Astronomy 150: Killer Skies
Lecture 5, January 27

Last time: began Astro Threat I: Impacts

Today: Meteors and Asteroids

Homework:

- **HW 1 due today, but allowing submission up until next Monday.**
- **HW 2 posted today, due next Friday at the start of class**

http://epod.usra.edu/blog/2011/01/fireball-breakup.html

http://epod.usra.edu/blog/2011/05/willamette-meteorite.html

Register your i>clicker

Go to link on class web page to register your i>clicker

- Register with first part of your @illinois.edu email (NetID)

If you can't read your i>clicker ID

- Go the Illini bookstore bag-check counter
- Vote with your i>clicker
- Clicker ID will be displayed on the base unit

https://online-s.physics.uiuc.edu/cgi/courses/shell/iclicker.pl

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Planetarium Session

Purpose:

- To help you understand the motions of the sky

Dates: 1/30, 1/31, 2/2, 2/6, 2/7, 2/8

@ Staerkel Planetarium, Parkland College

- Show starts at 7pm, runs ~80 minutes
- $3 door charge, please bring exact change

Report due Feb 24th in class

- Details on class website
- Attach ticket from the show to your report

Reserve a seat online

- Link to reservation site on class website

Fireballs

Since most meteors are from small objects, they burn up before they hit the ground.

But some are from larger objects, which survive all the way to the ground.

These leftover objects are then called **meteorites**

http://antwrp.gsfc.nasa.gov/apod/ap081011.html

Peekskill Fireball (October 9, 1992)

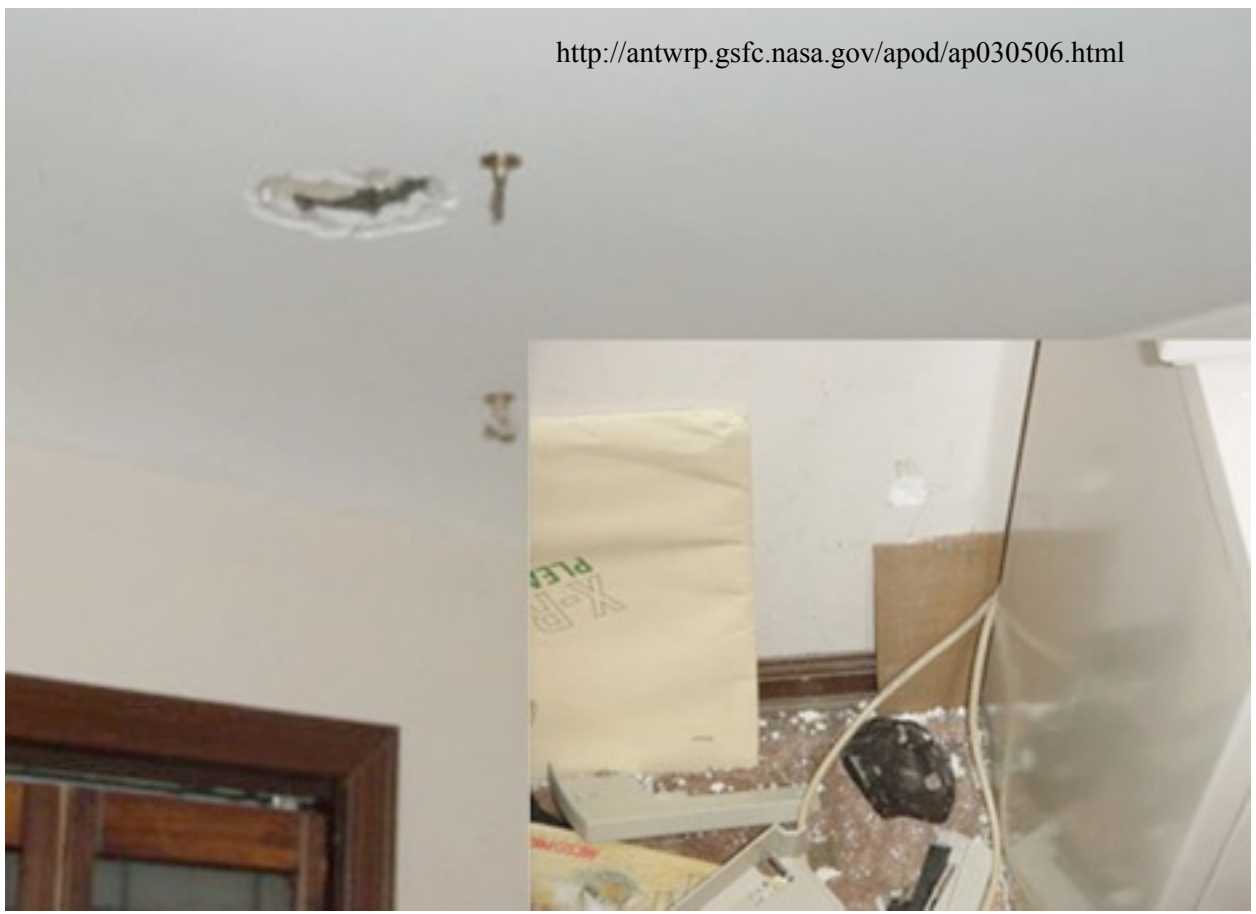
Objects in space <50 meters in size are called meteoroids

Closer to Home

March 26th, 2003

Park Forest, IL

Through the roof, hit the printer, hit the wall



Be Careful?

Be Careful?

http://www.youtube.com/watch?v=x0BifYPQQJE&feature=related
(1:40)

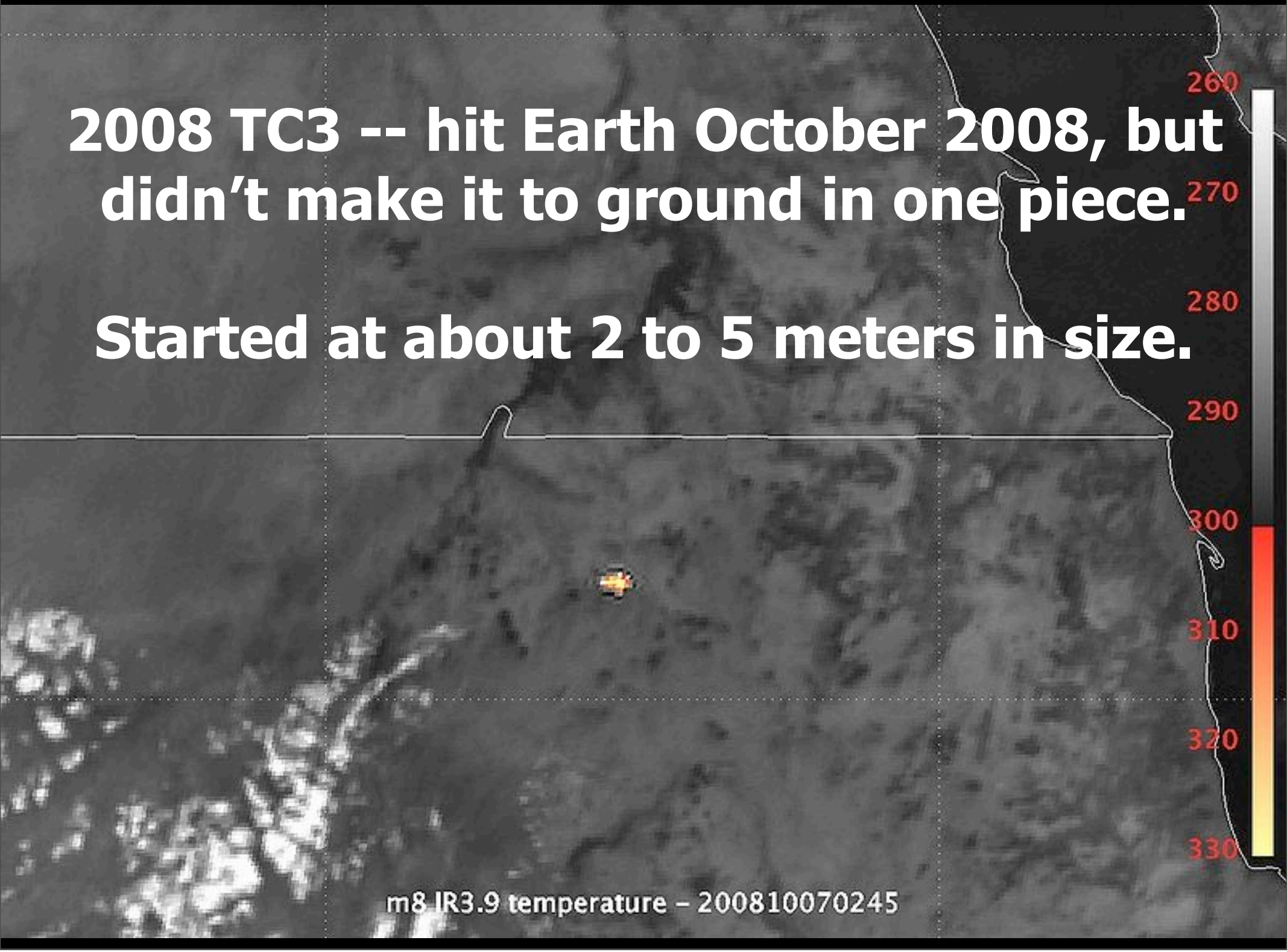
Do you have to ask if it was true?
http://wiki.answers.com/Q/
Is_Scott_Pendleton_and_Jen_Fox's_story_really_TRUE

