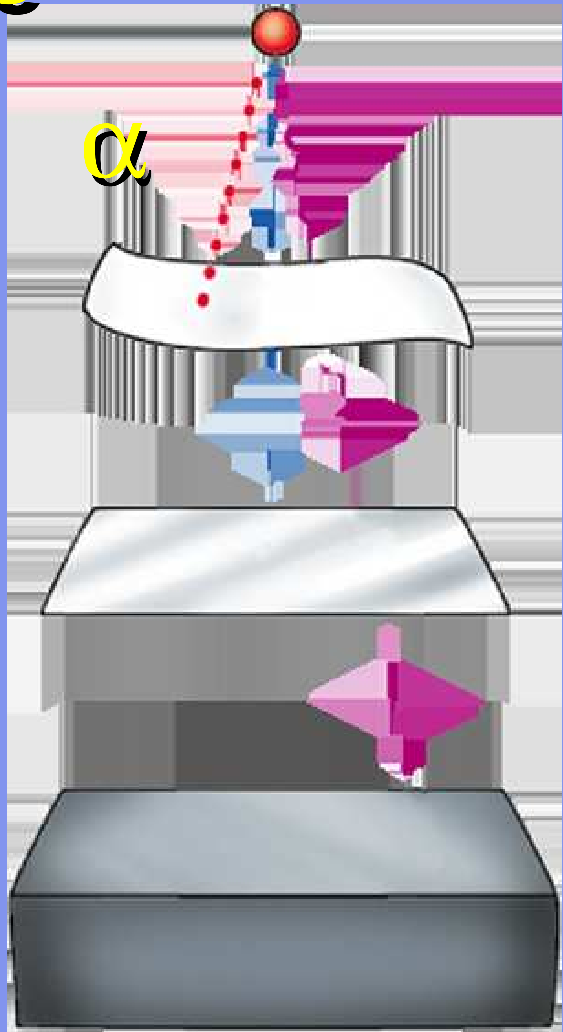


Paper

Aluminum

Lead

Radioactive Source

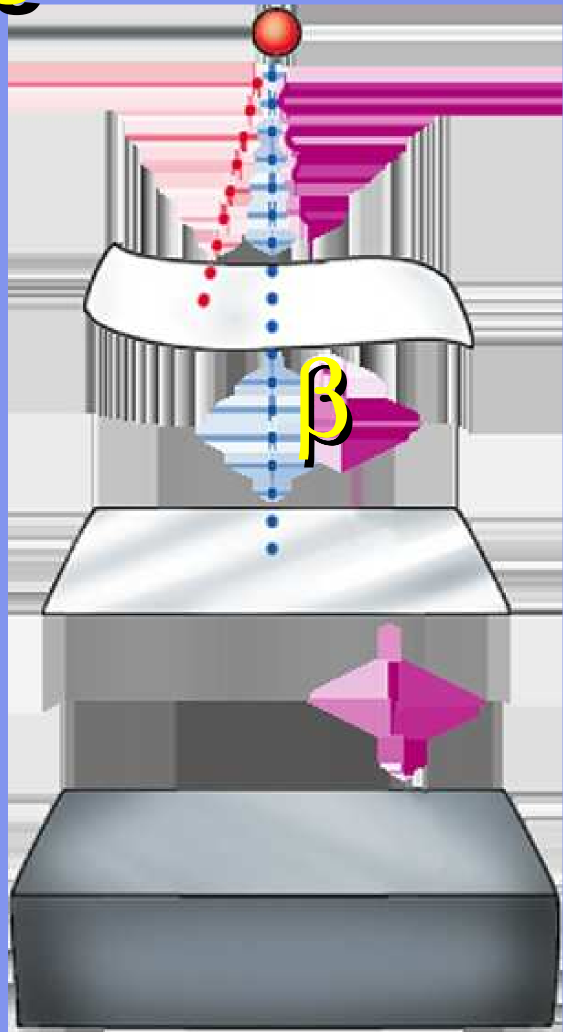


Paper

Aluminum

Lead

Radioactive Source

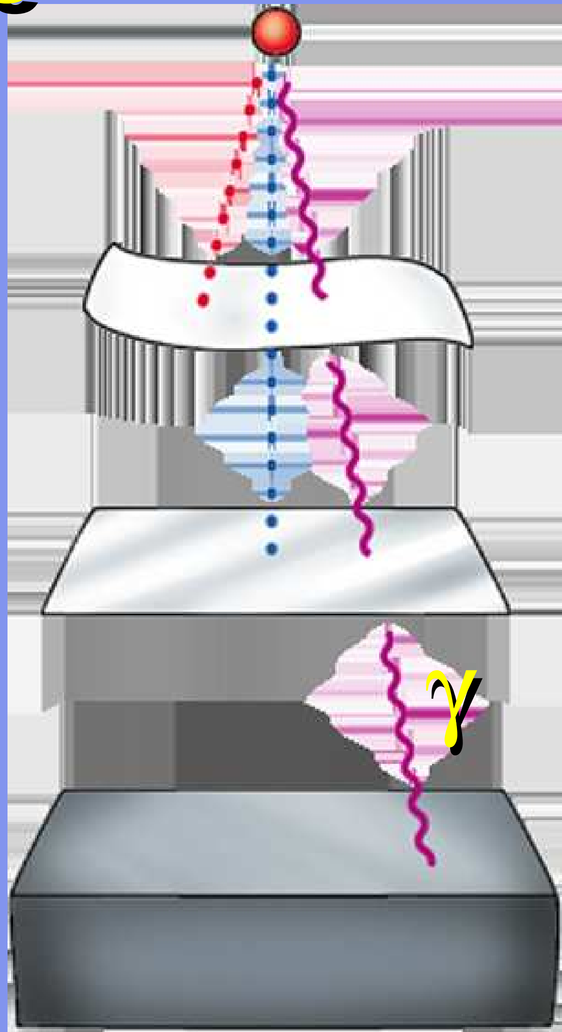


Paper

Aluminum

Lead

Radioactive Source



Paper

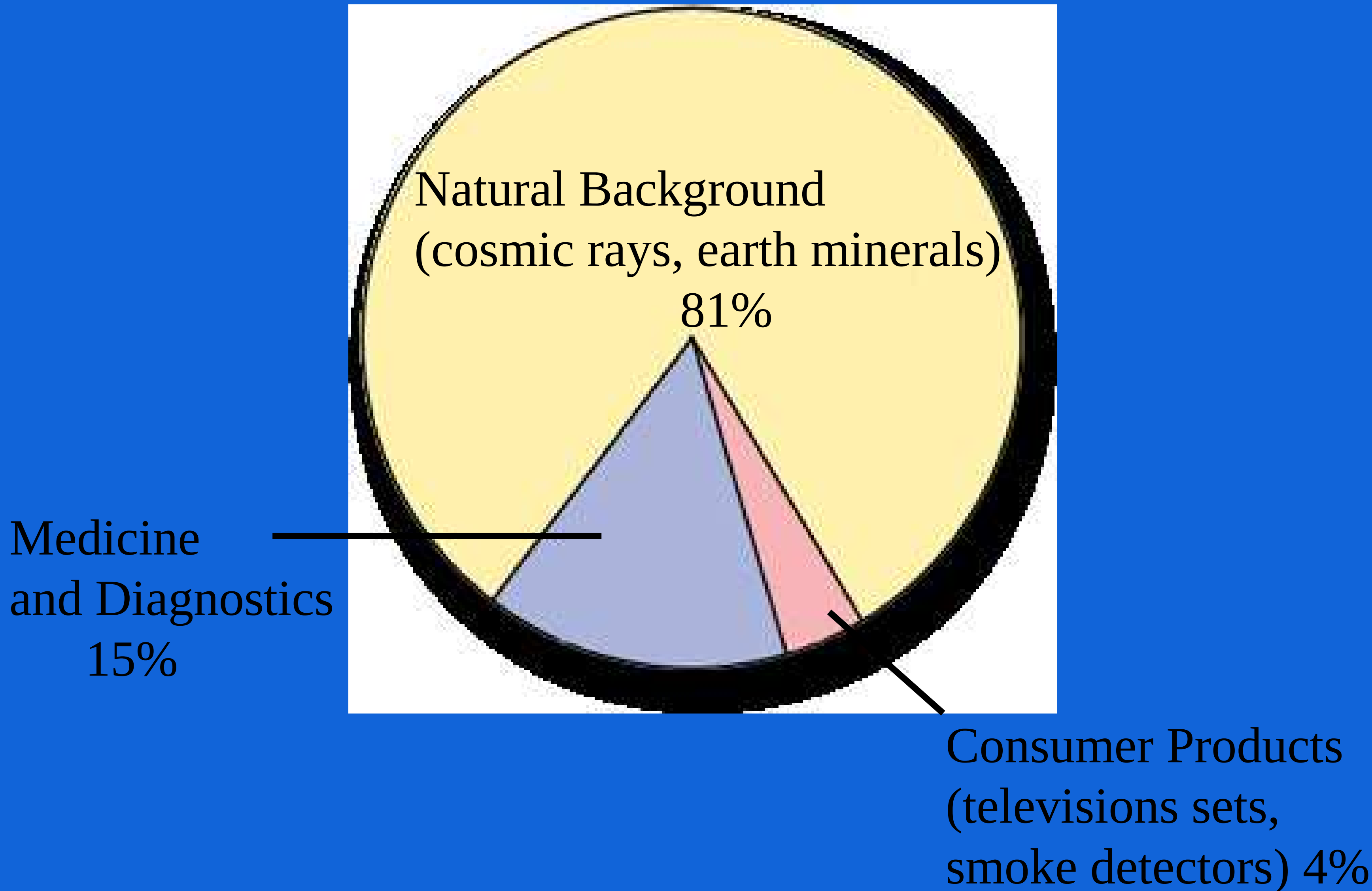
Aluminum

Lead

Radioactivity Is a Natural Phenomenon

Origins of radiation exposure

Origins of radiation exposure



Unit of radiation exposure

Unit of radiation exposure

rad

Unit of radiation exposure

$$\text{rad} = \frac{\text{0.01 joule radiant energy}}{\text{kilogram of tissue}}$$

Some forms of radiation are more harmful to living organisms than others…

Ability to cause harm is given in "rem"

---

rem = rad x factor

Particle	Dosage	Factor	Health effect

Particle	Dosage		Factor		Health effect
alpha	1 rad	x	10	=	10 rem

Particle	Dosage		Factor		Health effect
alpha	1 rad	x	10	=	10 rem
beta	10 rad	x	1	=	10 rem

1 rem = 1000 millirem

(mrem)

Average annual exposure per person In the United States

---

about 360 mrem

Major Source

Radon - 222

Typical Annual Radiation Exposure

Source	Typical Amount Received in 1 Year (millirems)
Natural Origin	
Cosmic radiation	26
Ground	33
Air (radon-222)	198
Human tissues (postassium-40; radium-226)	35
Human Origin	
Medical procedures	
Diagnostic X rays	33
Nuclear medicine	15
Television tubes, other consumer products	11
Weapons-test fallout	1

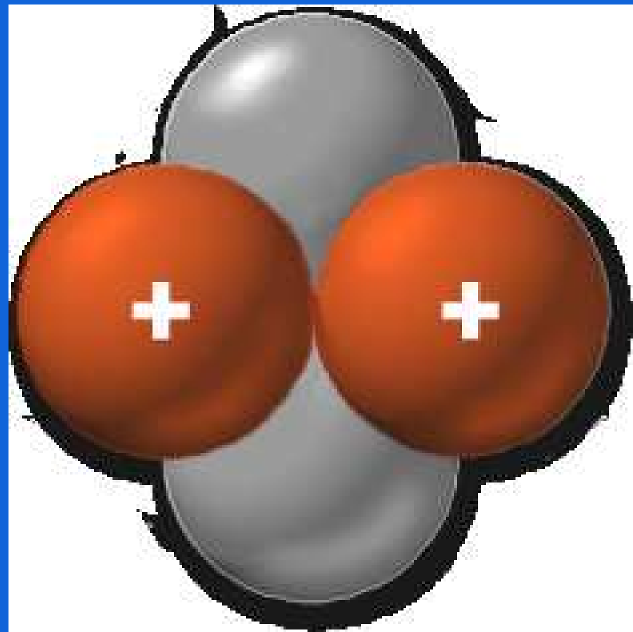
Radioactive Isotopes Are Useful
as Tracers
and for Medical Imaging

Uses of Some Radioactive Isotopes

Isotope	Usage
Calcium-47	Study of bone formation in mammals
Californium-252	Inspect airline luggage for explosives
Hydrogen-3 (tritium)	Life-science and drug-metabolism studies to ensure safety of potential new drugs
Iodine-131	Diagnose and treat thyroid disorders
Iridium-192	Test integrity of pipeline welds, boilers, and aircraft parts
Thallium-201	Cardiology and for tumor detection
Xenon-133	Lung-ventilation and flood-flow studies

Source: Nuclear Regulatory Council

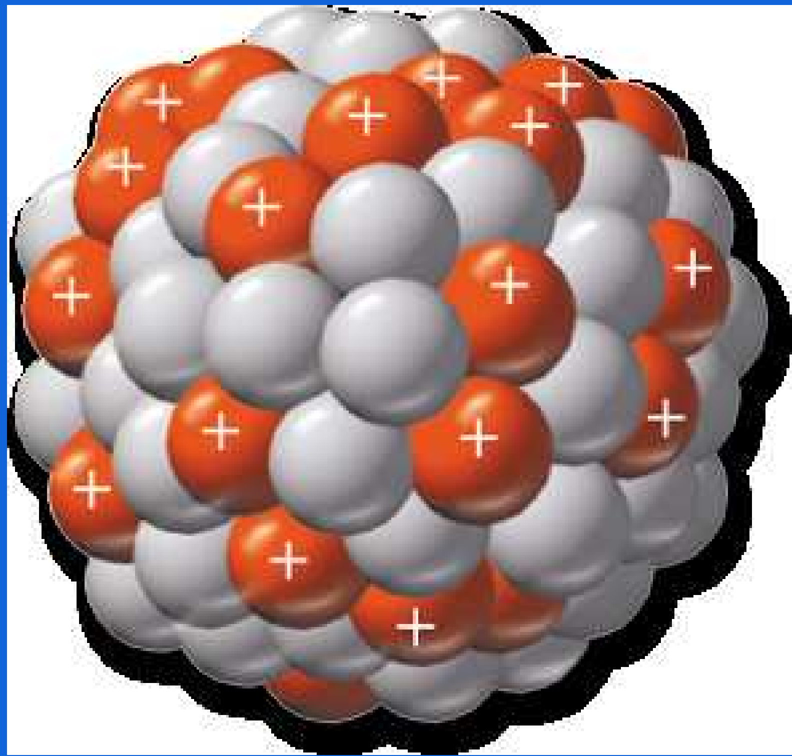
Radioactivity Results from an Imbalance of Forces in the Nucleus

