Isochrons

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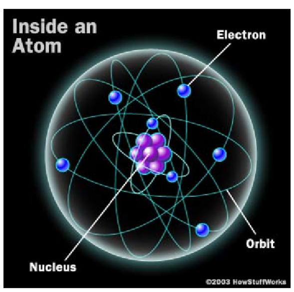
Outline

- What is radioactive decay?
- Why it measures time.
- Objections
  - Don't we have to know the rock's initial composition?
- Isochrons

Atom

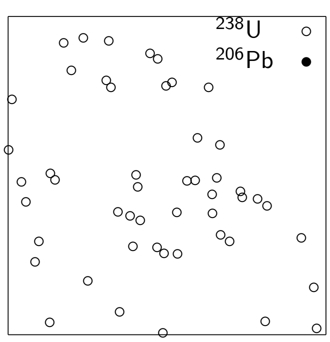


- electron shell
- nucleus
  - protons (determine which element)
  - neutrons
  - protons + neutrons = mass

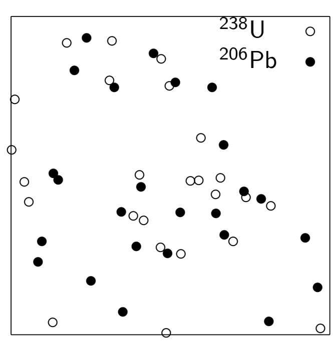
Isotopes

- Some atoms of oxygen (or any other element) weigh more than others.
- These variants are *isotopes*.
- Some isotopes are stable.
- Others are unstable, or radioactive.
- Atoms of a radioactive isotope tend to decay into something else.

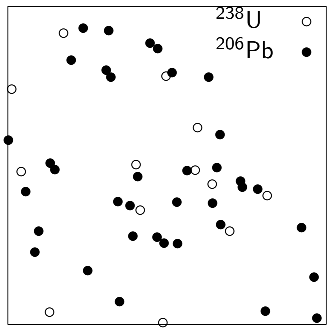
An initial collection of atoms



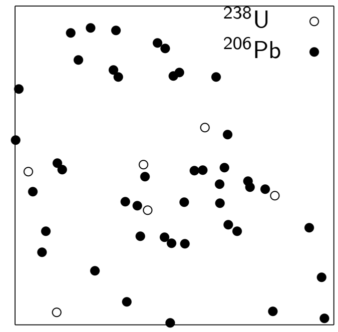
After 1 half-life



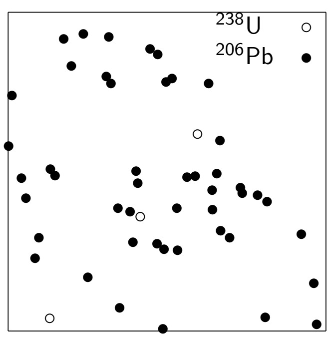
After 2 half-lives



After 3 half-lives



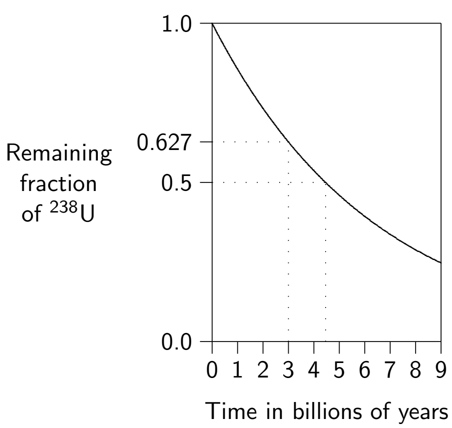
After 4 half-lives



Some radioactive isotopes used in dating

Element	Isotope	half-life
Carbon	^{14}C	5.730×10^{3} y
Potassium	^{40}K	1.248×10^{9} y
Uranium	^{238}U	4.468×10^{9} y
Rubidium	^{87}Rb	4.92×10^{10} y

Radiometric clock, using ^{238}U



The fraction of ^{238}U remaining tells us how much time has elapsed.

0.627 $\Longrightarrow$ 3 byr

0.5 $\Longrightarrow$ 4.468 byr

Objection

How can we tell what fraction remains unless we know how much was originally there?