Review: Meteor Terminology

- **Meteoroid**
  - A bit of interplanetary debris that is still in space
- **Meteor**
  - A streak of light caused by a meteoroid while it falls
  - Commonly called a *"shooting star"*
- **Meteorite**
  - A space rock on the ground

Meteoroid to Meteor to Meteorite: 2008 TC3

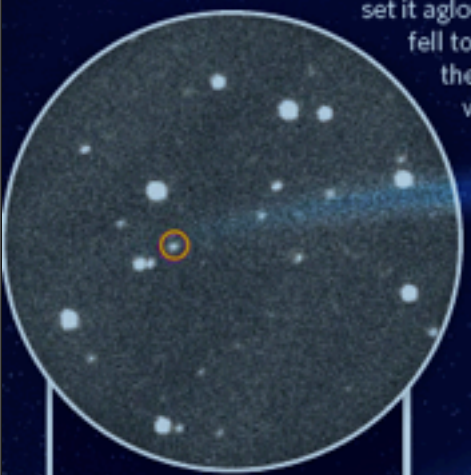
- Size of 2-7 meters
  - 7-16 ft
- Exploded tens of km above ground
- Energy release:
  - equivalent 0.9 to 2.1 kilotons of TNT!
- Caused a large fireball
- Meteoroids of this size hit Earth about two or three times a year


2008 TC3 -- hit Earth October 2008, but didn't make it to ground in one piece.
Started at about 2 to 5 meters in size.
260
270
280
290
300
310
320
330
m8 IR3.9 temperature – 200810070245

Significance: First meteoroid detected before it was going to hit Earth. First meteorite recovered from such an object.

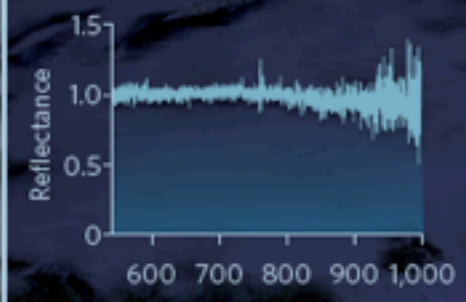
A 2008 TC_3 SPACE ODYSSEY

The little boulder 2008 TC_3 went through a series of name changes during its brief moment in the scientific spotlight. In space, the hunk of rock was called an asteroid or meteoroid. After it hit Earth's atmosphere, frictional heating set it aglow and it became a meteor. The pieces that fell to the ground are called meteorites. Here is the 2008 TC_3 biography, from the moment it was discovered.



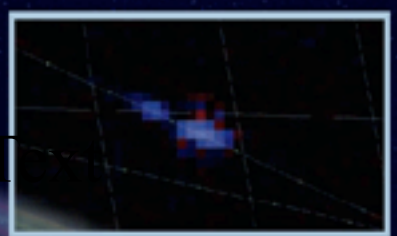
6 OCT 2008
06:39 UT
A fast-moving meteoroid close to Earth was spotted by the Catalina Sky Survey on Mount Lemmon in Arizona. Orbital calculations suggested it would hit the planet in 20 hours.

6 OCT 2008
22:22–22:28 UT
When the meteoroid was 121,100 kilometres from Earth, a telescope in the Canary Islands measured how much light the body reflected at different wavelengths.



7 OCT 2008
02:45:40 UT
Ron de Poorter, a KLM pilot flying at an altitude of 10,700 metres over Chad, saw three or four short pulses of light beyond the horizon as the meteoroid flared through the sky.

7 OCT 2008
02:45:46 UT
When the meteoroid broke apart, it left behind clouds of hot dust, observed by the Meteosat-8 weather satellite.



7 OCT 2008
03:27 UT
A photograph captured clouds left behind after the fireball disappeared.

DECEMBER TO MARCH
A search team combed the desert multiple times and recovered some 280 meteorites.

What are Meteorites Made of?

Very useful to know what meteorites are made of

- practical: better threat assessment if we know the properties of the impactors
- meteorites are extraterrestrial matter! unique insight into the ingredients of the rest of the solar system

Throughout the course, will want to know what things are made of--what is "composition"

- how to answer scientifically?

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Consider a 1 kg stony meteorite--basically, a rock

- cut in half--two smaller rocks, look and act similar
- cut again--still smaller rocks, still similar properties
- but: process does not go on forever: after 75 cuts, something new--atoms

The World of Atoms

"If, in some cataclysm, all of scientific knowledge were to be destroyed, and only one sentence passed on to the next generation of creatures, what statement would contain the most information in the fewest words? I believe it is the atomic hypothesis (or the atomic fact, or whatever you want to call it) that

all things are made of atoms--little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another.

In that one sentence, you will see, there is an enormous amount of information about the world, if just a little imagination and thinking are applied."