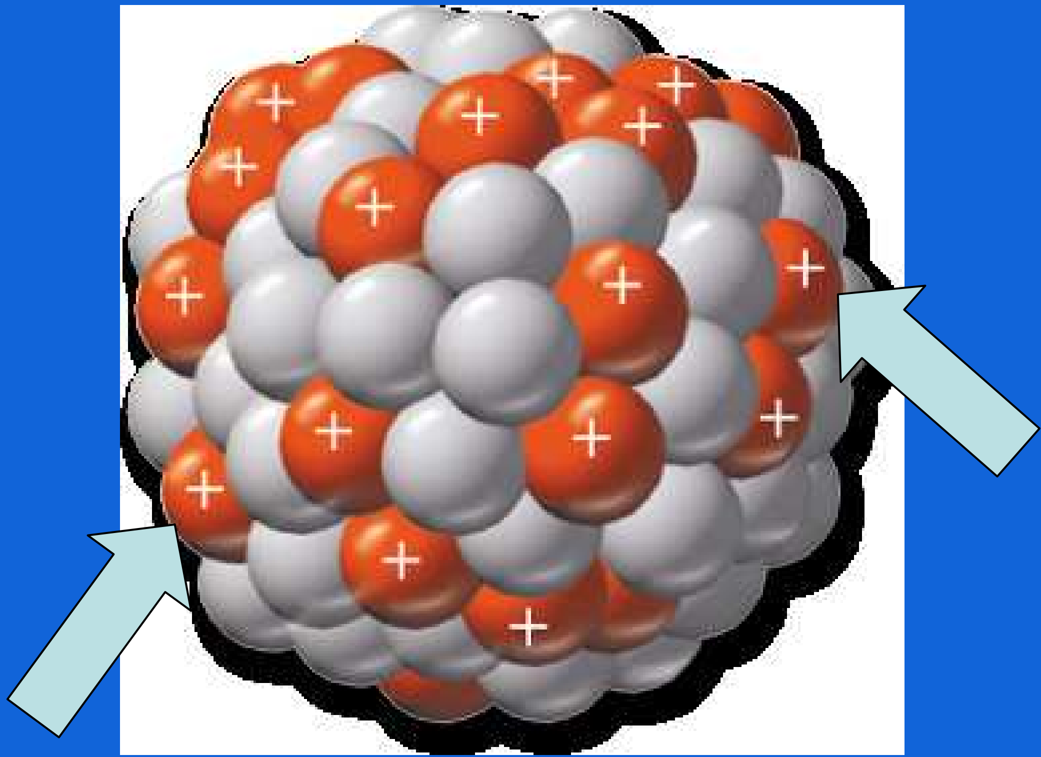


Helium nucleus

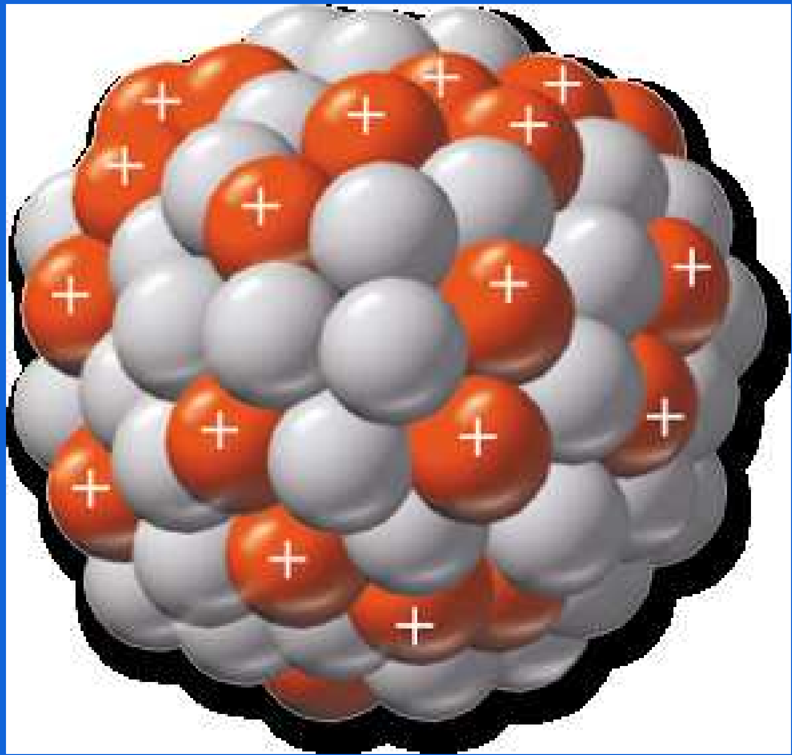
Strong Nuclear Force

An attractive force that acts between all nucleons





These protons are not normally attracted to each other



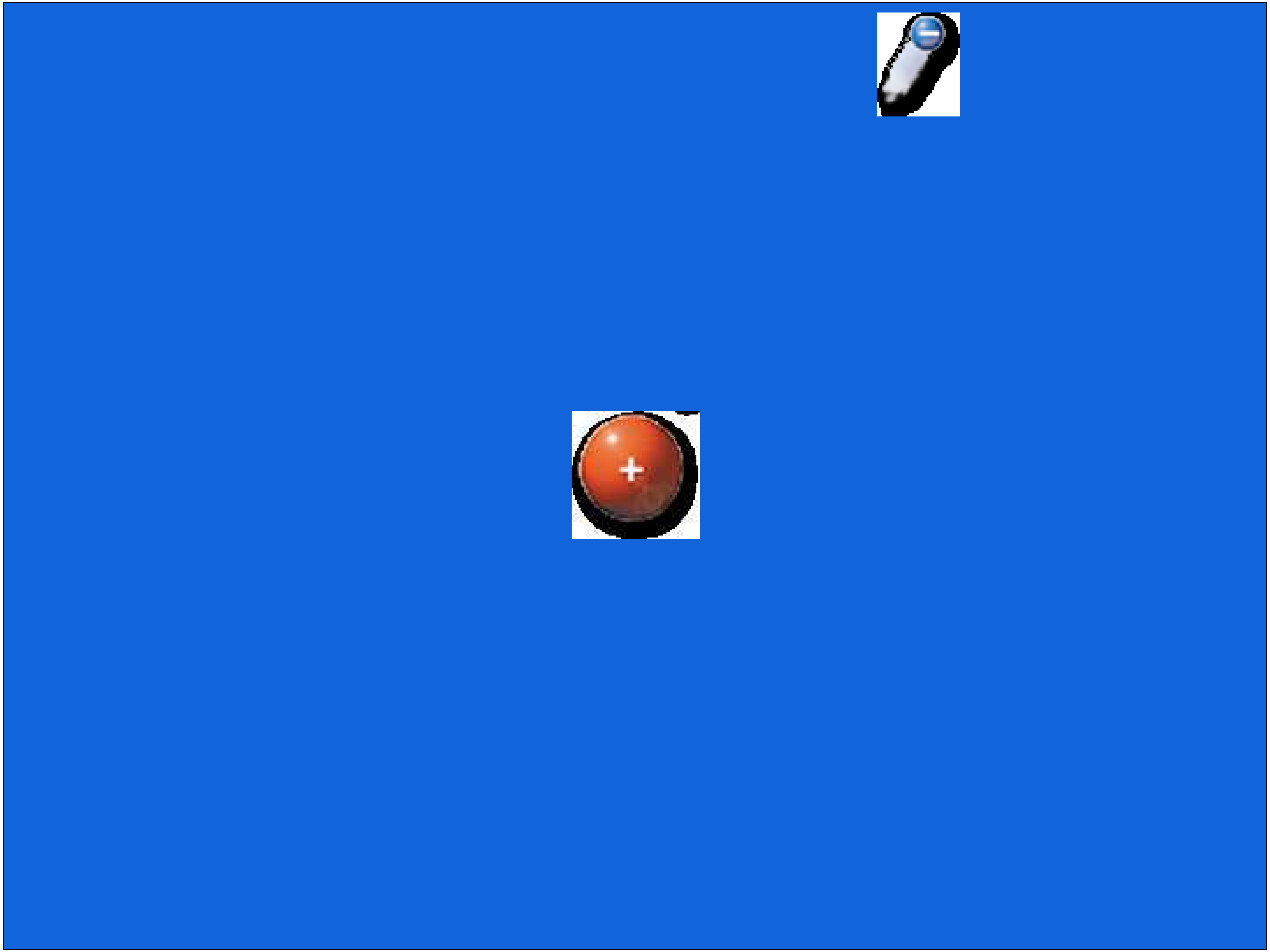
Neutrons are needed to create the strong nuclear force

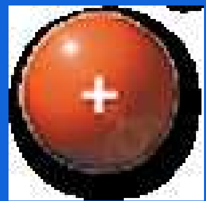
There is a limit to the number of neutrons that can be added to an atomic nucleus...

...neutrons need to have protons around them in order to remain stable...

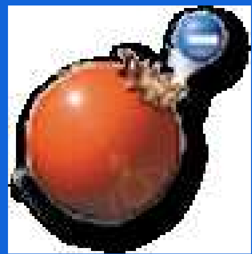
...with too many neutrons, and not enough protons, something most bizarre occurs...

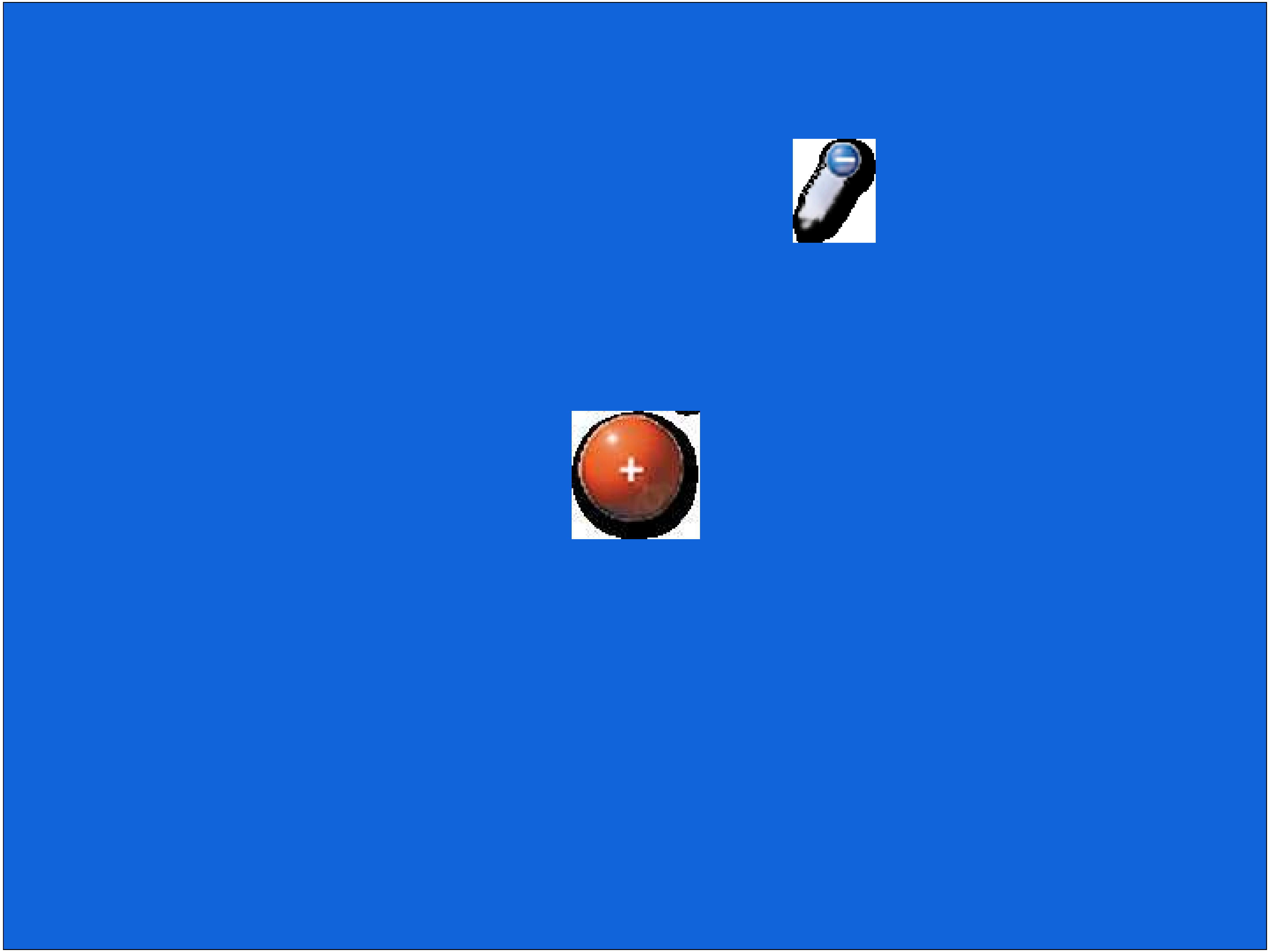
A lone neutron…

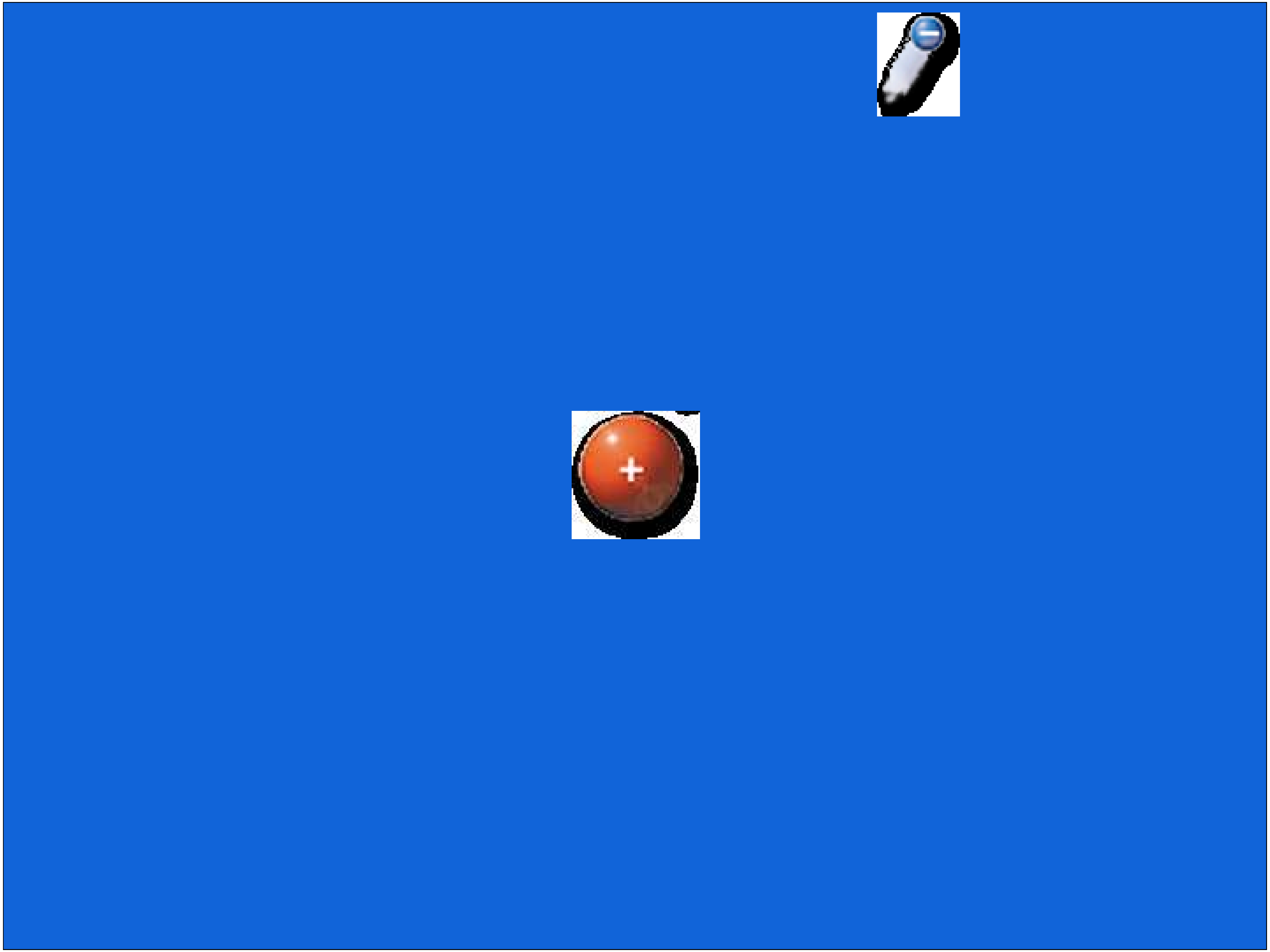


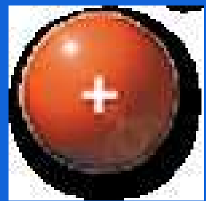


...converts to a proton!









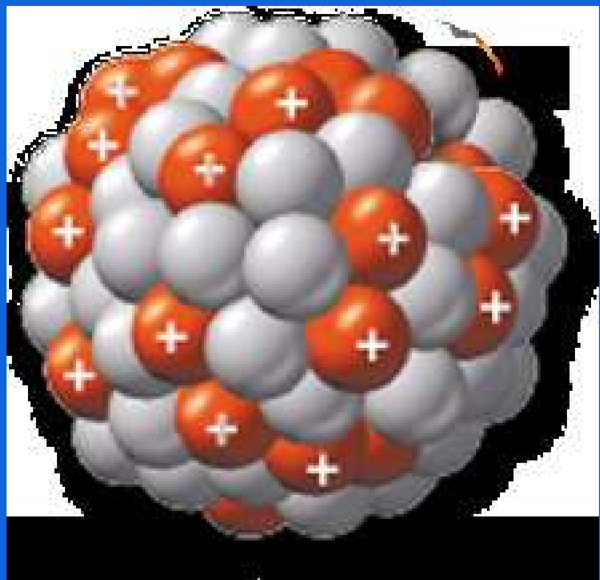
Proton to Neutron ratios

Proton to Neutron ratios

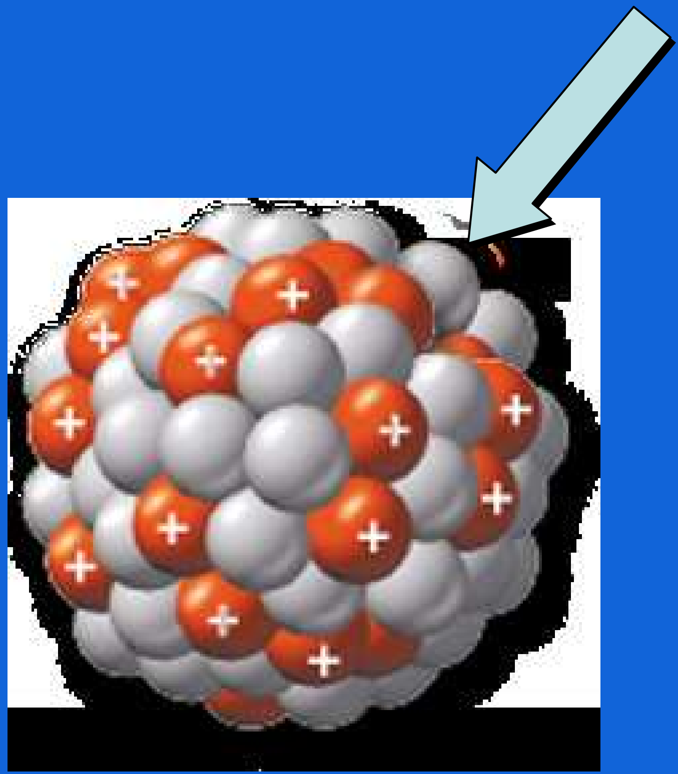
Optimum 1 to 1

Proton to Neutron ratios

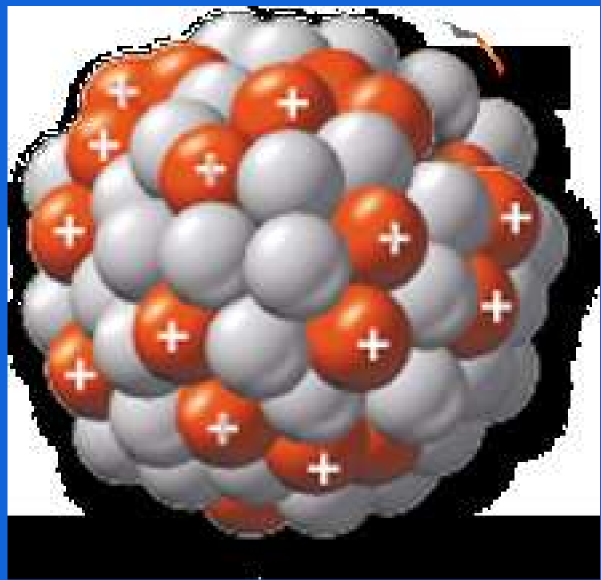
Optimum	1 to 1
Limit	1 to 1.4

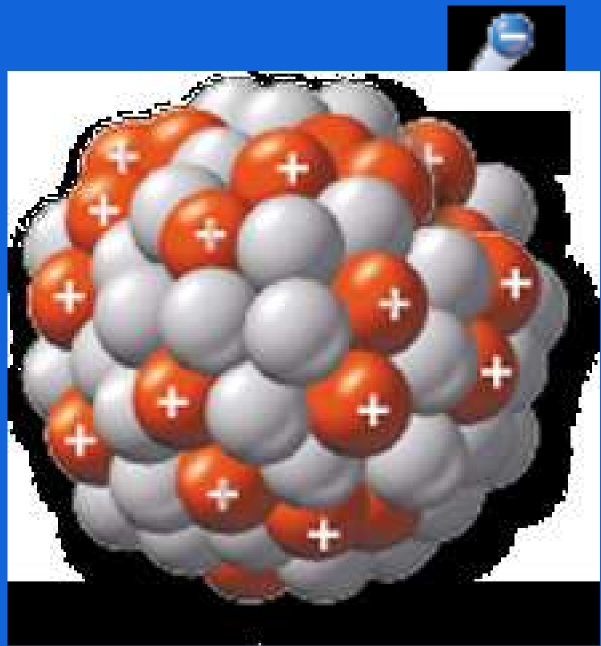


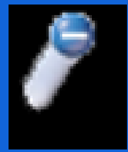
A nucleus with “too many neutrons”

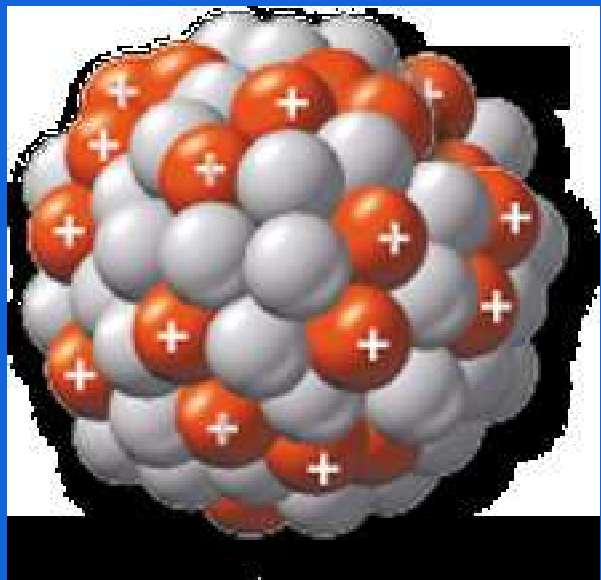


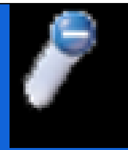
A nucleus with “too many neutrons”