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Hypothetical example

- Begins with three samples from a rock that formed 4.46 billion years ago—the half-life of ^{238}U.
- We will see original isotope ratios, and also those in modern rock.
- We will estimate age from modern ratios.

When rock was formed

Columns B–C show the number of atoms of each isotope.

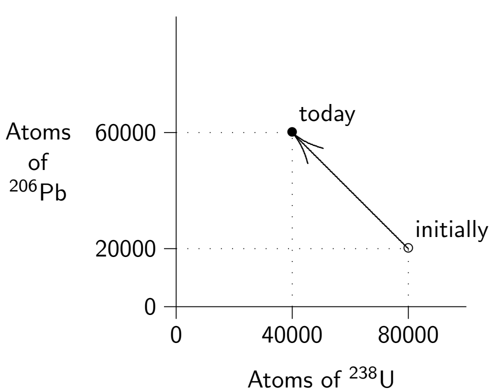
A	B	C
Samp.	^{238}U	^{206}Pb
1	80000	20000
2	30000	10000
3	90000	50000

Today

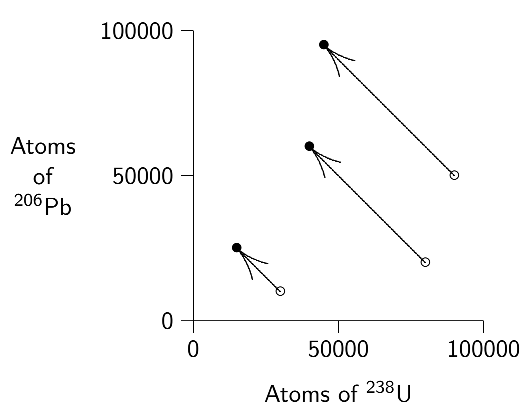
Columns B–C show the number of atoms of each isotope.

A	B	C
Samp.	^{238}U	^{206}Pb
1	40000	60000
2	15000	25000
3	45000	95000

Change in sample 1



All three samples



Adding an inert isotope

- ^{204}Pb does not decay.
- Nothing decays into ^{204}Pb.
- The number of ^{204}Pb atoms is unchanging.
- Let us add ^{204}Pb to the data table.

When rock was formed

1 atom of ^{204}Pb for every 15 of ^{206}Pb.

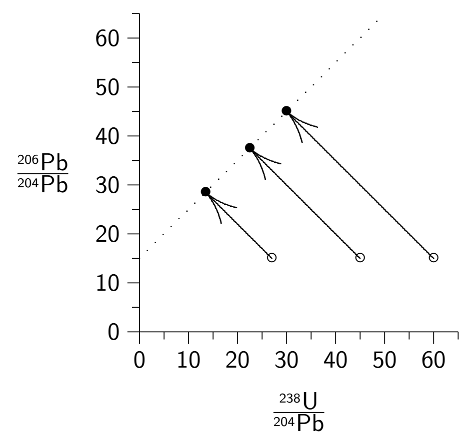
A	B	C	D	E	F
Samp.	^{238}U	^{206}Pb	^{204}Pb	$\frac{^{238}U}{^{204}Pb}$	$\frac{^{206}Pb}{^{204}Pb}$
1	80000	20000	1333	60	15
2	30000	10000	667	45	15
3	90000	50000	3333	27	15

Today

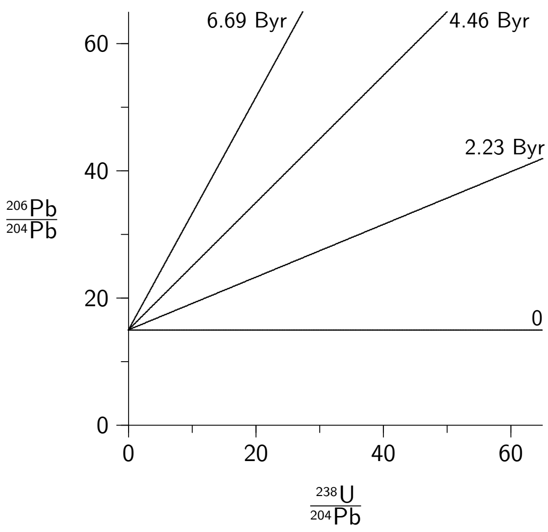
Number of atoms of ^{204}Pb doesn't change.