--Richard Feynman

http://www.youtube.com/watch?v=v3pYRn5j7oI

http://www.nobelprize.org/nobel_prizes/physics/laureates/1965/feynman.html

Matter*

All known substances ever studied in any lab have this structure

matter

**Wierdo dark matter not included in this discussion*

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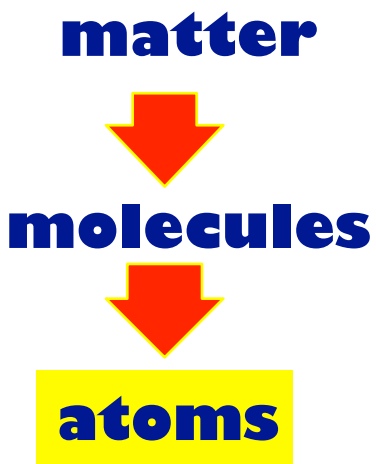

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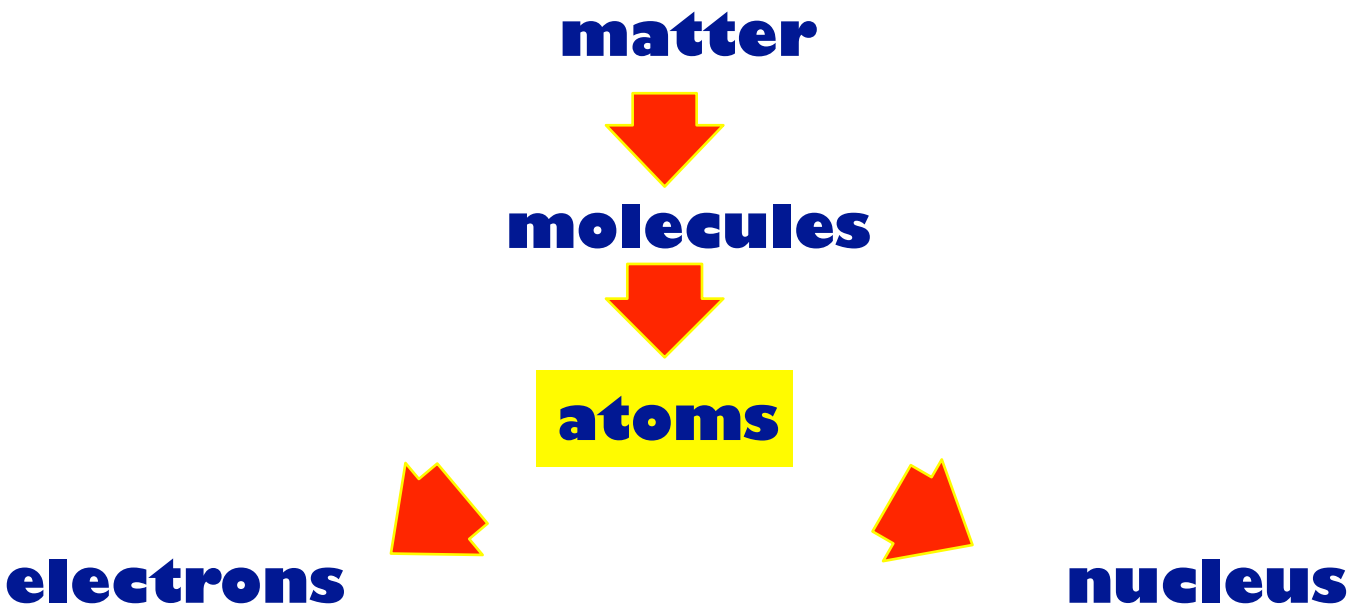

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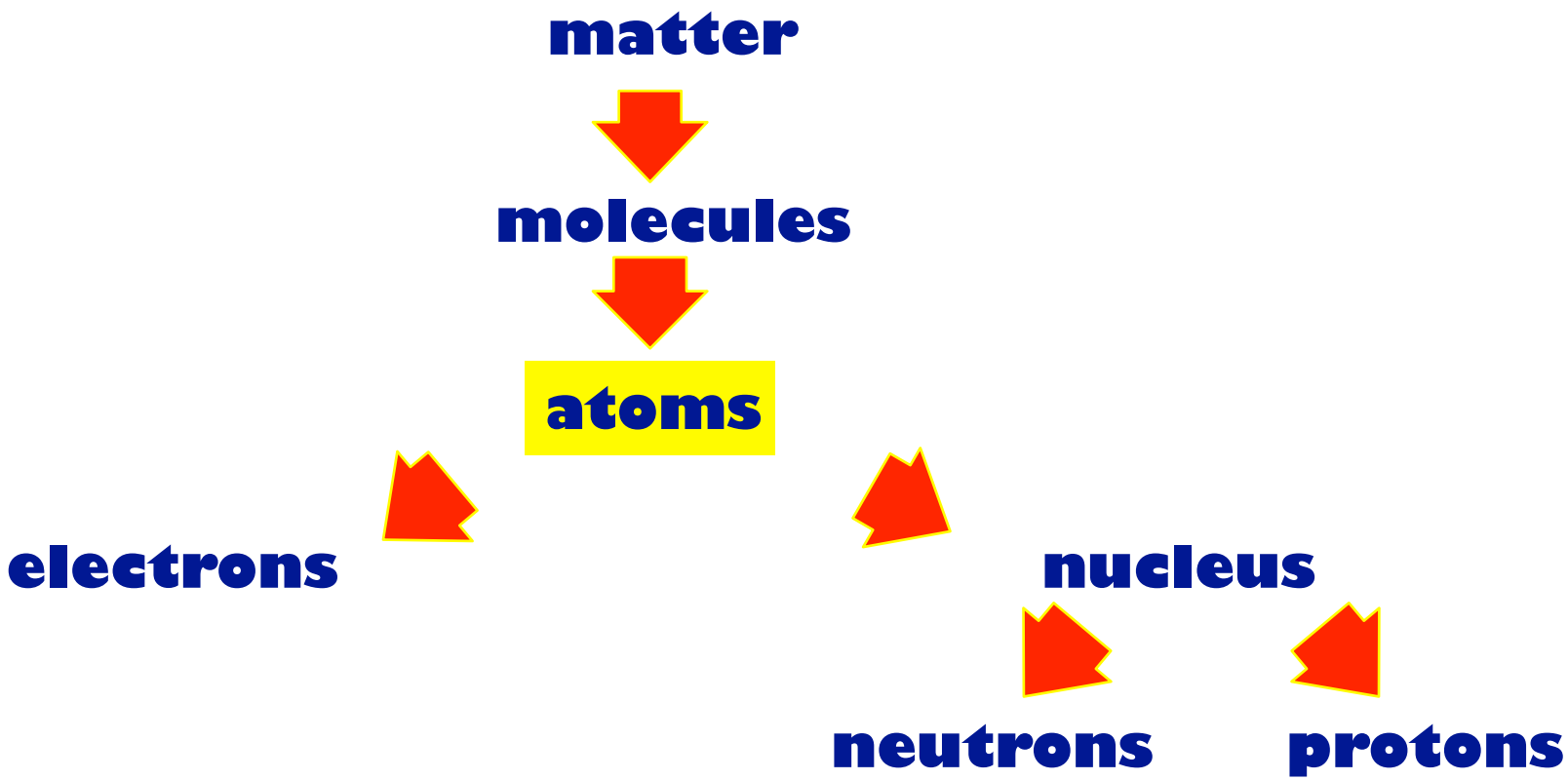