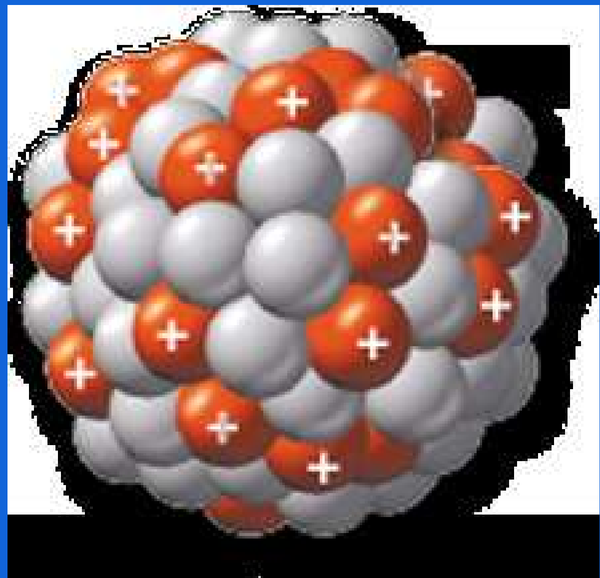


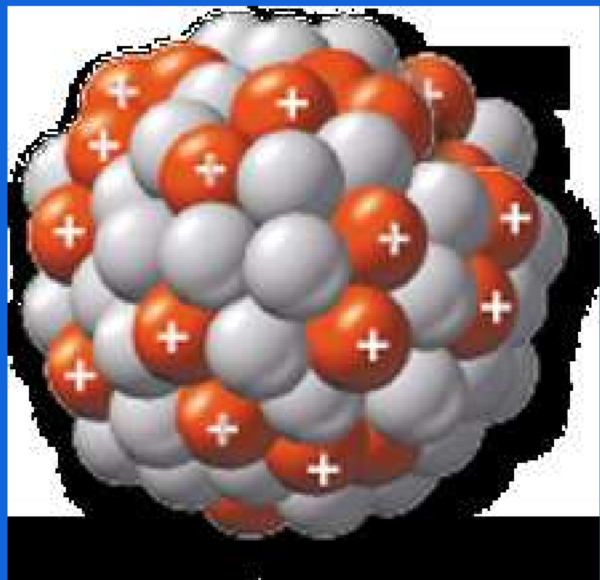




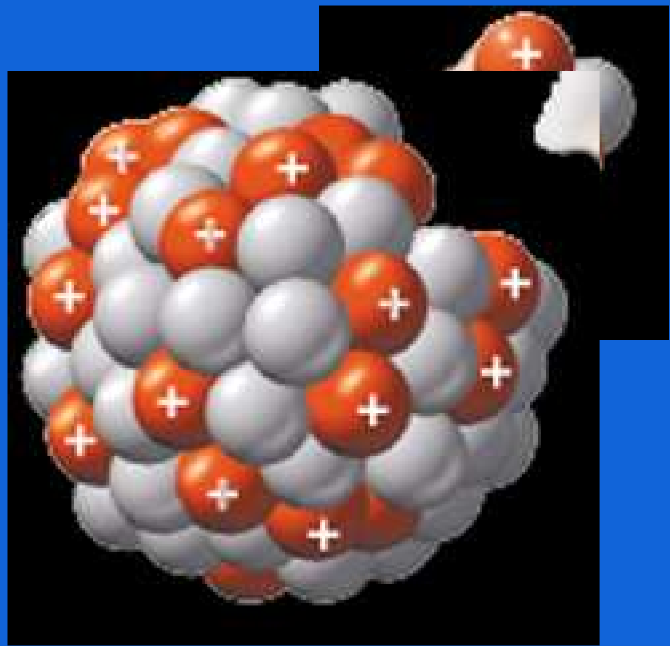


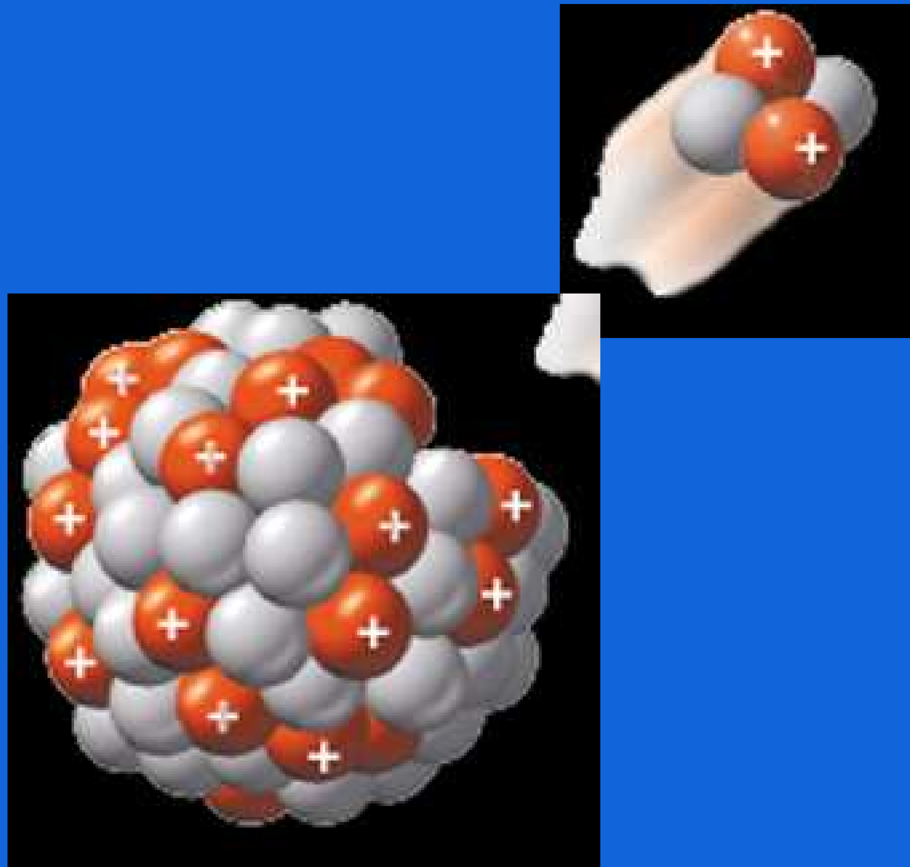


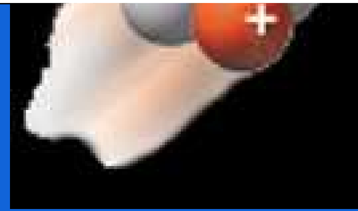


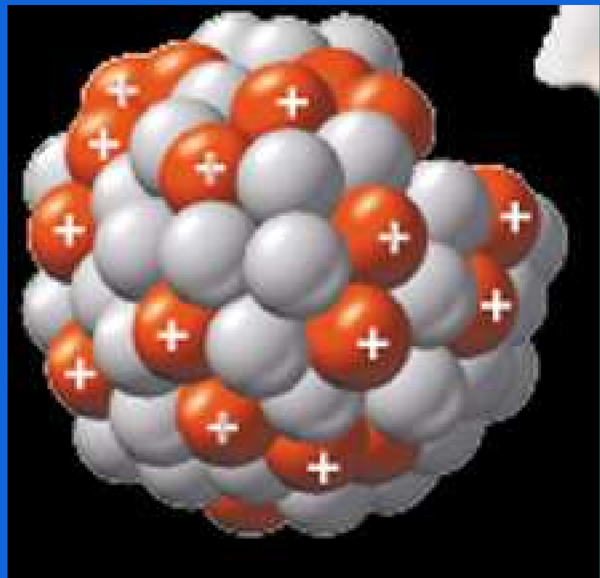


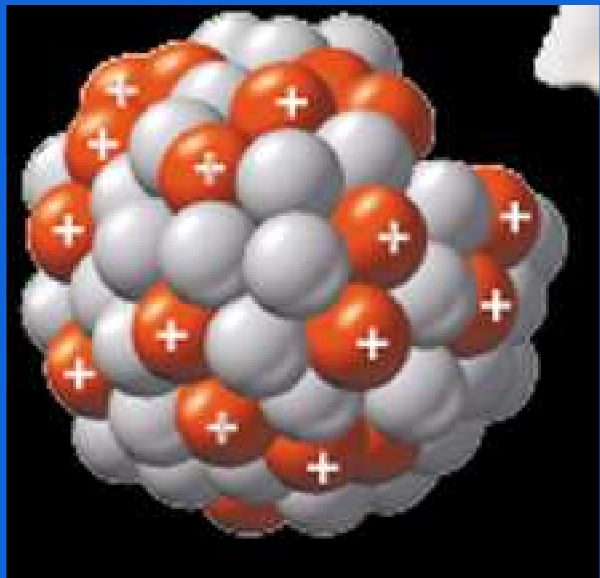
Hmm…extra proton?











The size of the nucleus is limited

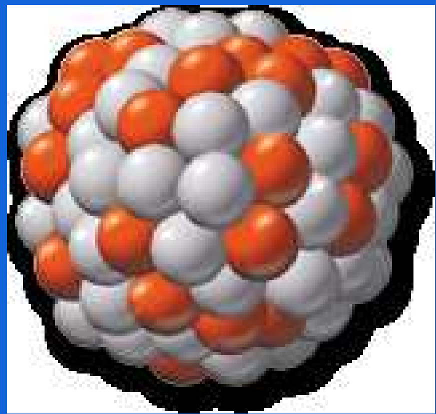
1) The nucleus cannot hold a very large number of protons together.

2) There cannot be an unlimited number of neutrons.

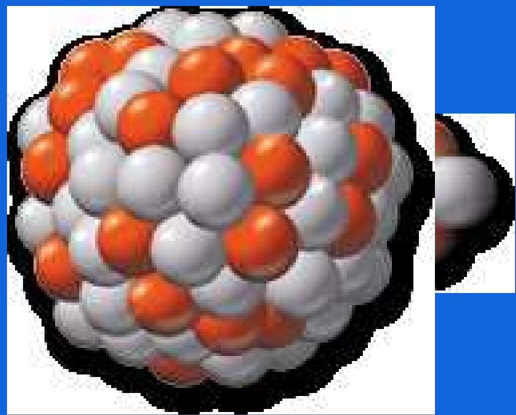
A Radioactive Element Can Transmute to a Different Element