A	B	C	D	E	F
Samp.	^{238}U	^{206}Pb	^{204}Pb	$\frac{^{238}U}{^{204}Pb}$	$\frac{^{206}Pb}{^{204}Pb}$
1	40000	60000	1333	30.0	45.0
2	15000	25000	667	22.5	37.5
3	45000	95000	3333	13.5	28.5

Isochron



Slope of isochron shows age of rock



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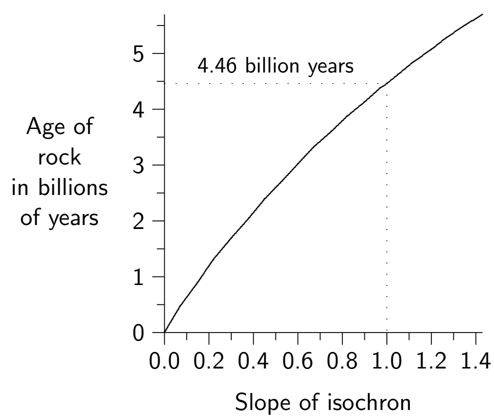
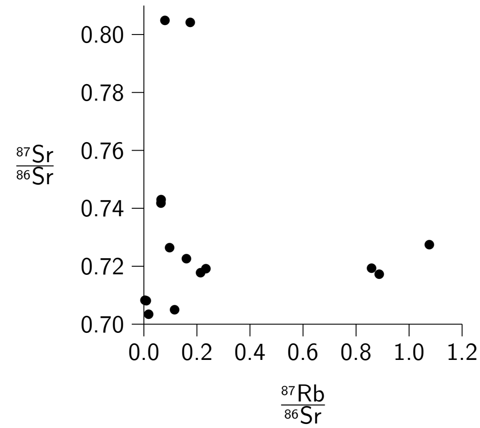


Objection

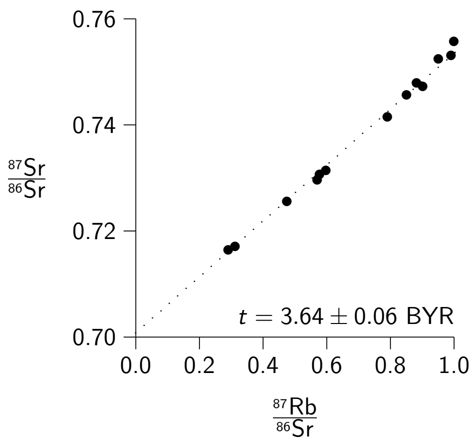
What if you lose or gain something?

When the assumptions fail

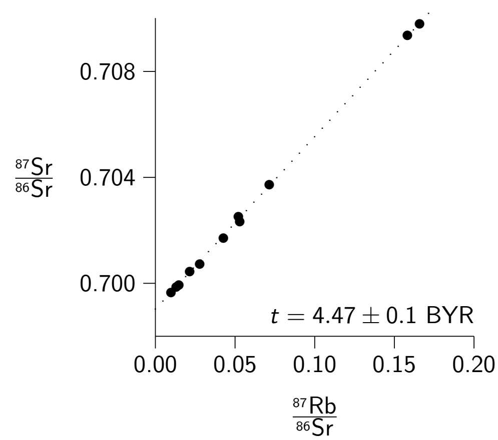


When the assumptions hold

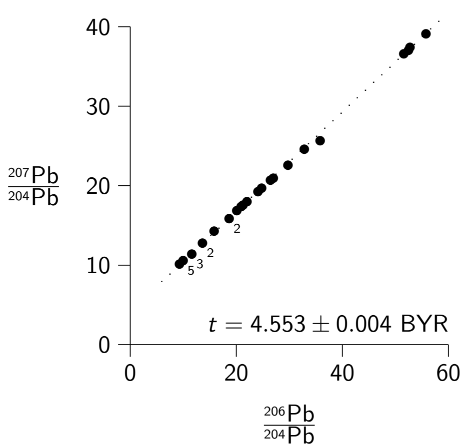
Greenland gneiss



Moon rock



Allende meteorite



Summary

- Radioactive decay is clock-like
- Isochrons avoid the problem of the rock's unknown initial condition.
- When the isochron's assumptions fail, you can tell.
- The oldest known rocks are:

Age (Byr)	
4.4	Australia
4.47	Moon
4.55	Meteorites