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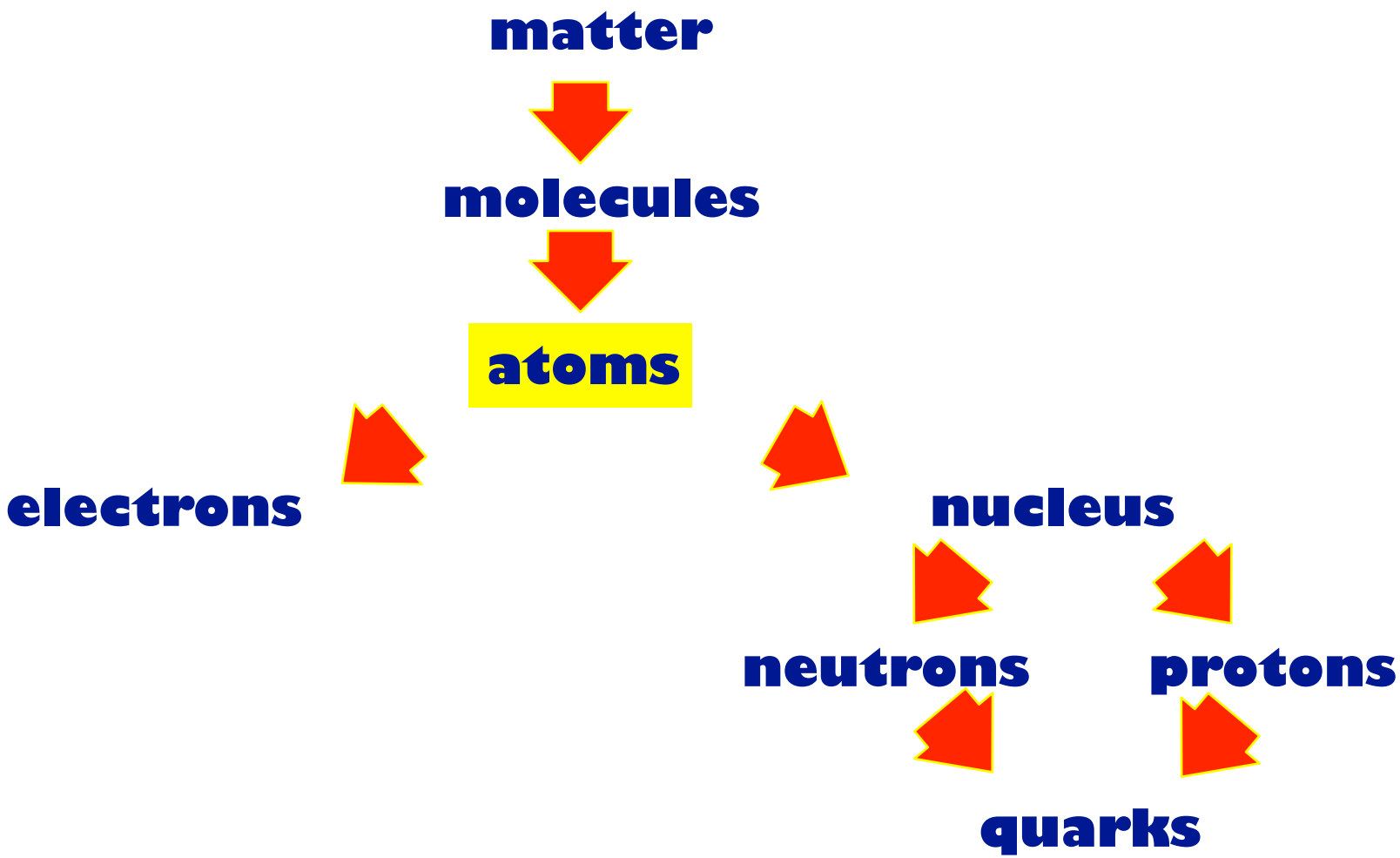

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iClicker Poll:

Atoms in a Grain of Sand

Think of the smallest grain of sand between your toes at the beach

Go with your gut, vote your conscience!

Pick the largest answer that works

the number of atoms in 1 grain of sand is:

A. more than the number of people in this room
B. more than capacity of sold-out Memorial Stadium
C. more than the Chicagoland population
D. more than the population of Illinois
E. more than population of planet Earth

Answer:

- 1 grain of sand is made of about 10^{19} atoms
- that is: 10,000,000,000,000,000,000 atoms

compare: global population $\approx 6.5 \times 10^{9}$ people

lesson: atoms are numerous and tiny!

The Structure of Atoms

at the atom's center: a single nucleus

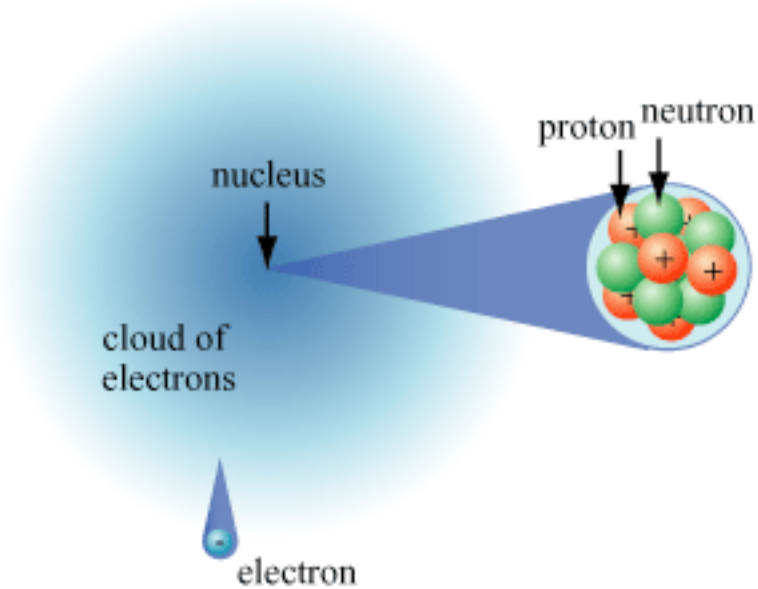
in orbit around nucleus: one or more electrons

electron:

- electric charge -1

nucleus:

- made of protons: charge +1
- and neutrons: charge 0)



total charge of atom: set by # electrons

- if # e = # p → atom is neutral
- if # e = # p−1 → charge = +1: atom is (singly) ionized

masses: $m_p \approx m_n \approx 2000 m_e$

- most of atom mass is in dense nucleus
- most of atom volume occupied by electron orbits

e moves around nucleus

Q: what does this tell us about forces in atoms?

http://www.hk-phy.org/energy/power/nuclear_phy/images/atom.gif

Forces in Atoms: Chemistry

electron orbits: curved paths

- motion must be accelerated
- → needs to be a net force
- and there is! nucleus & electrons attracted by electric force

rule: opposite charges attract, like charges repel

- atom structure similar to Solar System: attractive force → orbits
- big object in center, orbiting smaller objects

http://education.jlab.org/itselemental/

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charge of nucleus = # p

- sets force on e → e orbit properties
- determines how atoms interact: chemistry!
- 92 atom varieties = elements
- from hydrogen = 1p to uranium = 92p