Transmutation

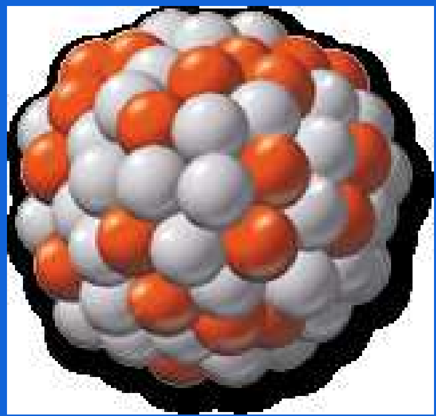
The changing of one element to another



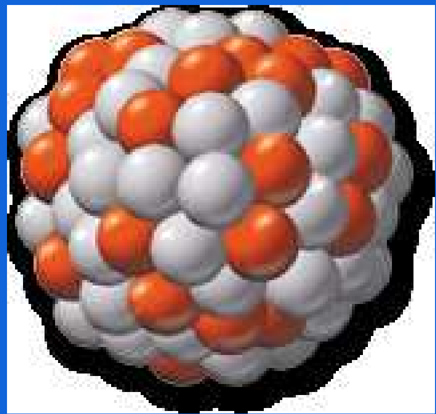
$$^{238}_{92}U$$



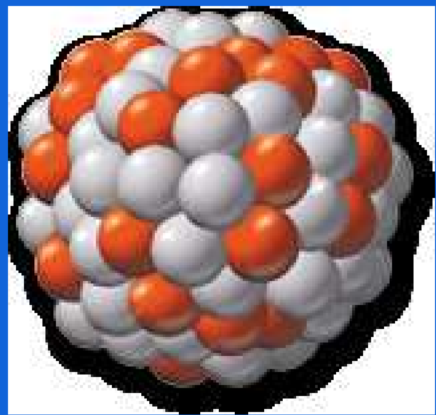
$^{234}_{90}Th$ $^{4}_{2}He$



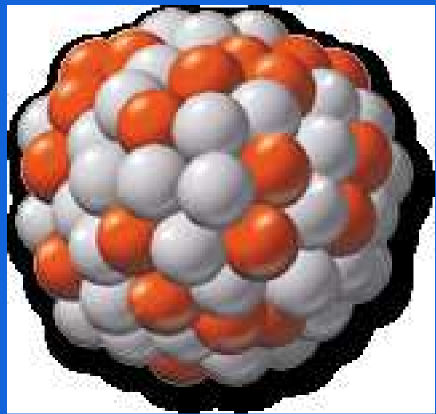
$^{234}_{90}Th$ $^{4}_{2}He$



$^{234}_{90}Th$ $^{4}_{2}He$

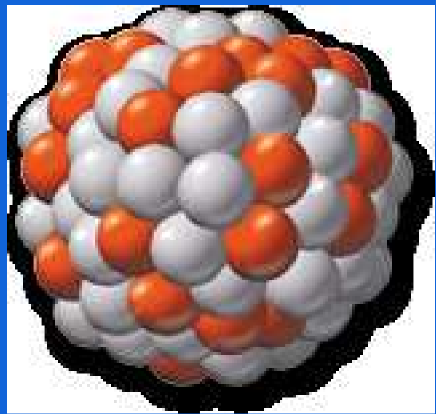


$^{234}_{90}Th$

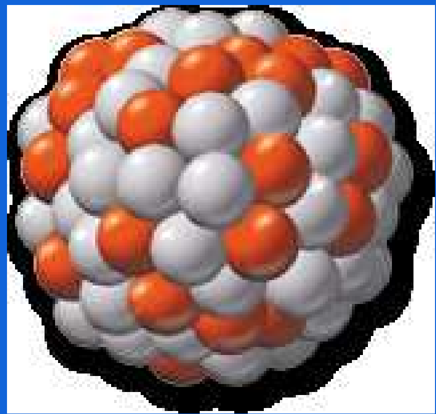


$^{238}_{92}U$

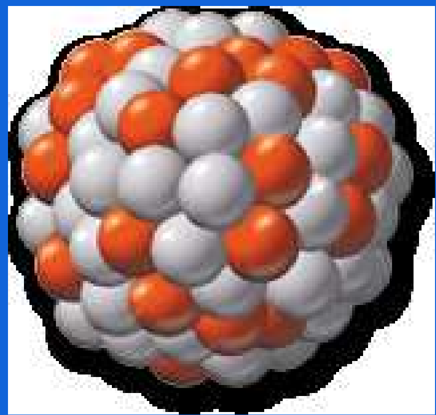
$^{234}_{90}Th$ $^{4}_{2}He$



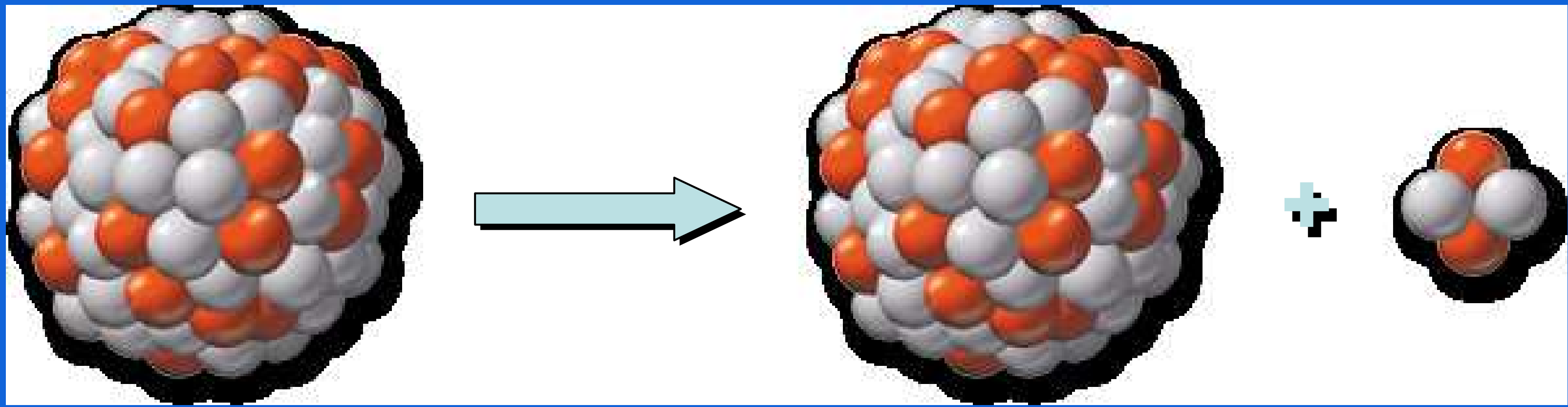
$^{234}_{90}Th$ $^{4}_{2}He$

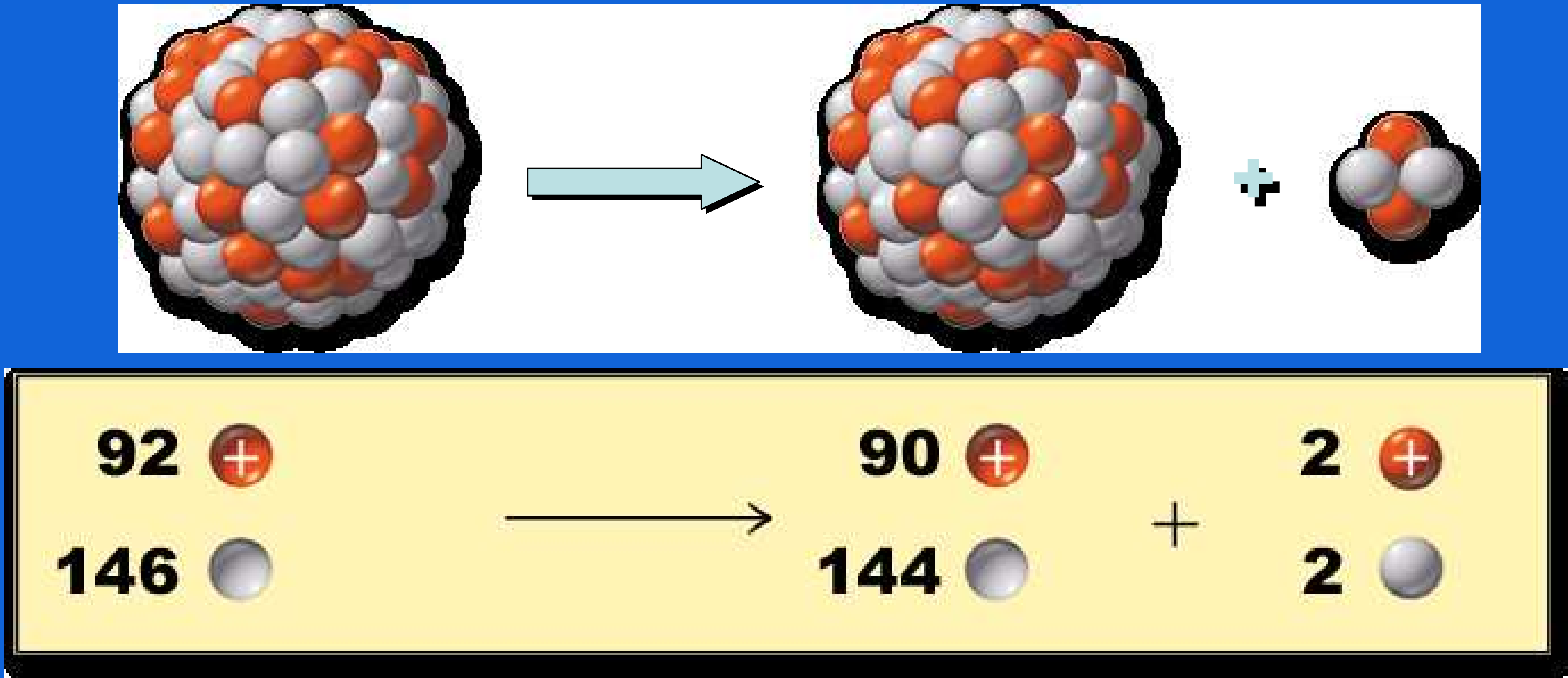


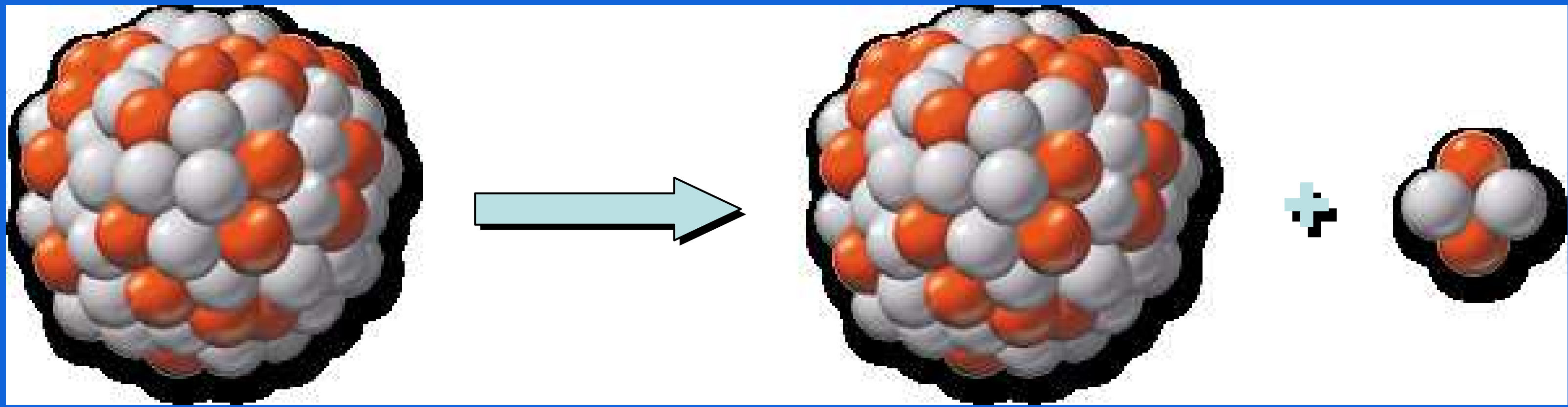
$^{234}_{90}Th$ $^{4}_{2}He$

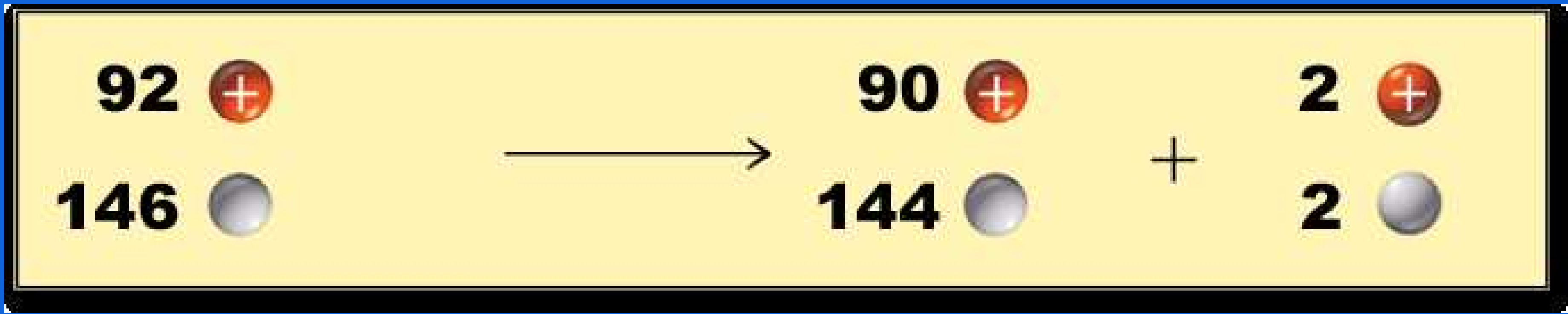


$^{234}_{90}\mathrm{Th}$

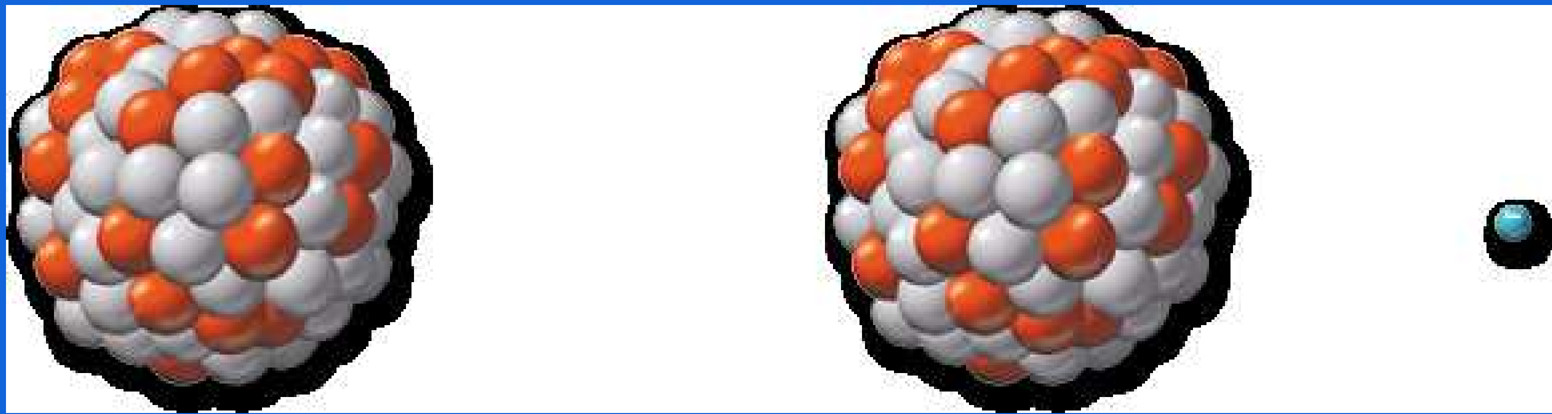


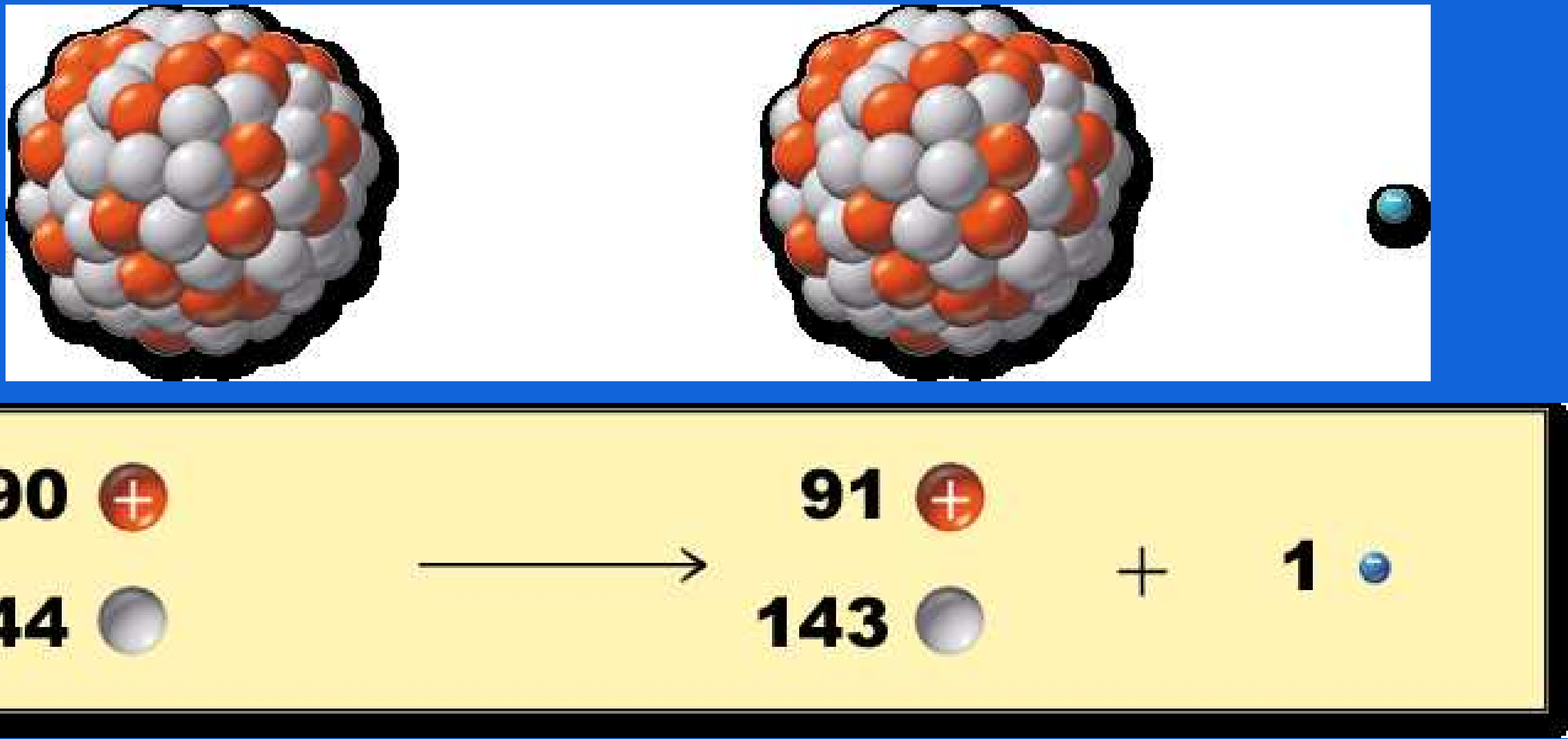

92
146
90
144
+
2
2

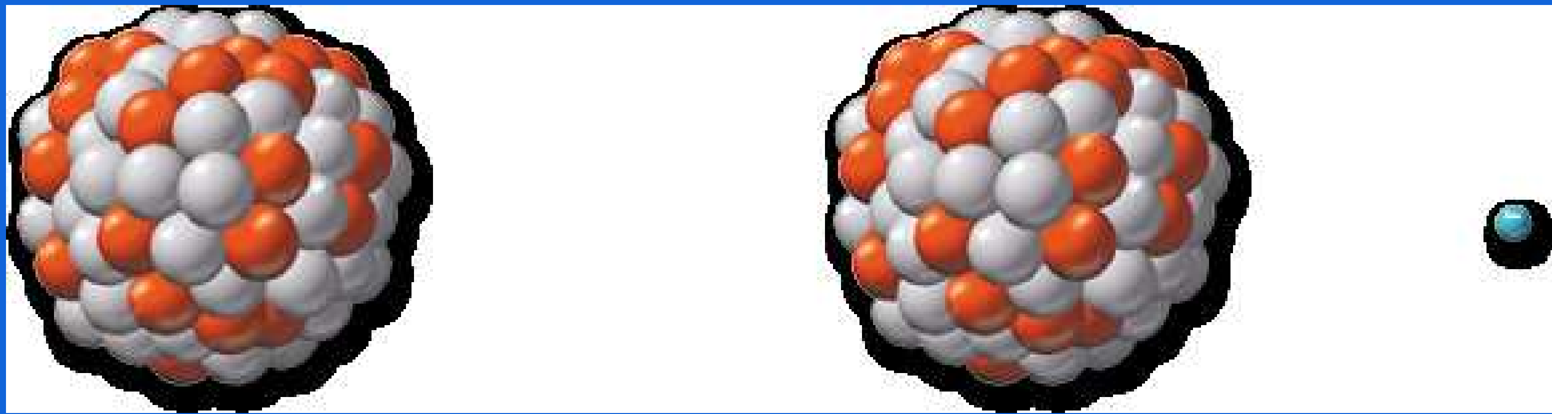


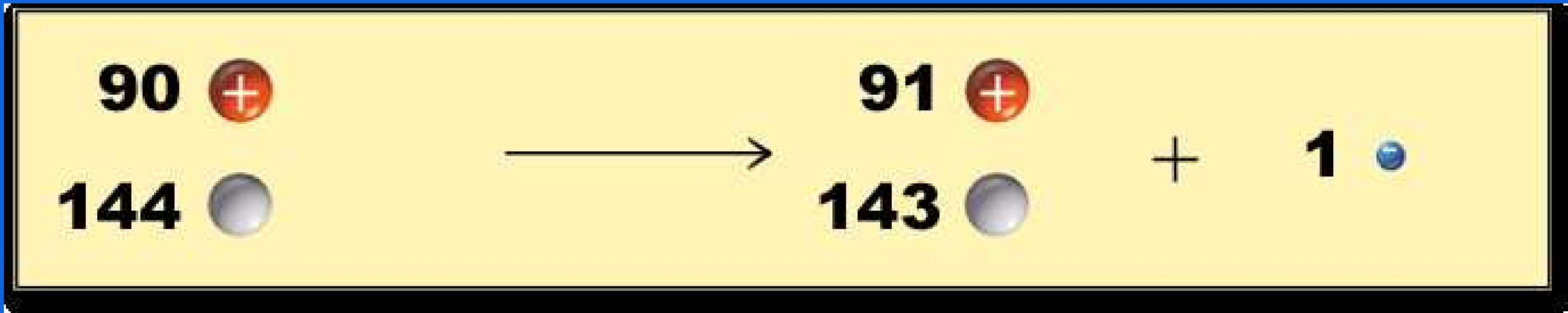


$$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$$




90
144
91
143
+
1





$$^{234}_{90}Th \rightarrow\ ^{234}_{91}Pa +\ ^{0}_{-1}e$$

Radioactive Half-Life

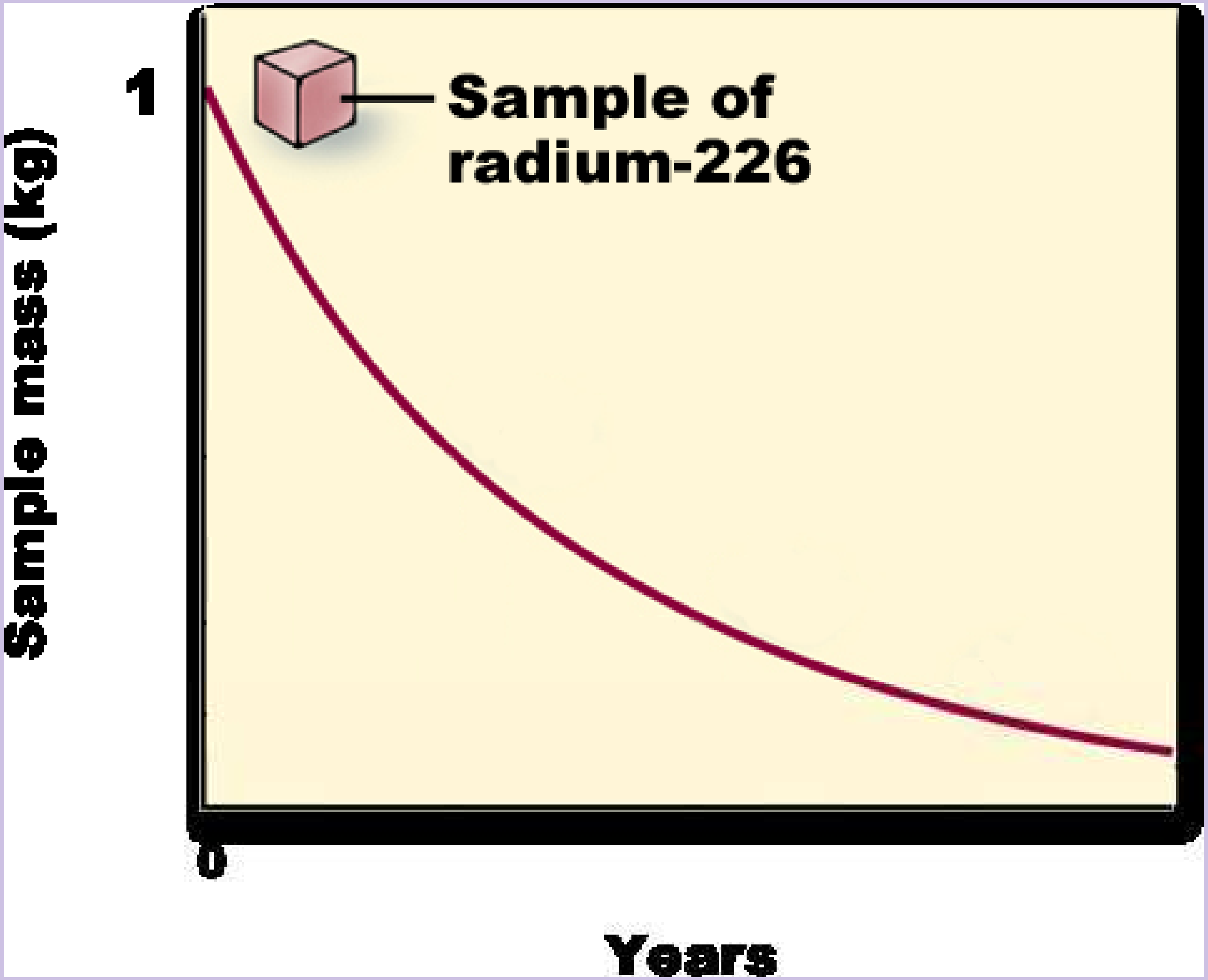
The time it takes for one-half of a radioactive sample to decay

Element	Half-Life
Uranium-238	4.5×10^{9} years

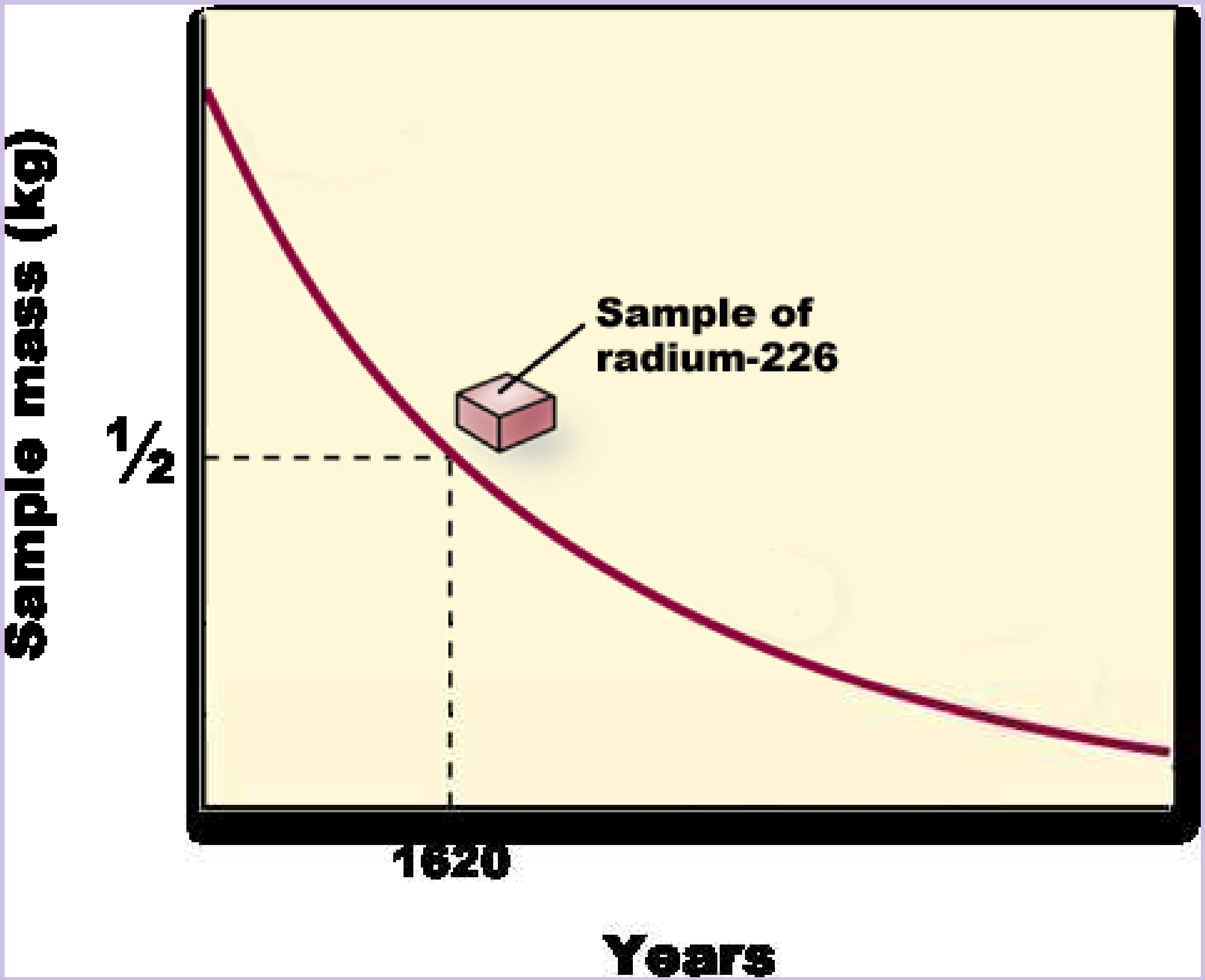
Element	Half-Life
Uranium-238	4.5×10^{9} years
Carbon-14	5730 years

Element	Half-Life
Uranium-238	4.5×10^9 years
Carbon-14	5730 years
Bismuth-210	5.0 days

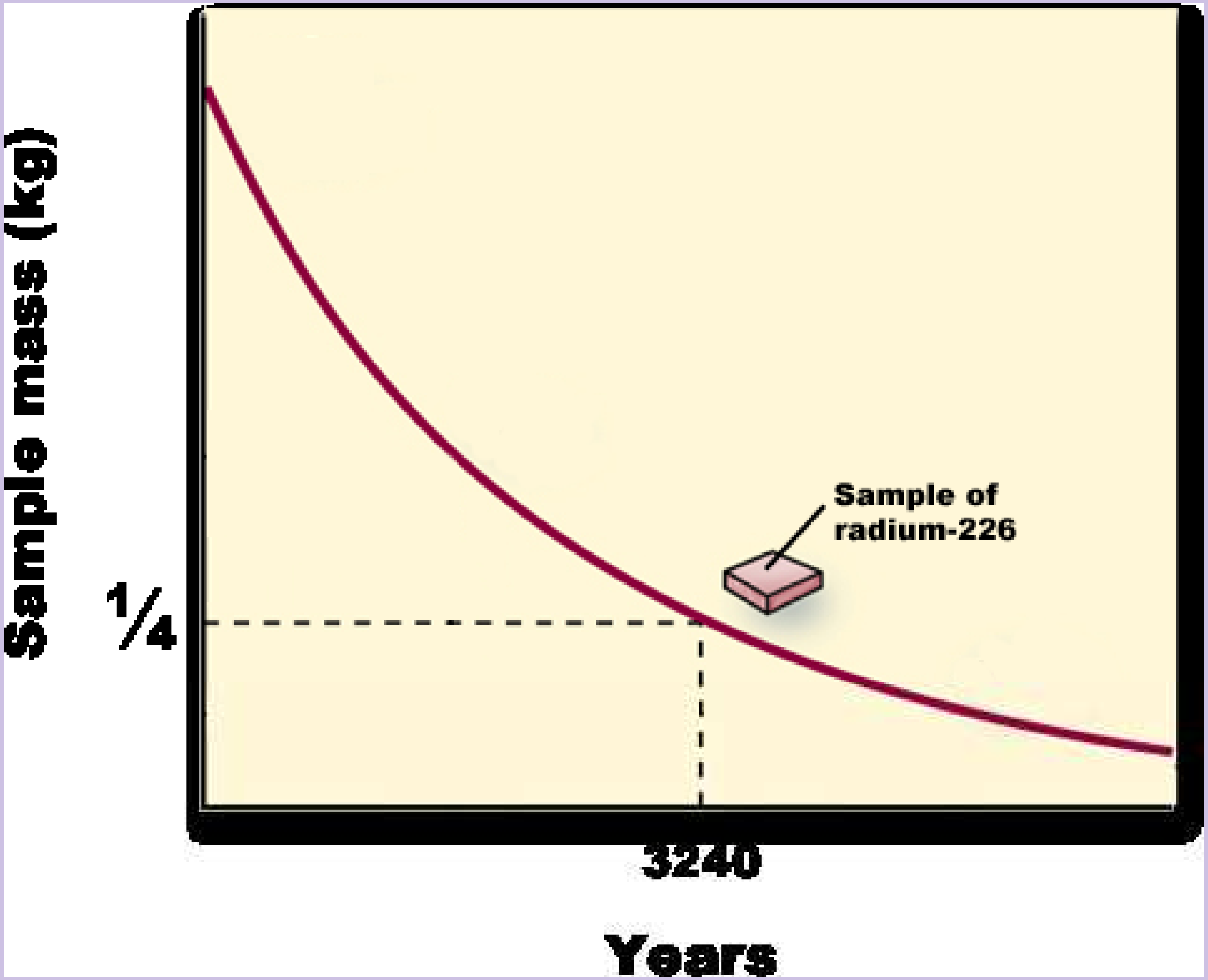
Element	Half-Life
Uranium-238	4.5×10^{9} years
Carbon-14	5730 years
Bismuth-210	5.0 days
Polonium-214	1.6×10^{-4} sec

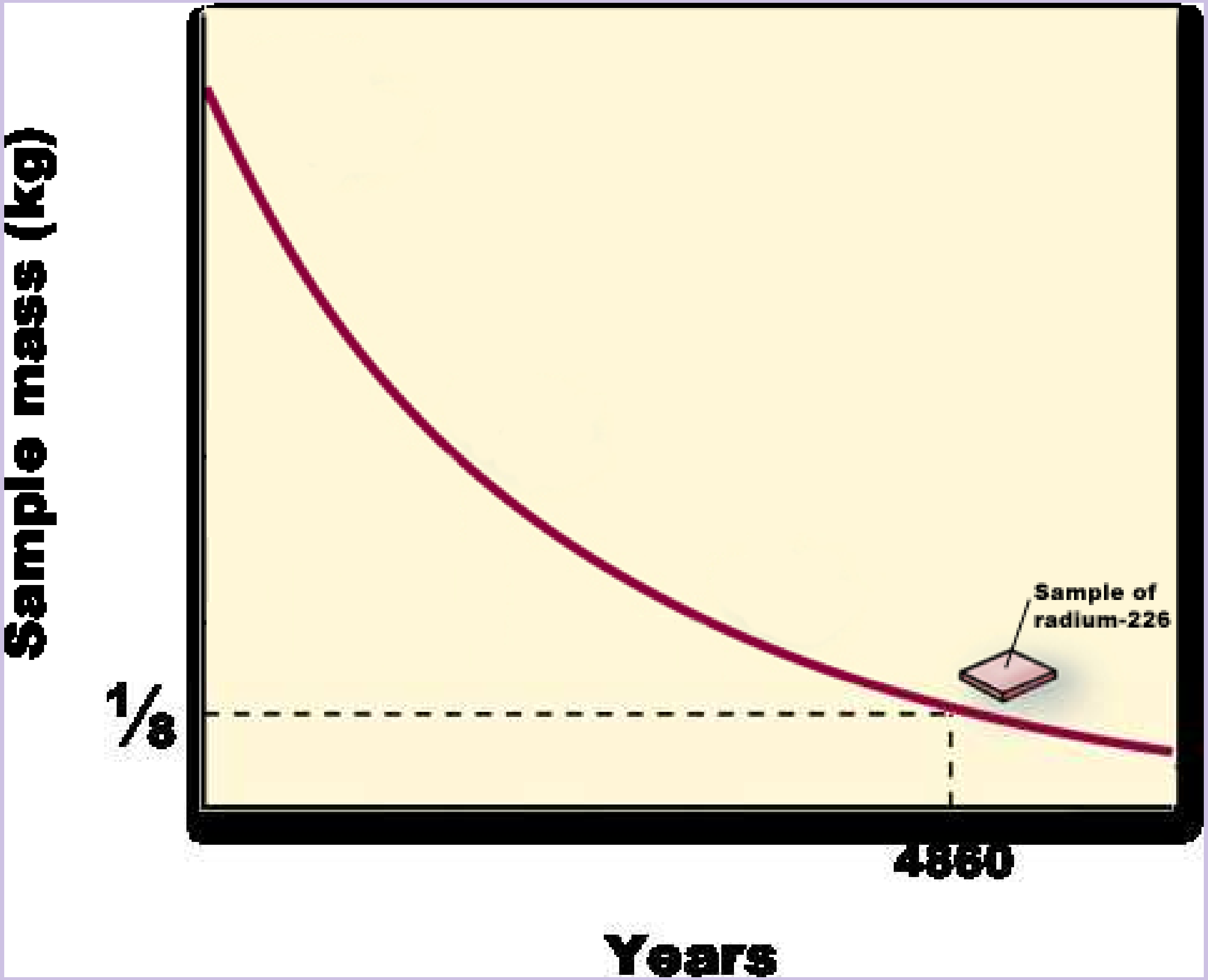


Sample mass (kg)
1
Sample of radium-226
0
Years

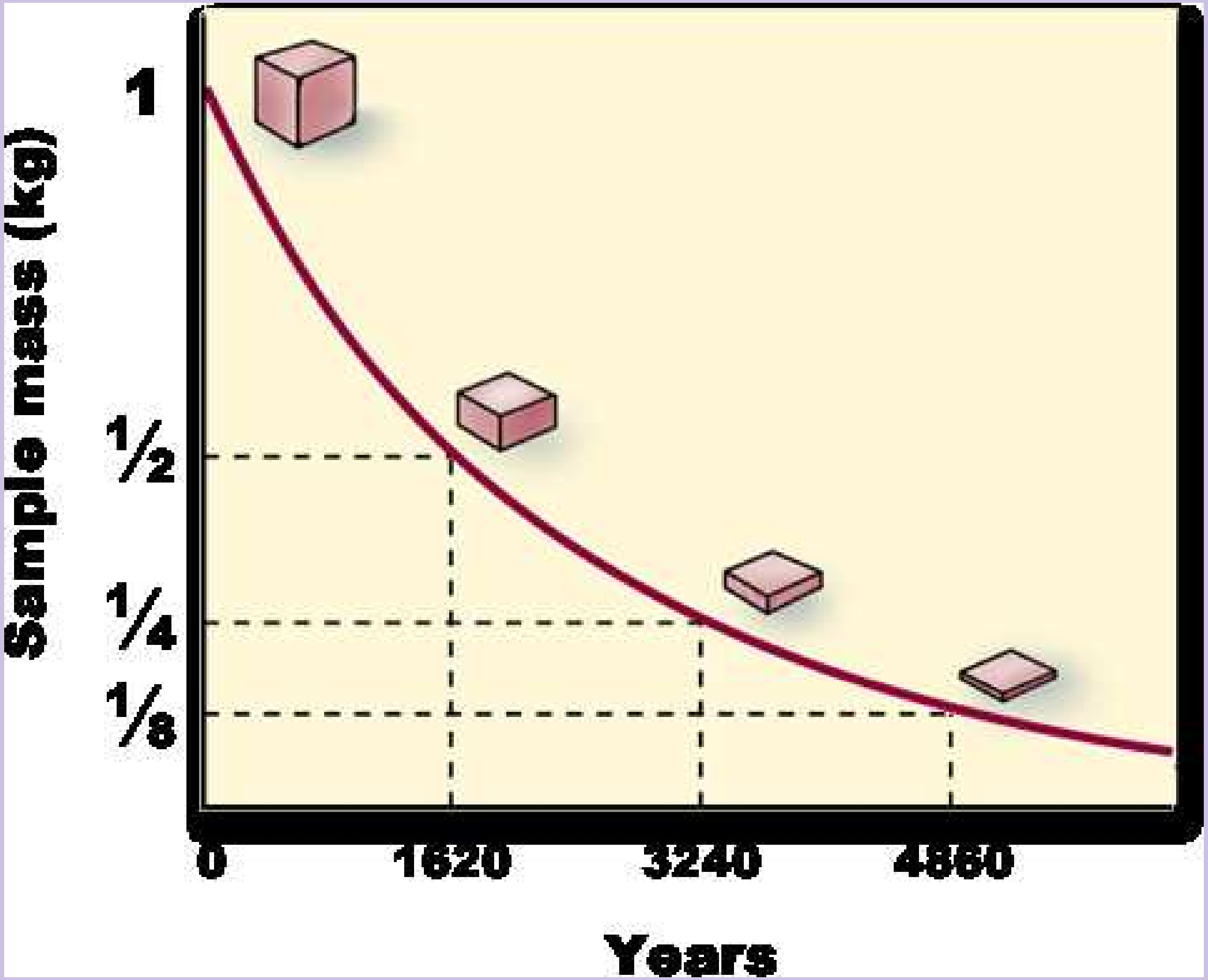


Sample mass (kg)
½
Sample of
radium-226
1620
Years


Sample mass (kg)
¼
Sample of
radium-226
3240
Years



Sample mass (kg)
1/8
Sample of radium-226
4860
Years


Sample mass (kg)
1
½
¼
⅛
0
1620
3240
4860
Years

Radioactive Half-Life

The time it takes for one-half of a radioactive sample to decay

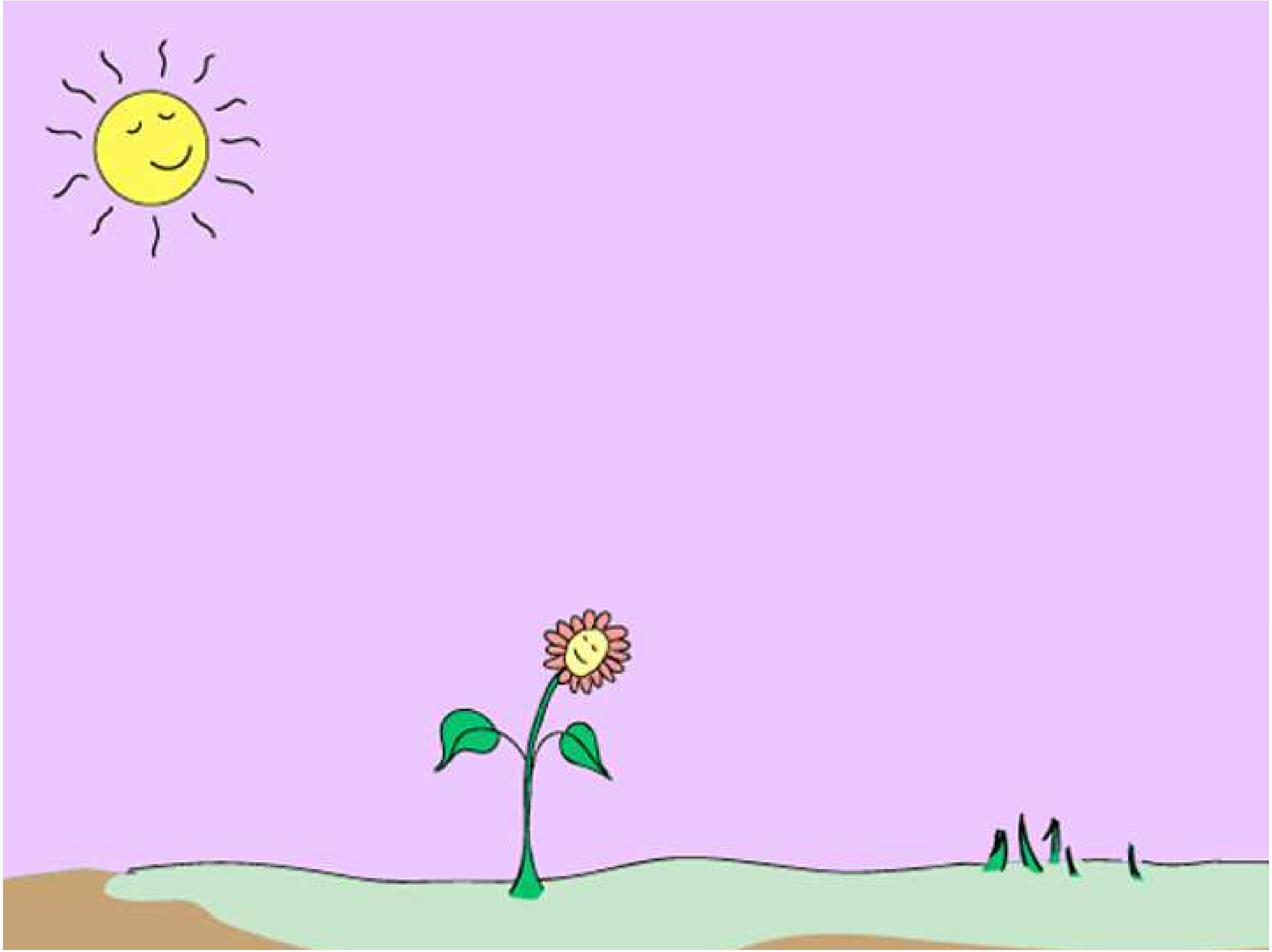
Look at factors of 2

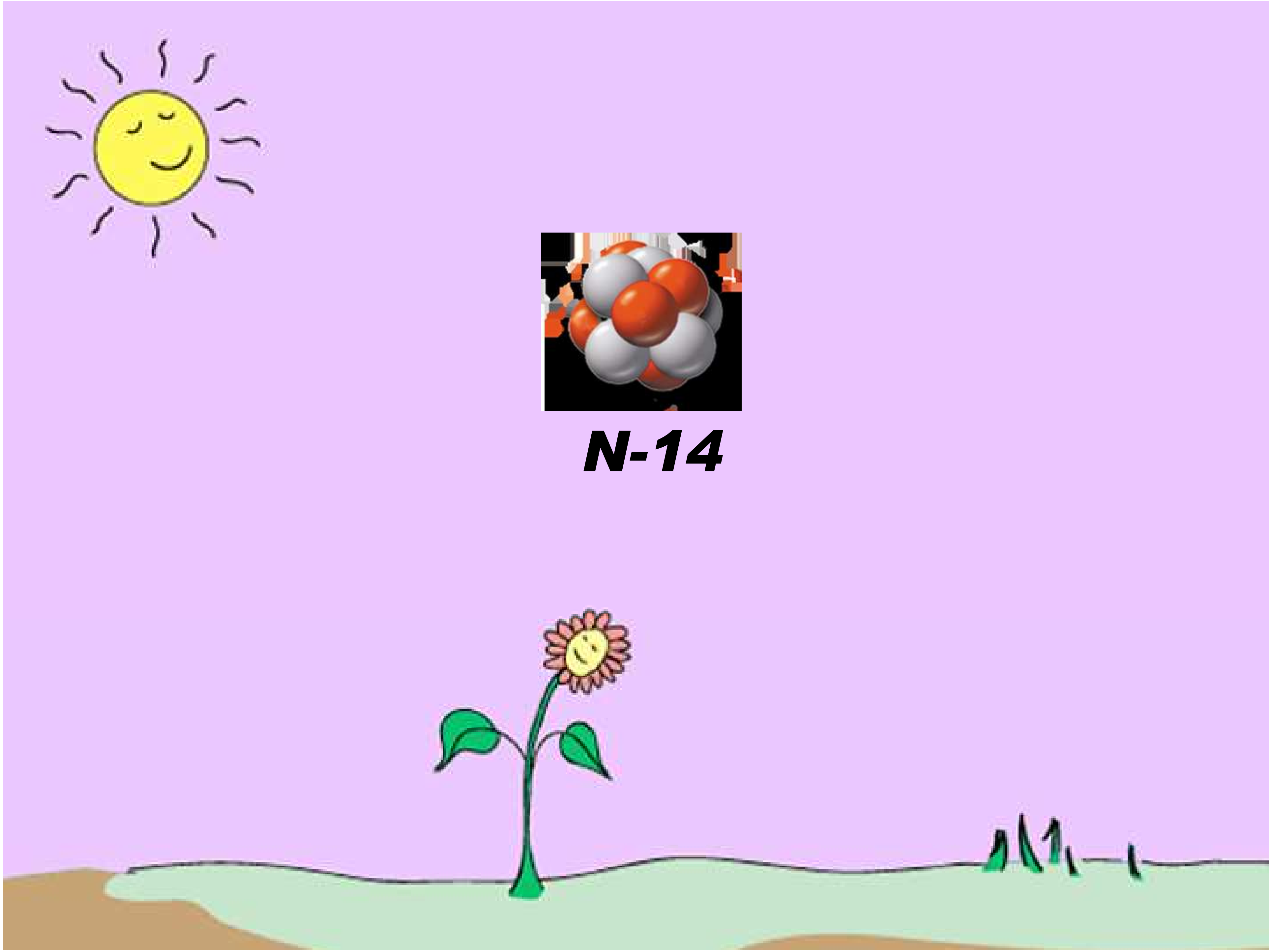
One half-life (1/2)