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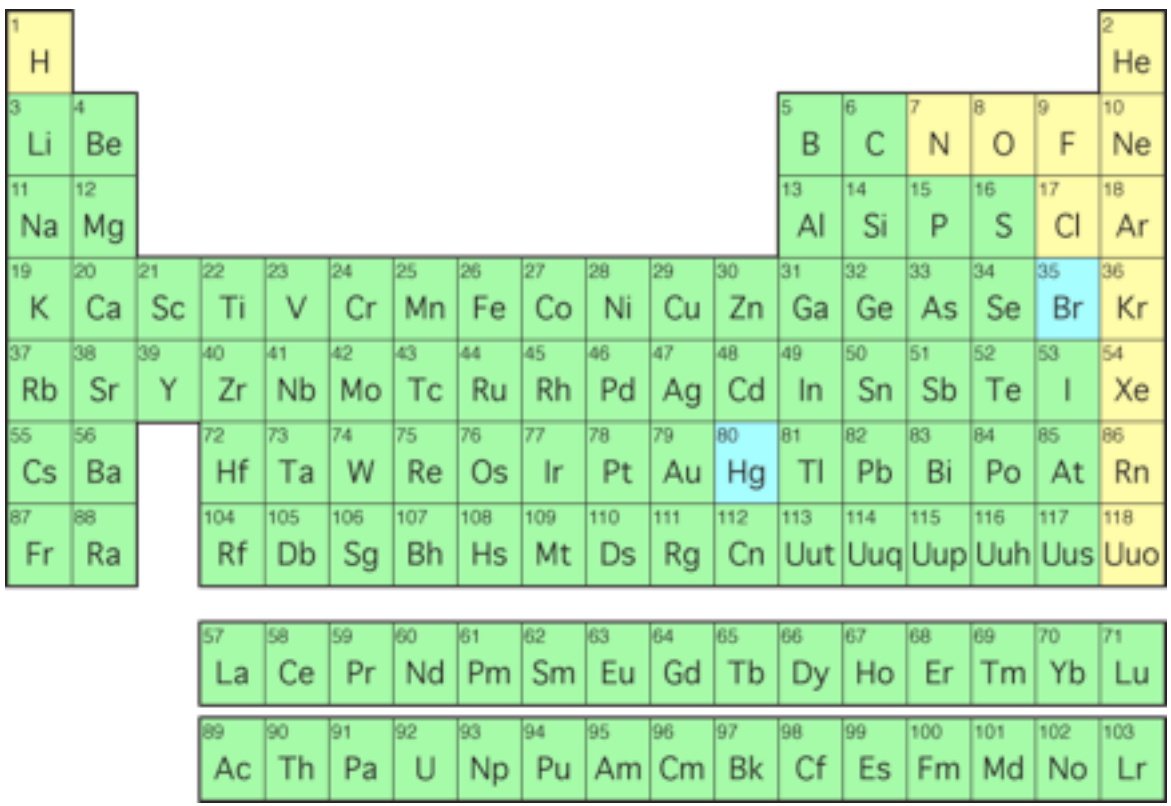

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Chemical Composition

different elements combine/ react differently ⇒ chemistry

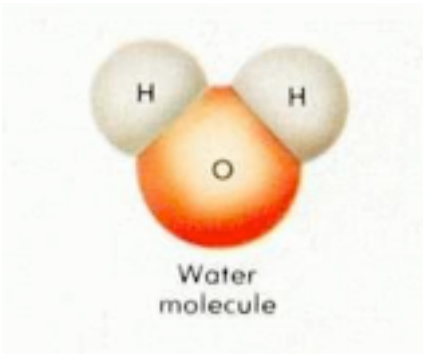
- example: water = H_2O

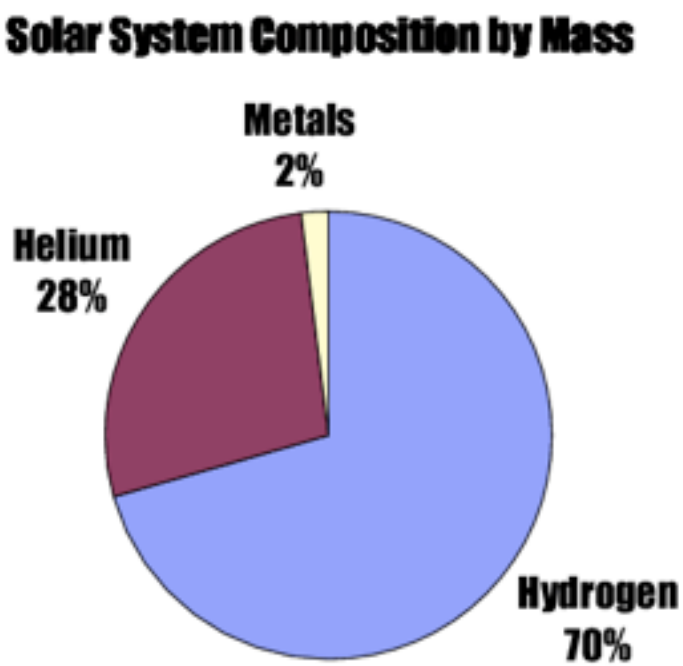
So: "what made of" = "chemical composition":

- what kinds of atoms?
- which are most, least numerous?

Examples

- Sun, Jupiter: about 70% hydrogen, 28% helium, 2% other="metals"
- Earth: about 50% oxygen, 30% silicon, only 0.1% hydrogen





Types of Meteorites: Stonys

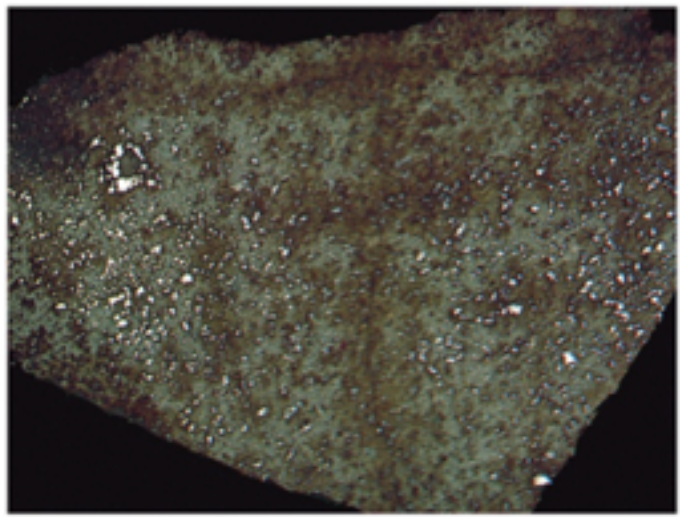
95-97% of meteorites are stony

Made of silicates: combinations of silicon and oxygen atoms

- Very similar to Earth rocks: hard to distinguish

Many stony meteorites have chondrules

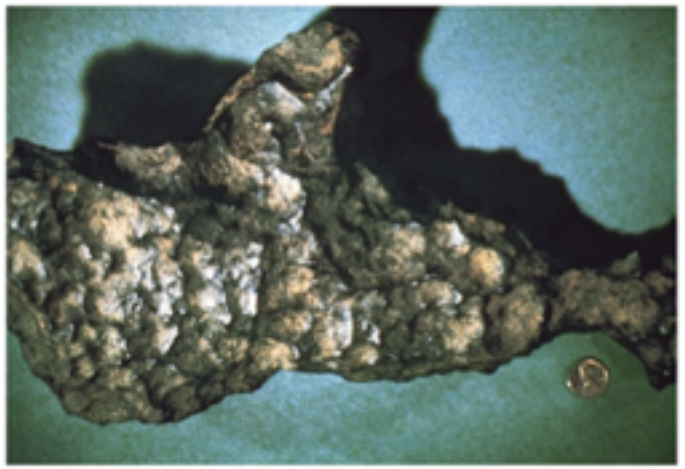
- Solidified droplets of ancient material from the early solar system



Types of Meteorites: Irons

2-3% of meteorites are irons

But, they make up about 40% of the meteorites found



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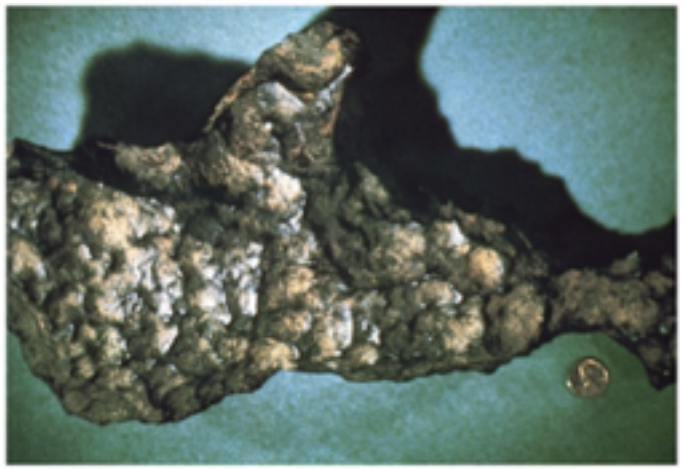
Q: why?