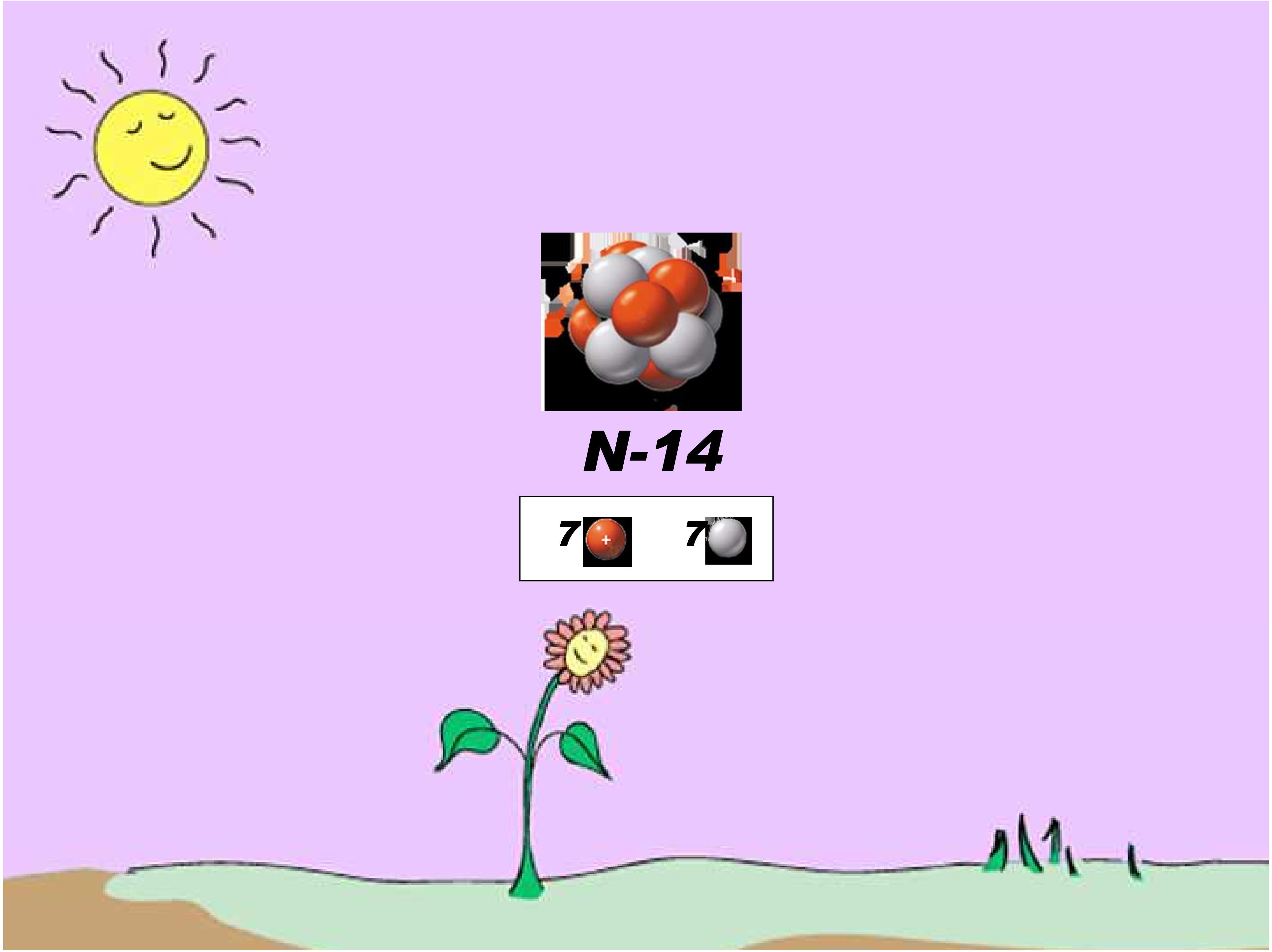
Two half-lives (1/4)

Three half-lives (1/8)

For Example: A material has decreased by ¼ of its original amount it has gone through two half-lives




N-14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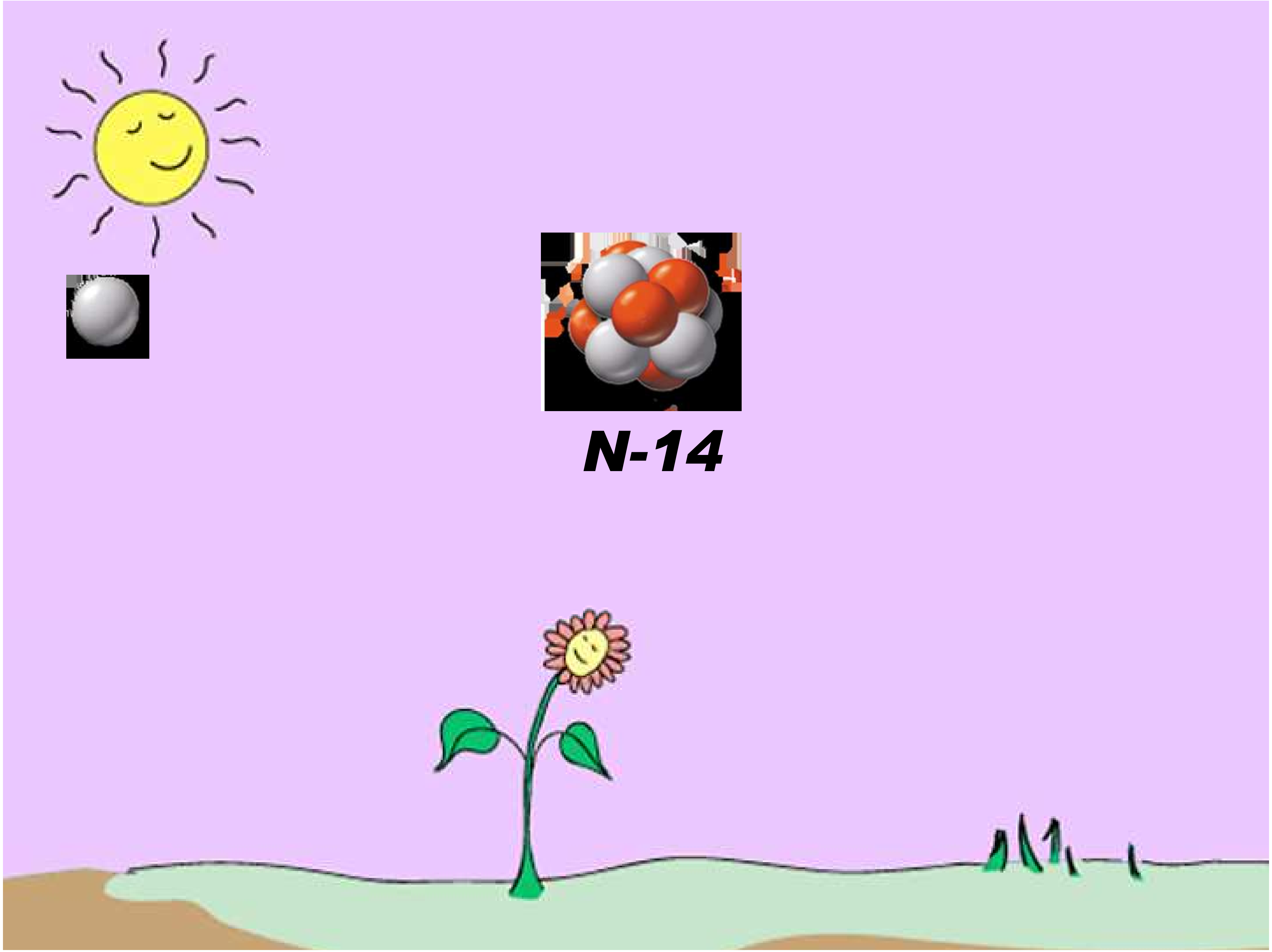
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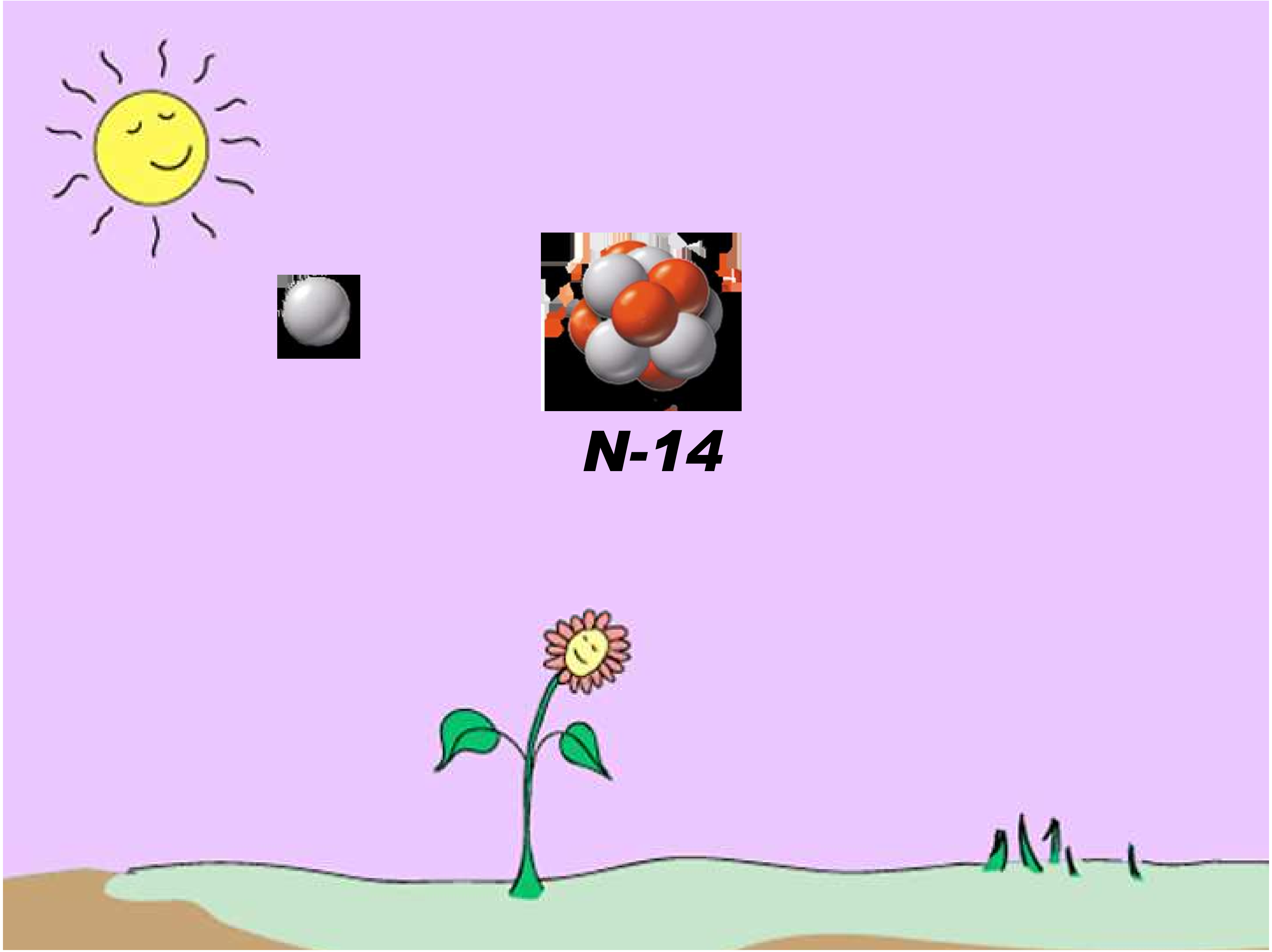
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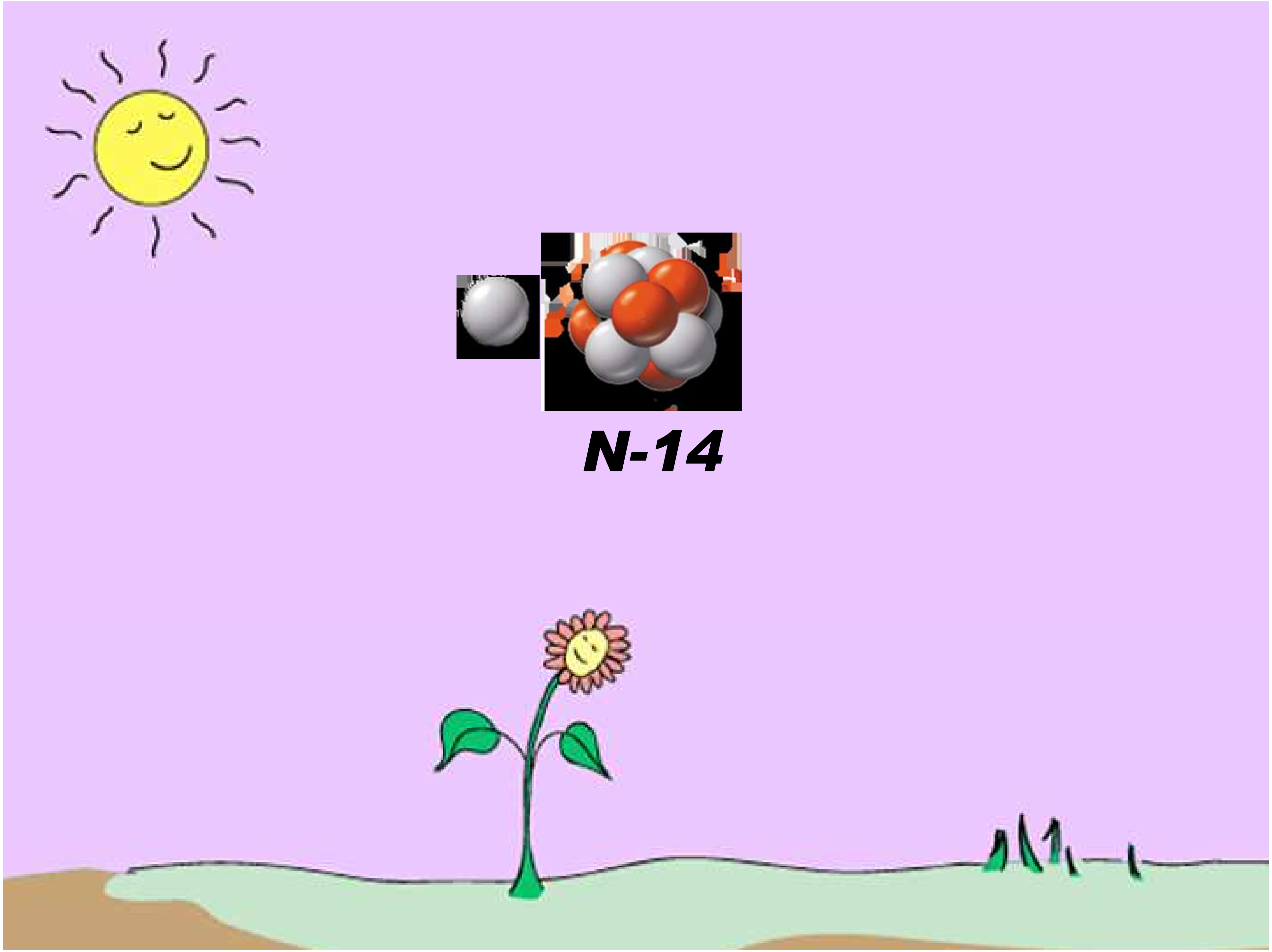
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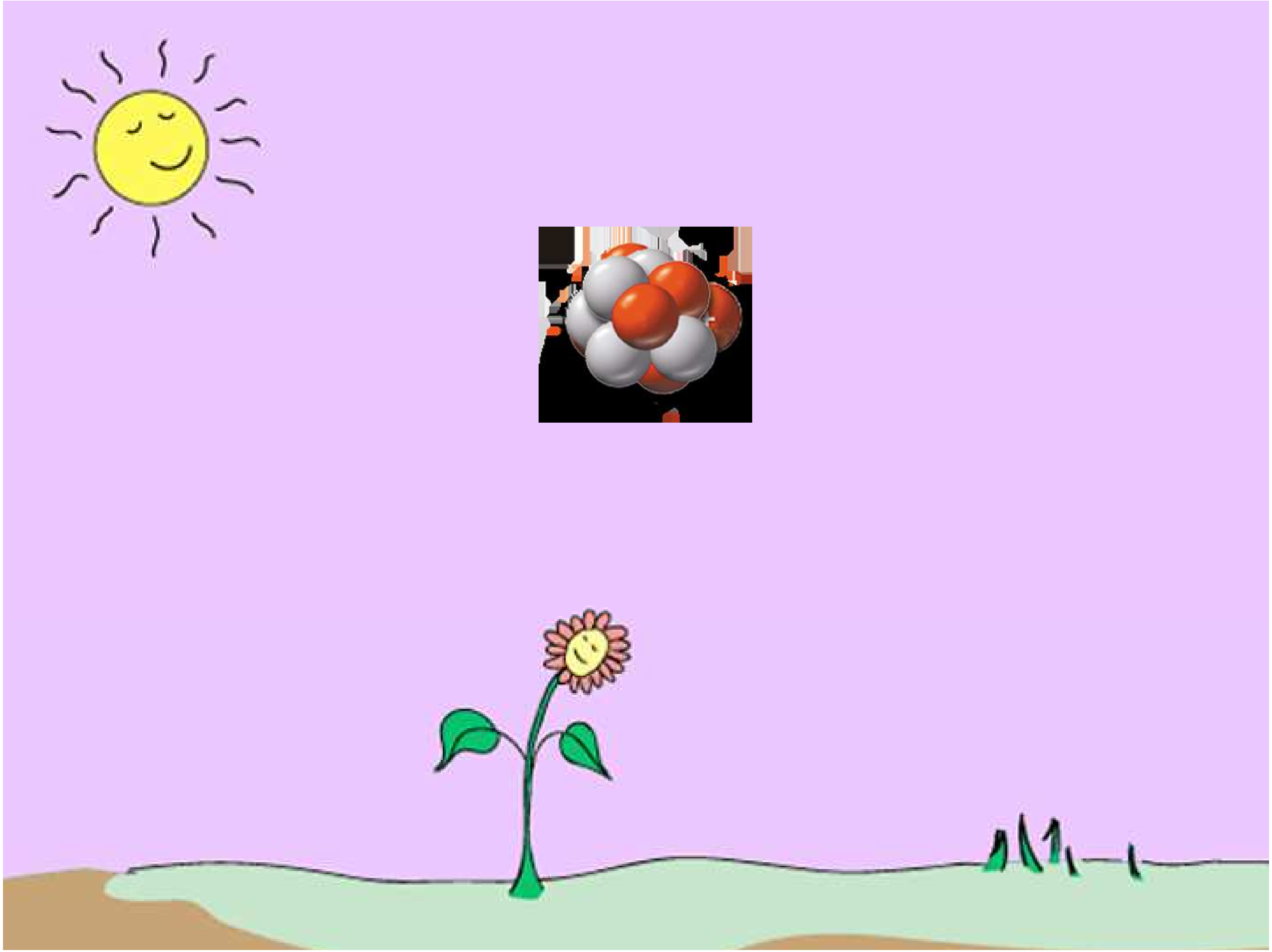