Types of Meteorites: Irons

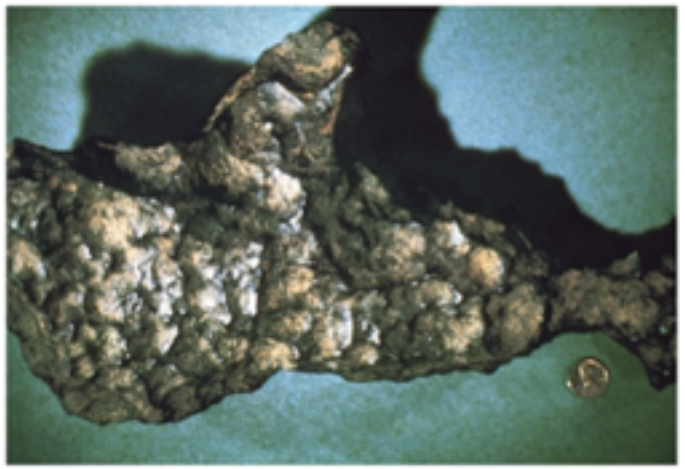
2-3% of meteorites are irons

But, they make up about 40% of the meteorites found

Q: why?

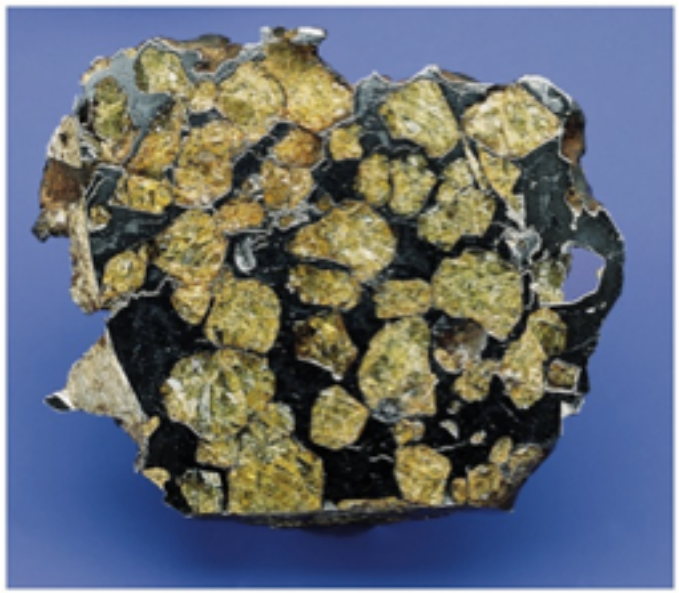
Easily distinguished from Earth rocks

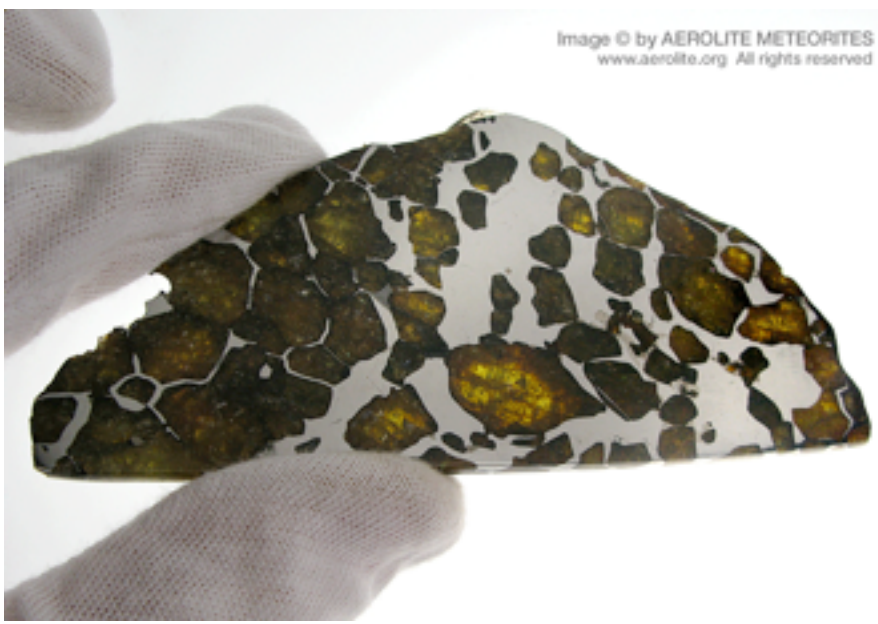
Not pure iron – but iron-nickel alloy



Types of Meteorites: Stony-Irons

- 1% of meteorites are stony-irons
- Mixture of silicate rock and iron-nickel alloy
- Often they are fragmental, suggestive of violent processes





Largest Meteorite in the World

The Hoba Meteorite in Namibia

Meteorites from the Moon and Mars

A few meteorites arrive from the Moon and Mars!

Composition differs from most meteorites

A cheap (but slow) way to acquire moon rocks and Mars rocks

A Mars rock found on Earth as a meteorite

Meteorites from the Moon and Mars

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Q: how do we know a meteor came from Mars?

A Mars rock found on Earth as a meteorite

Meteorites from the Moon and Mars

A few meteorites arrive from the Moon and Mars!

Composition differs from most meteorites

A cheap (but slow) way to acquire moon rocks and Mars rocks

Q: how do we know a meteor came from Mars?
Q: how would a piece of Mars get to Earth?

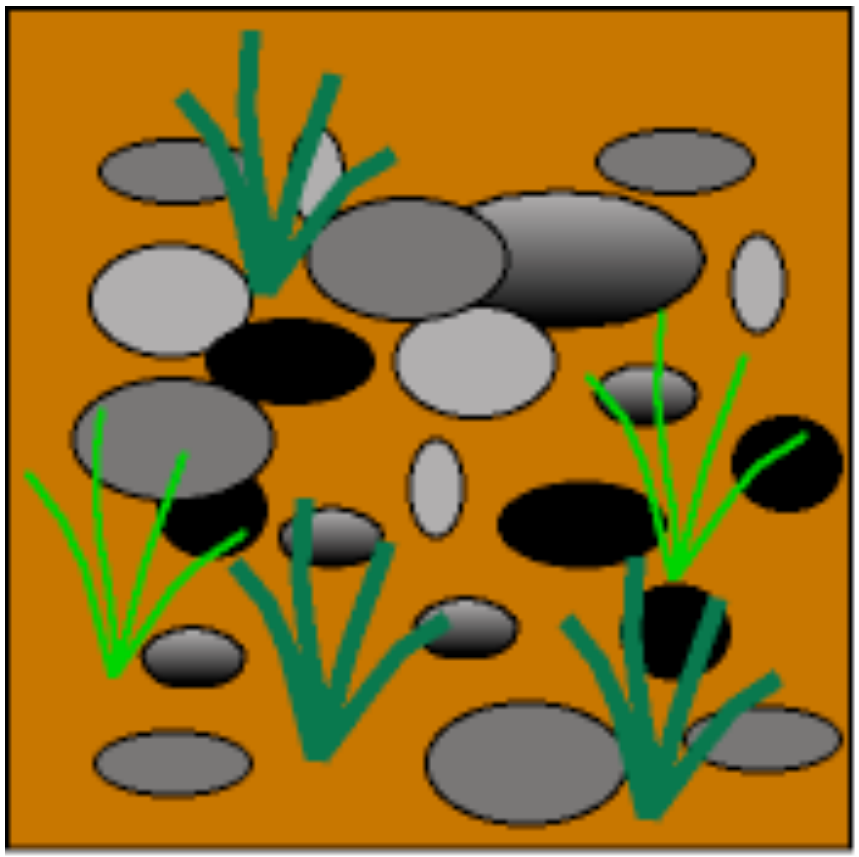
A Mars rock found on Earth as a meteorite

i>clicker question

You are your friends really want to go looking for meteorites. What would be the best place to look?