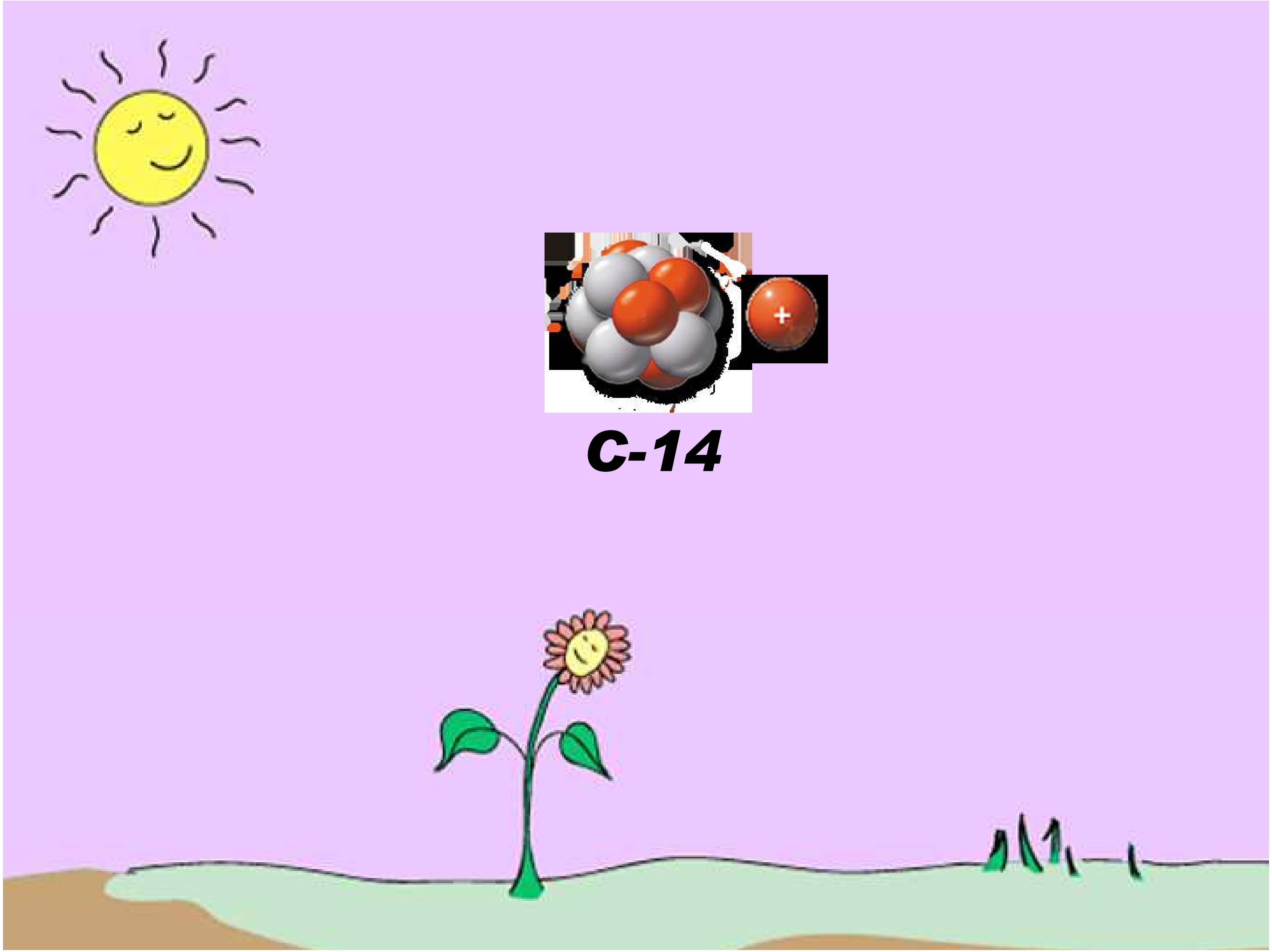
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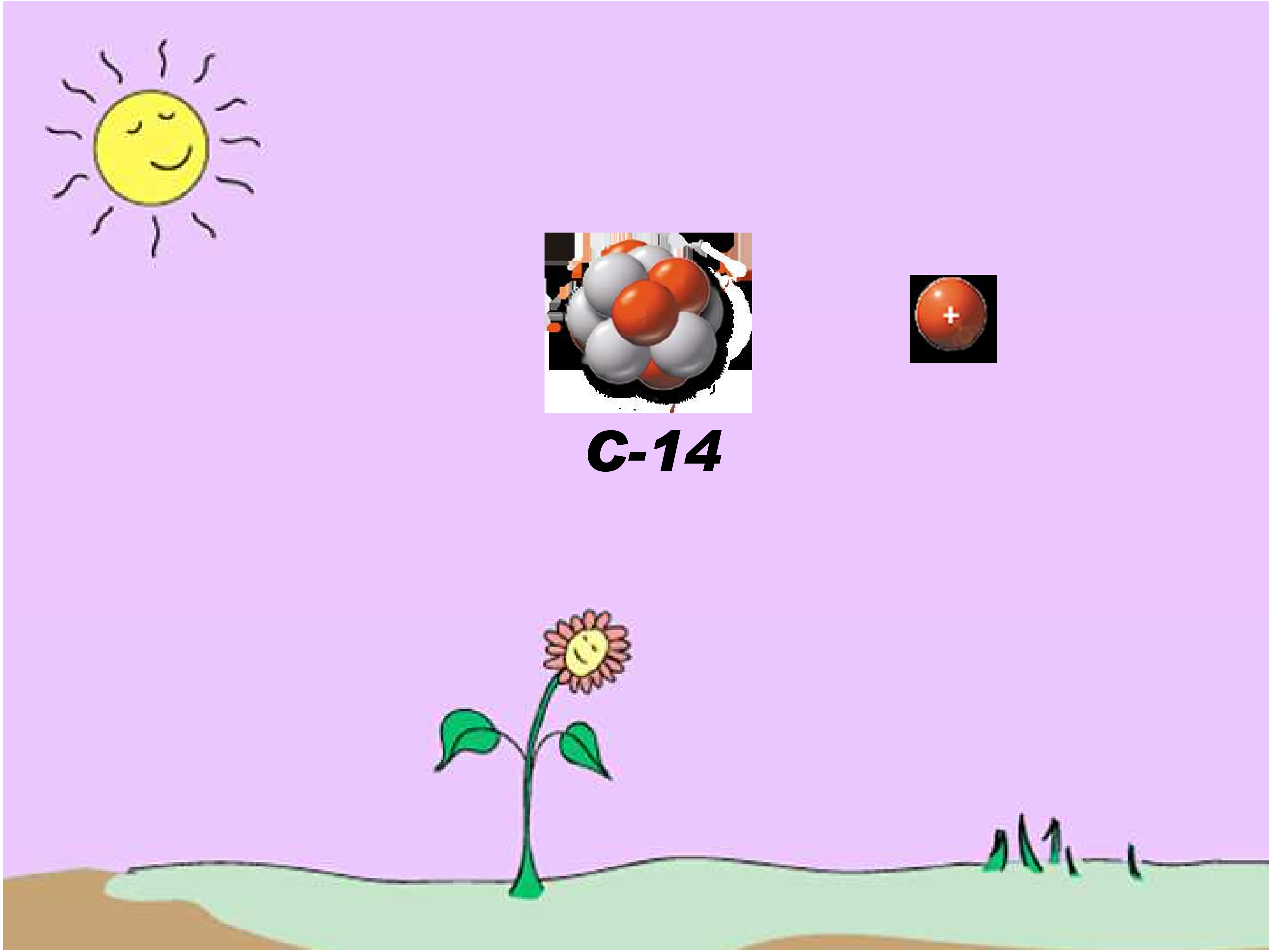
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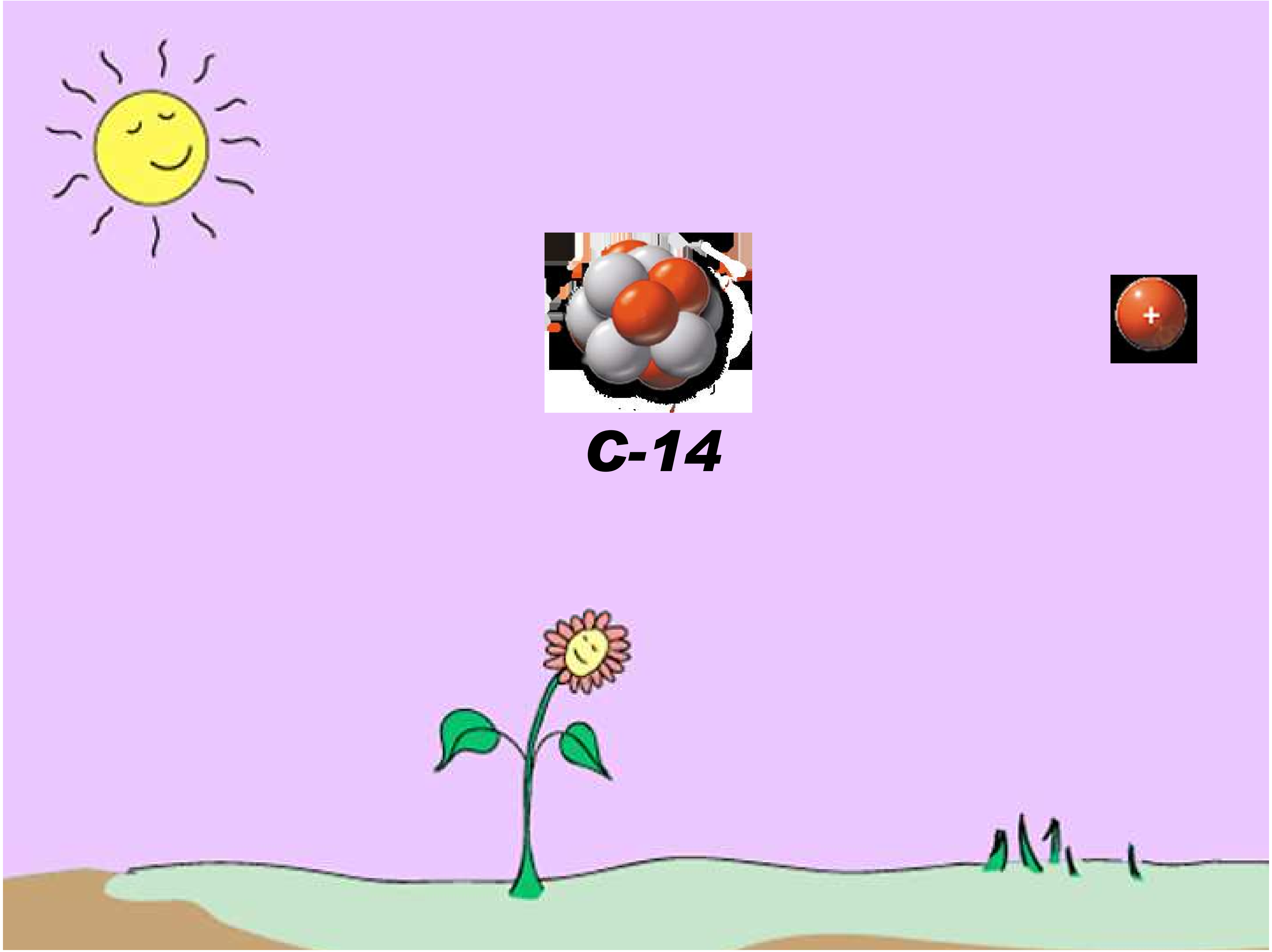
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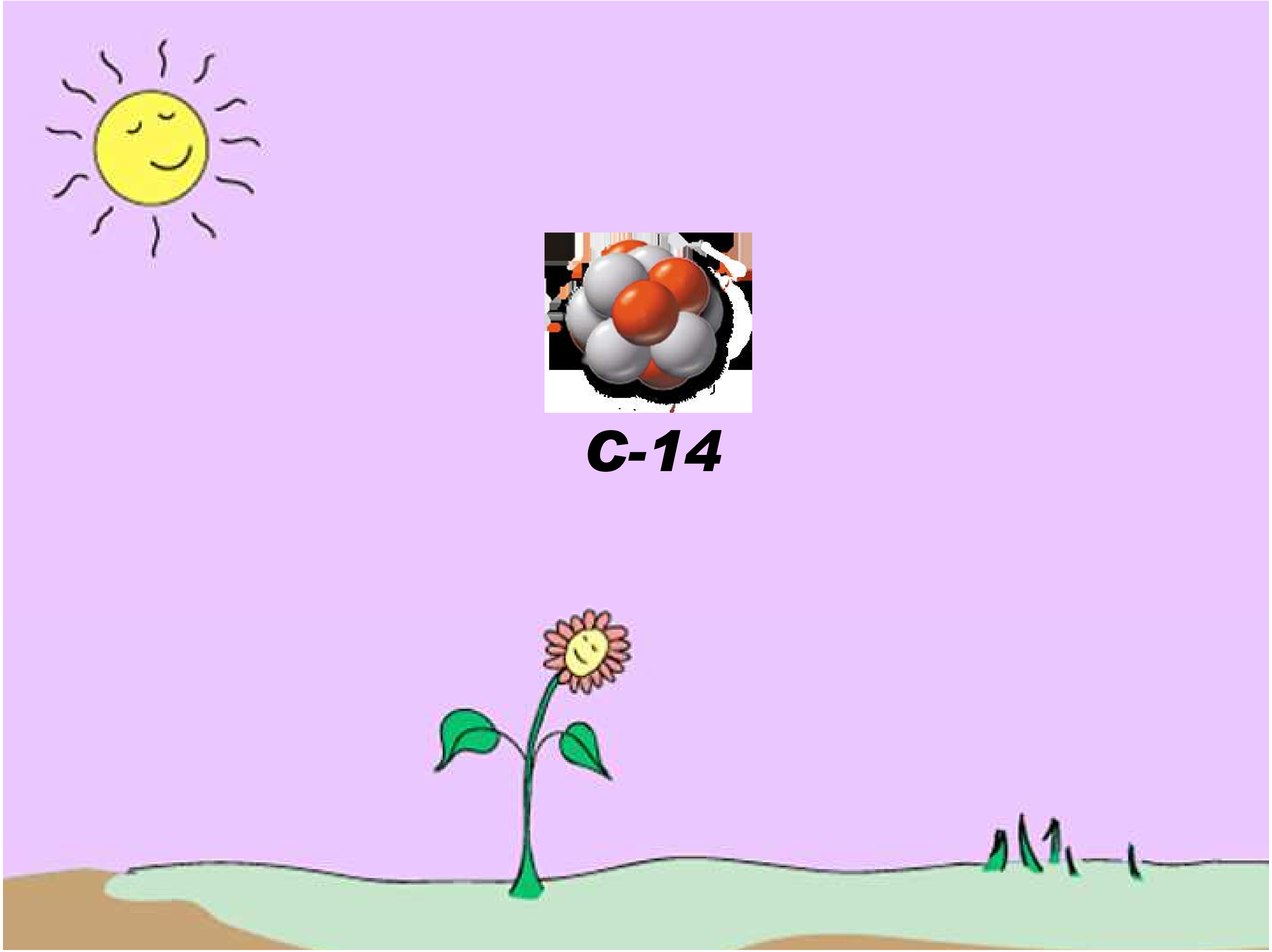
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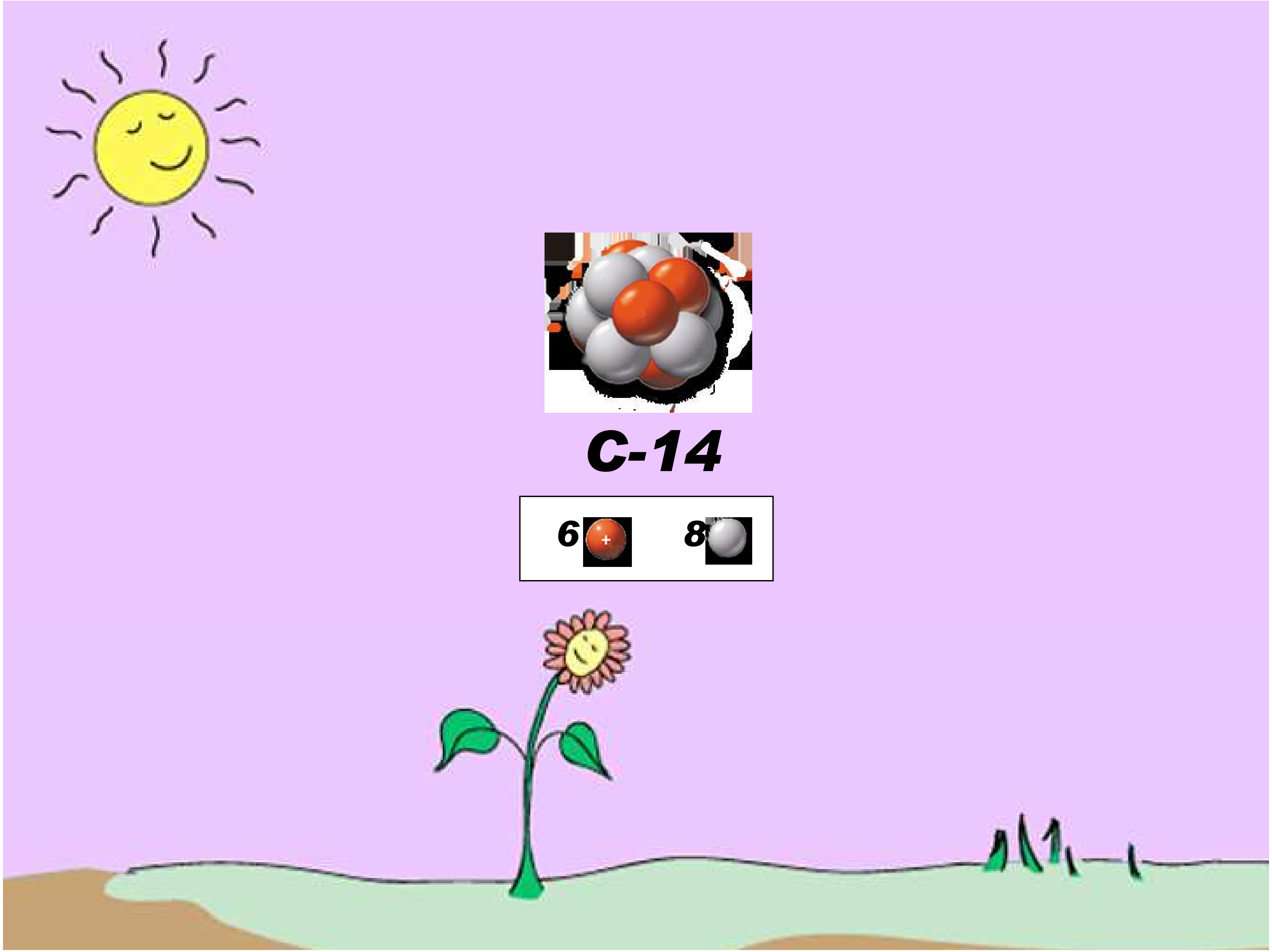
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6
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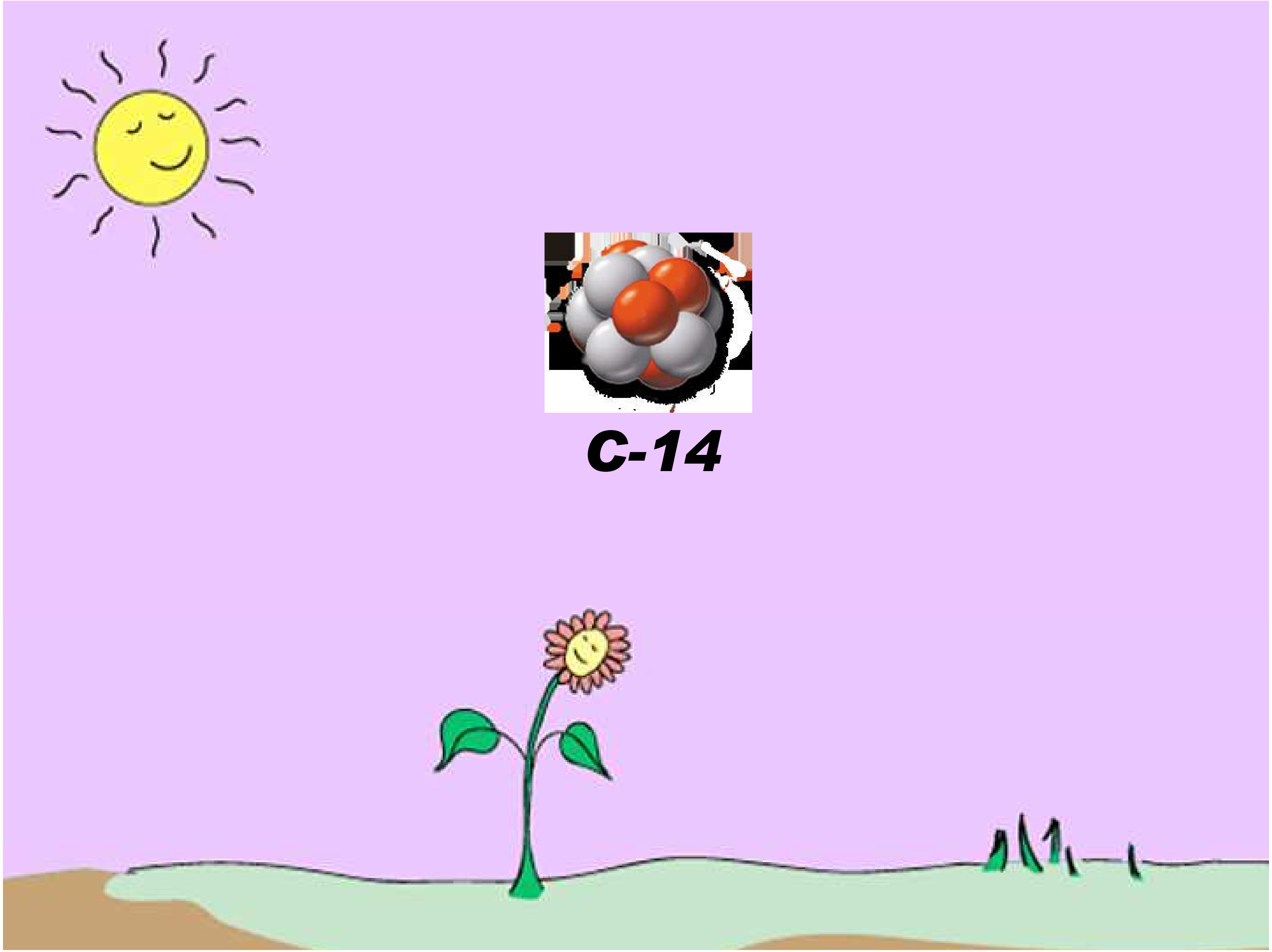
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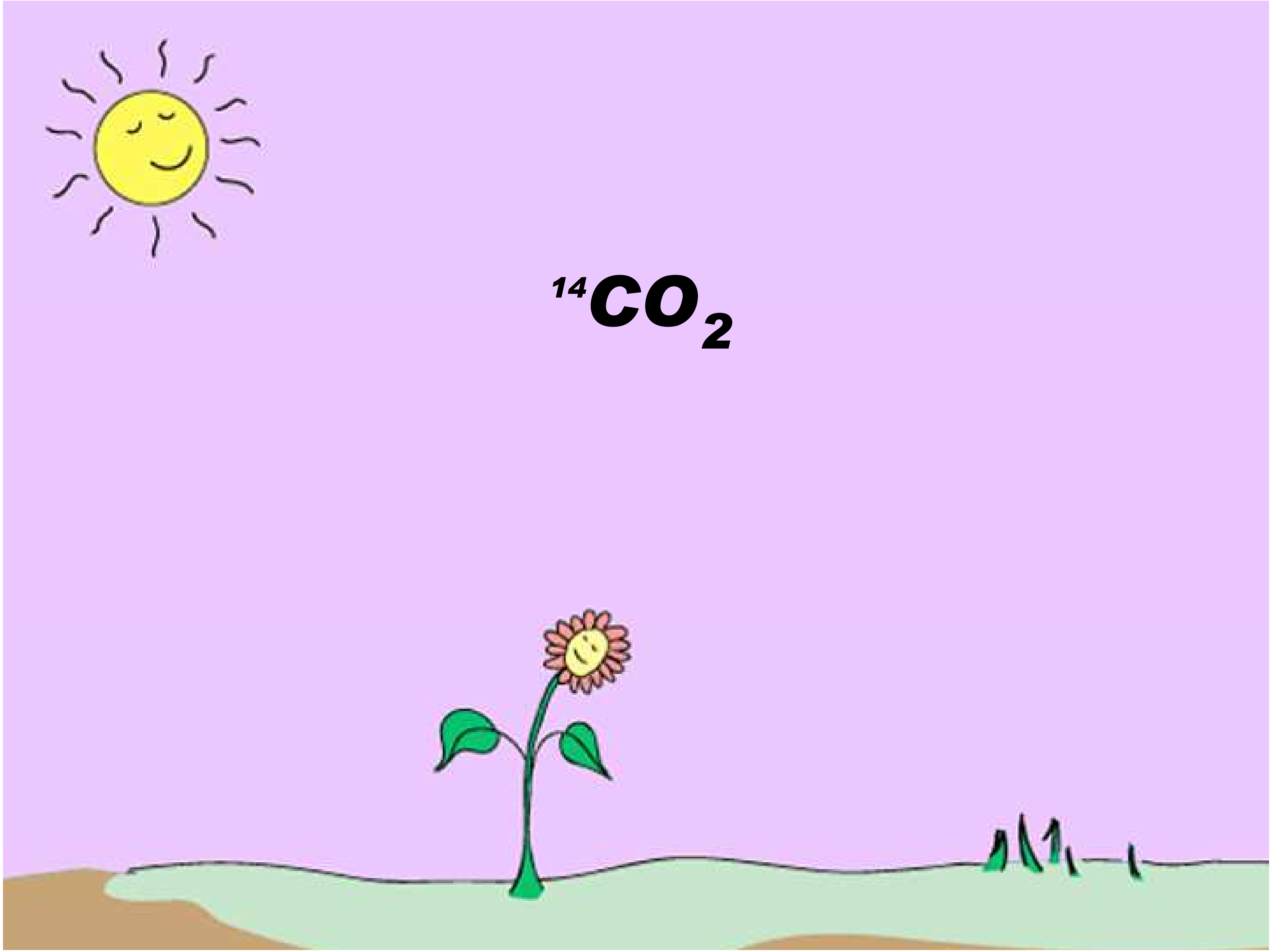
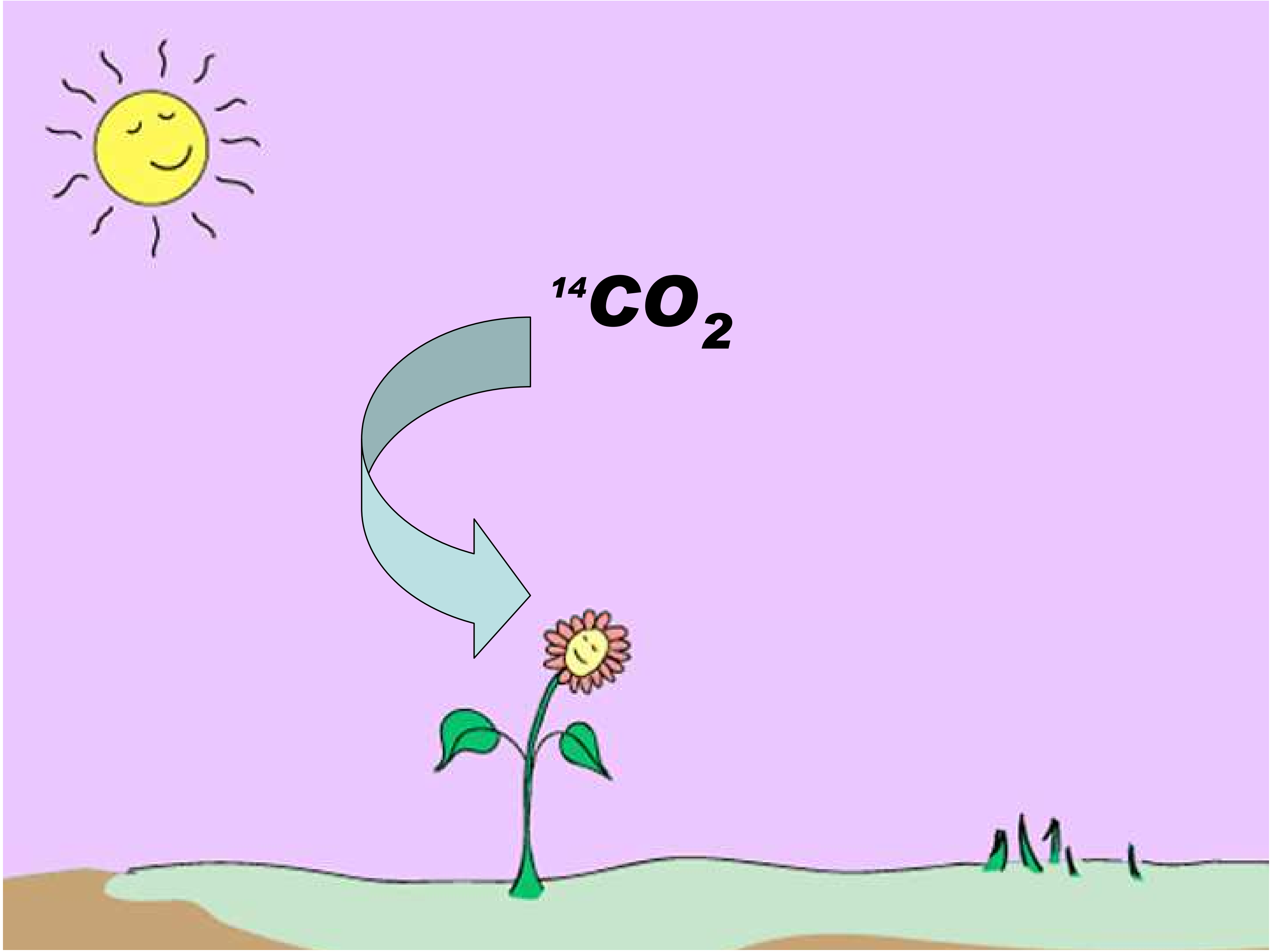
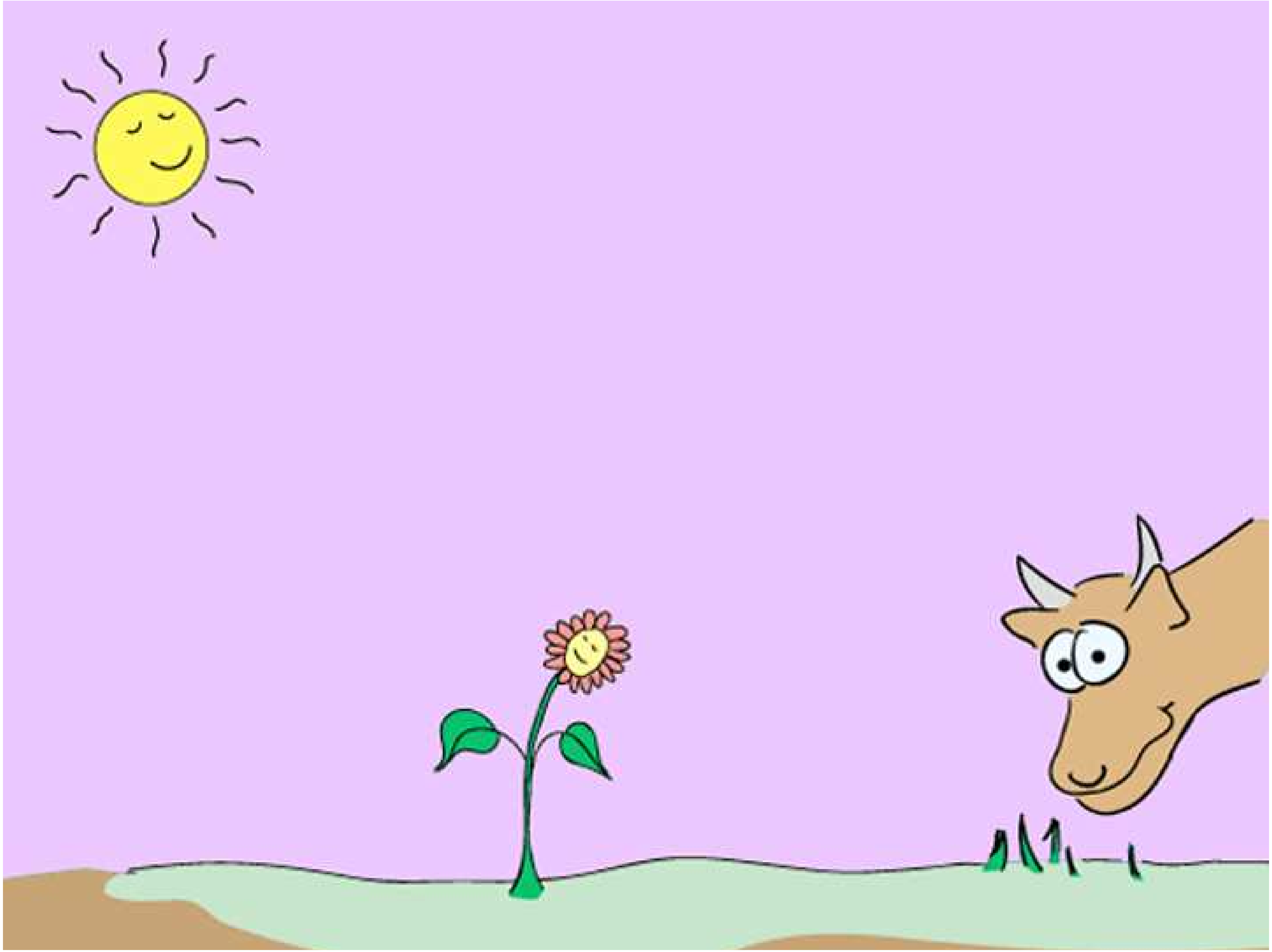

$^{14}CO_2$


$^{14}CO_2$



Carbon-14 is a radioactive isotope that is naturally incorporated from carbon dioxide into living organisms, the amount remains relatively constant during the life of the organism

When the living organisms dies the carbon 14 is no longer being replaced in the organism and will start to decay. The amount of loss from the that compared to living organisms can be used to determine when the organism died.

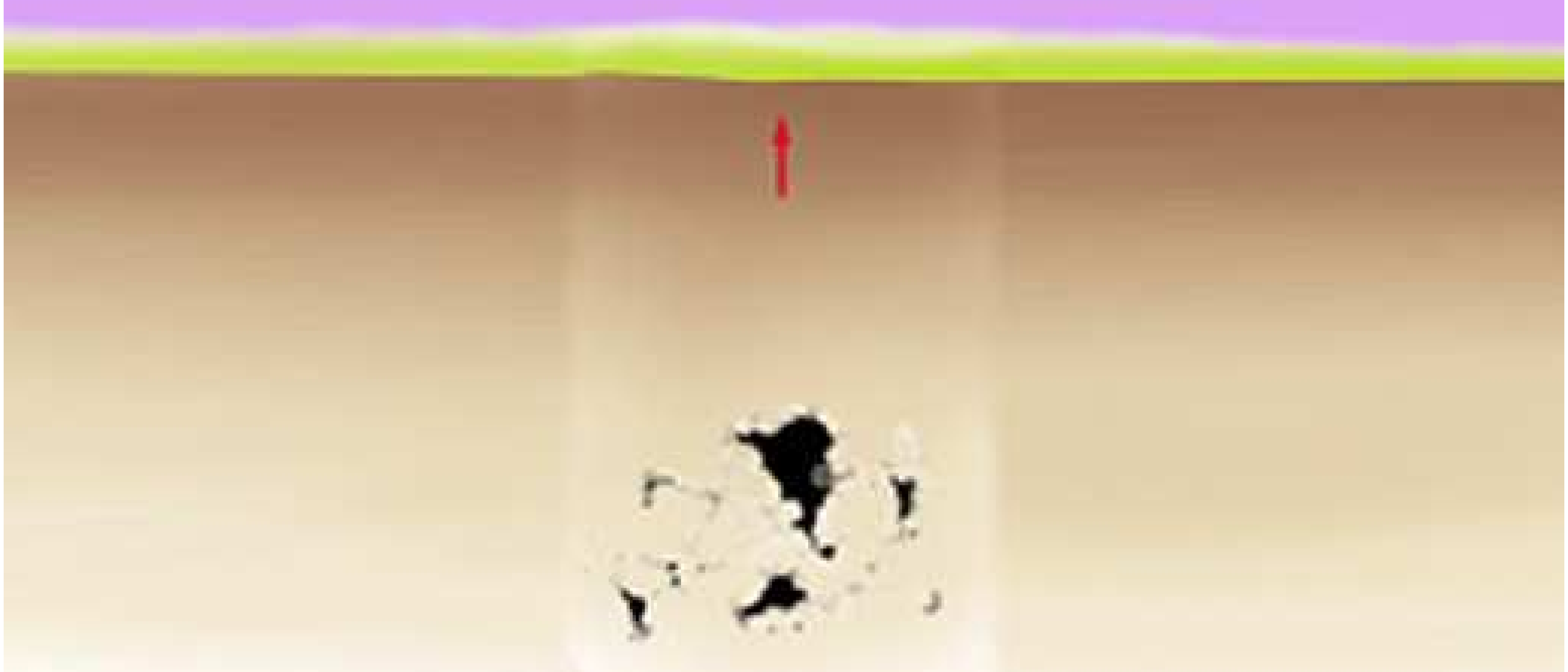
22,920 years ago

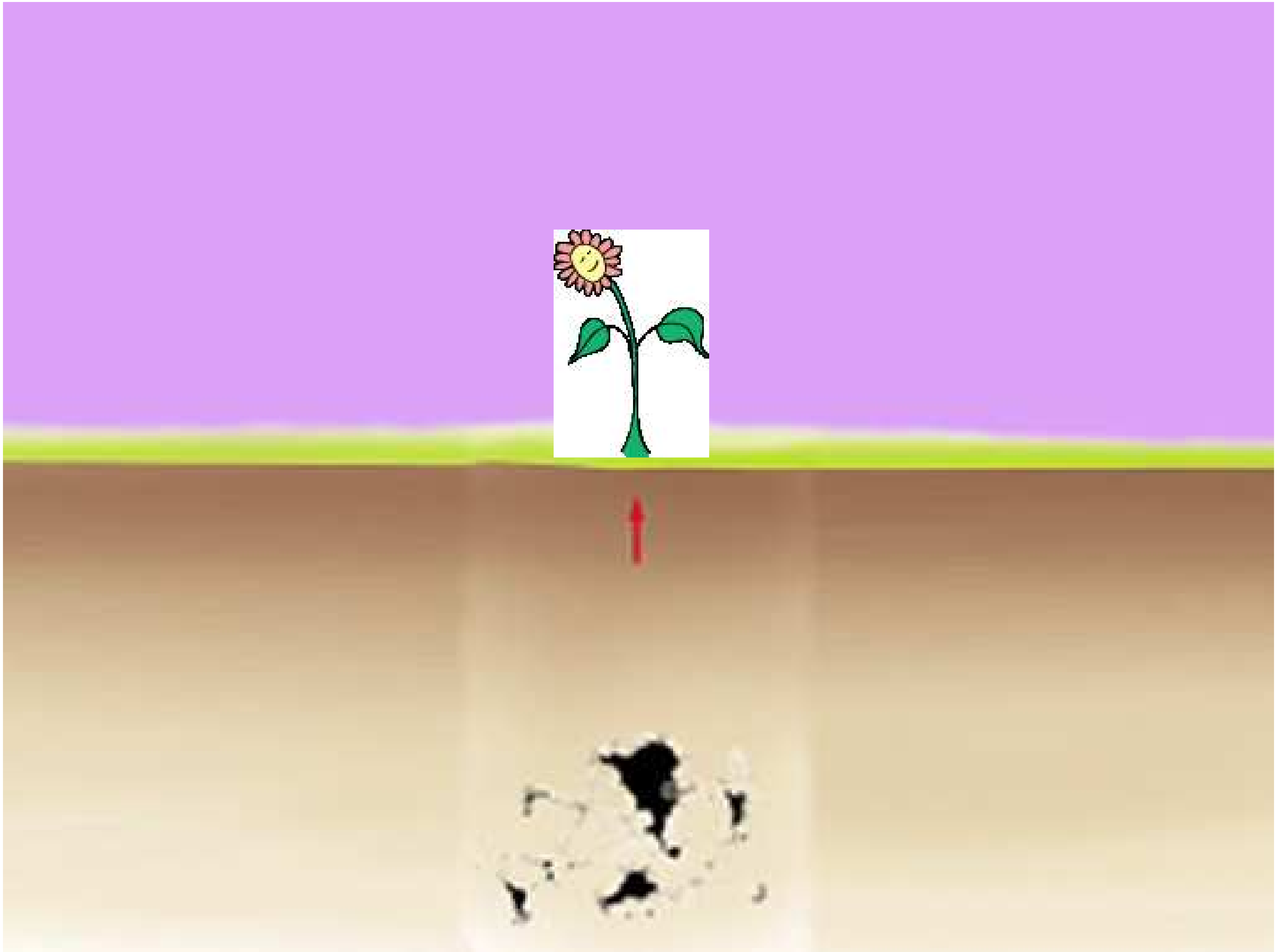
17,190 years ago

11,460 years ago

5730 years ago

Present





Calculate Age

Problem:

The carbon-14 radioactivity in the bones of a body was measured to be 1/8 of that compared to a living person

How long ago did the person live?

Calculate Age

Calculation of Age:

The carbon-14 has decreased by 1/8 which is three half lives (1/2 times 1/2 times 1/2 = 1/8)

Carbon-14 half life = 5730 years

3 times 5730 = 17,190 years


Present

One Half-Life
5730 years ago

Two Half-Lives
11,460 years ago

Three Half-Lives
17,190 years ago