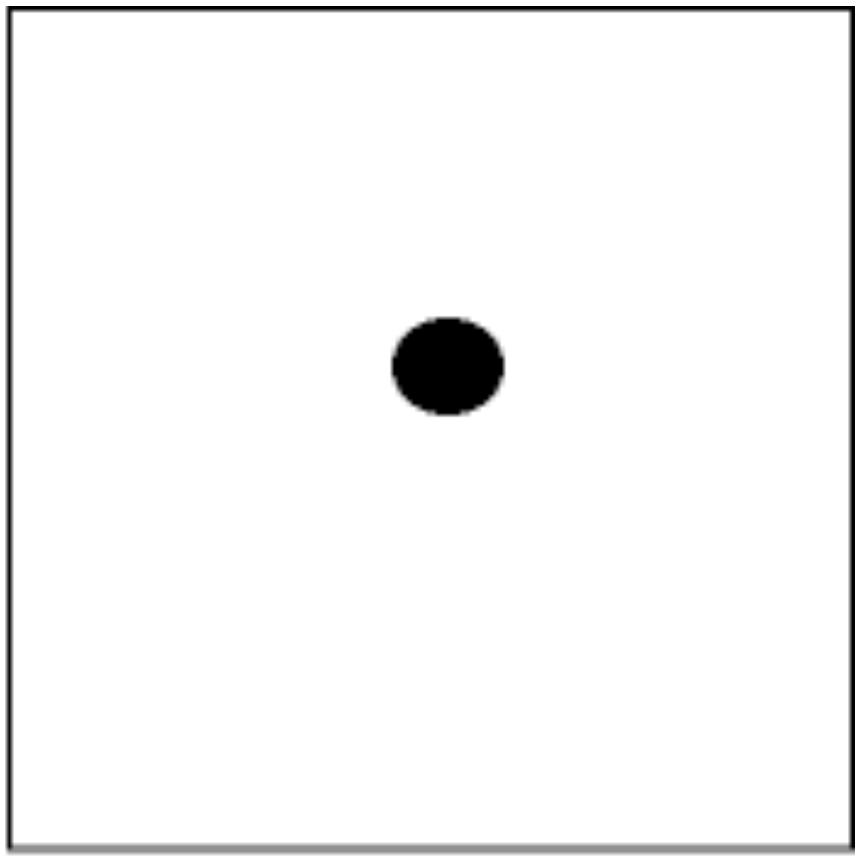
A. A farm field in Illinois
B. An urban landscape like Chicago
C. The Sahara Desert
D. Antarctica
E. I really like cake

Why Antarctica?



Typical Earth location

Where's the meteorite?



Antarctica

Where's the meteorite?

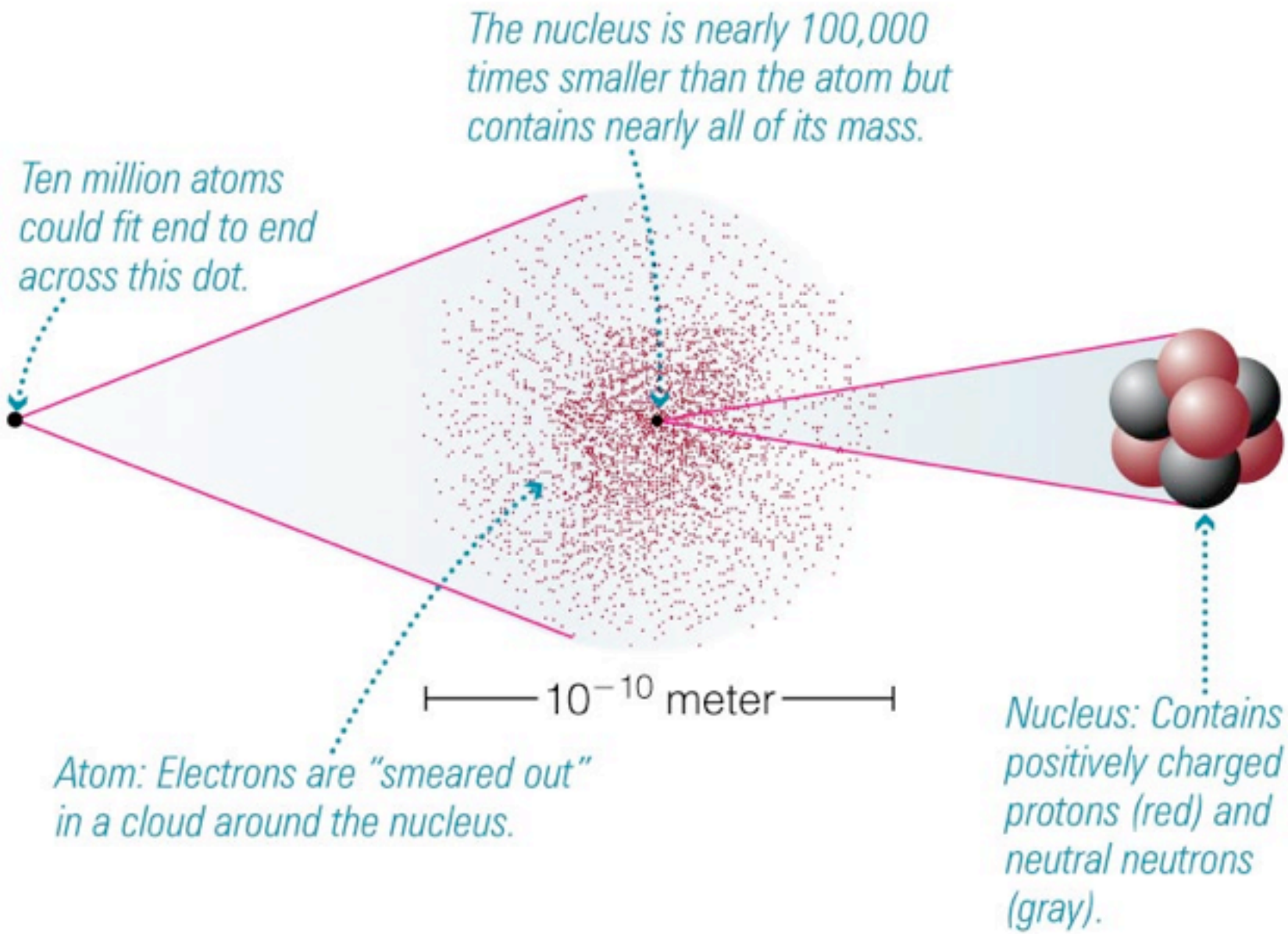
Meteorites stand out against the snow and ice background of Antarctica

Meteorites are Ancient

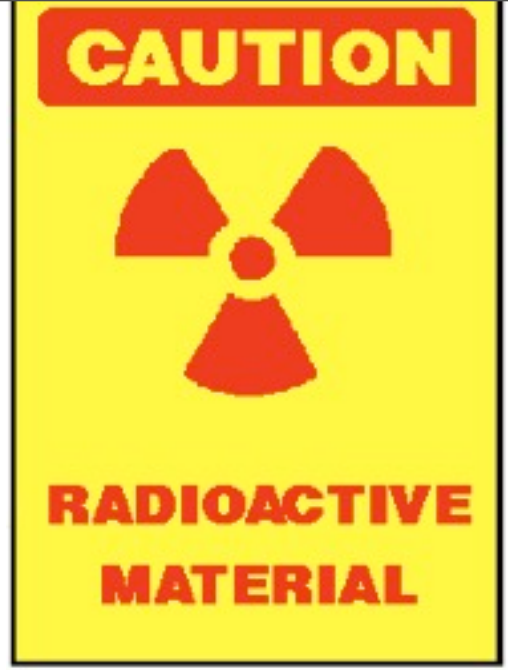
- We have found that meteorites are the oldest objects in the Solar System
- Oldest meteorites: age = 4.56 billion years
- Meteorites tell us the age of the solar system itself!

How do we know?

Inside Atoms: Nuclei



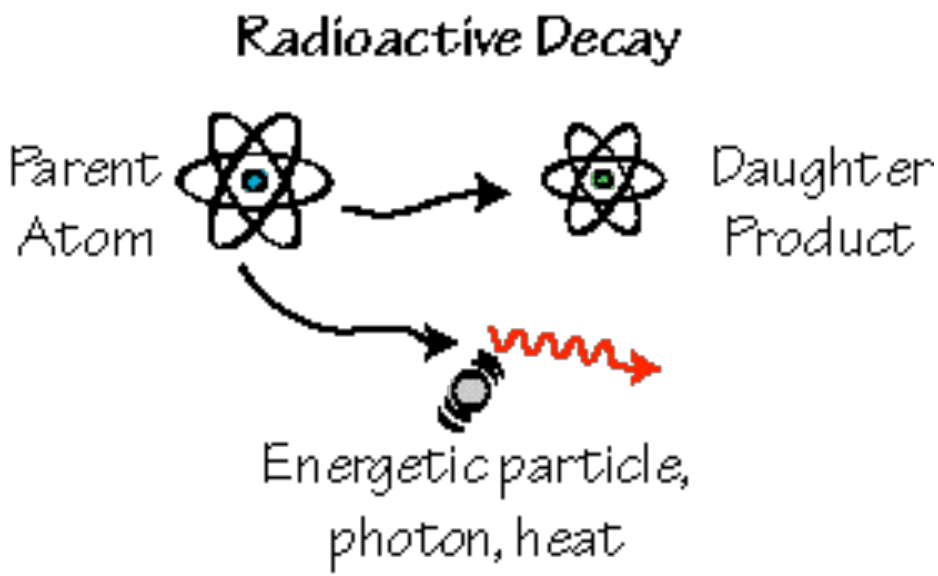
Radioactive Decay



Most atomic nuclei: stable

But some nuclei are unstable: radioactive

- **after some time, decay, producing**
  - ★**new nucleus ("daughter"): different element! alchemy!**
  - ★**high-energy particles (electron, sometimes photon) that act as heat source**

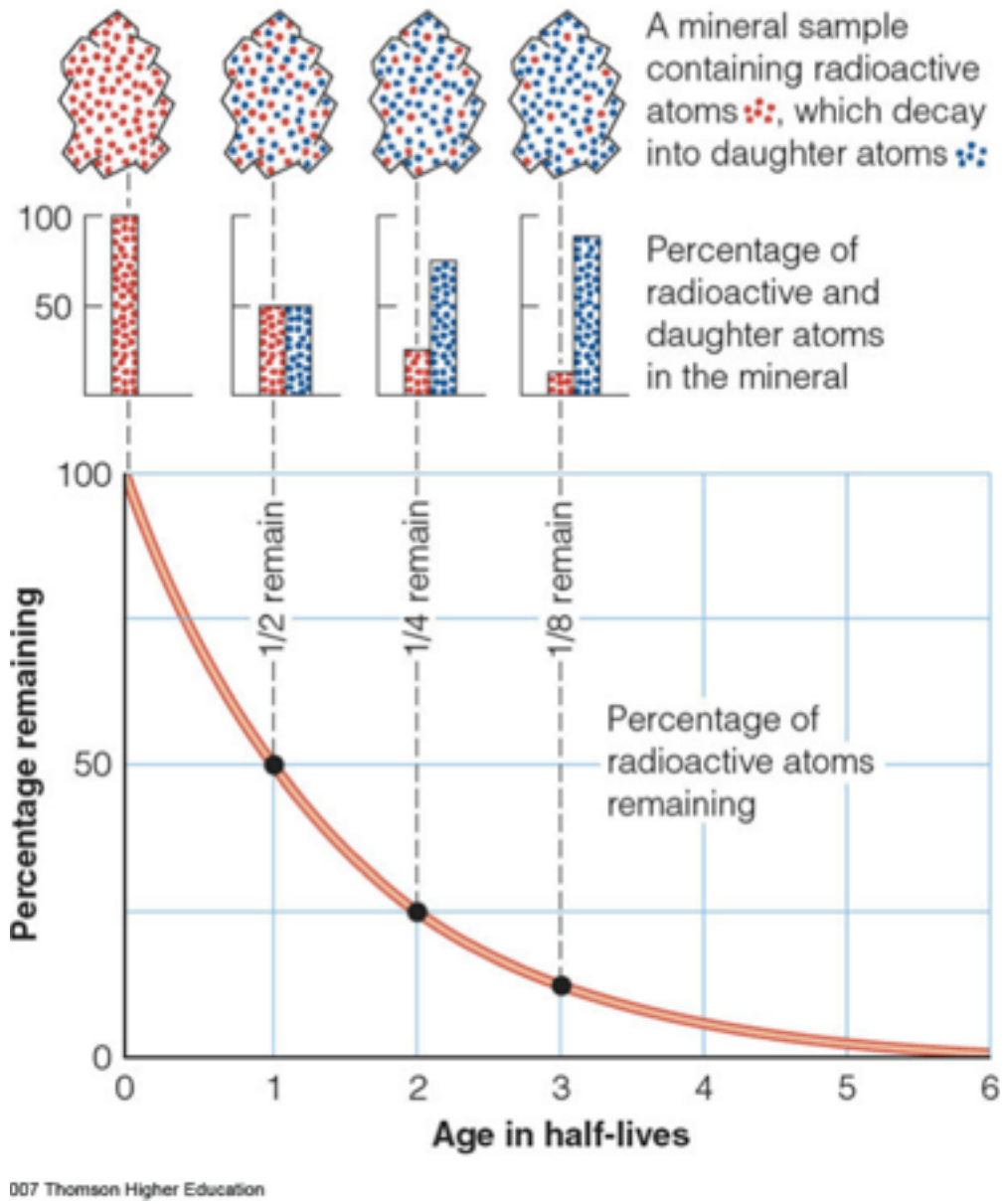


Radioactivity is a good clock!

As radioactive parent decays, the amount of daughter product increases

Rate of decay is measured by half-life

- Time it takes for 50% of the radioactive atoms to decay
- different half-lives for different types of nuclei: some << 1 sec, some >> age of universe



Meteorite Dating

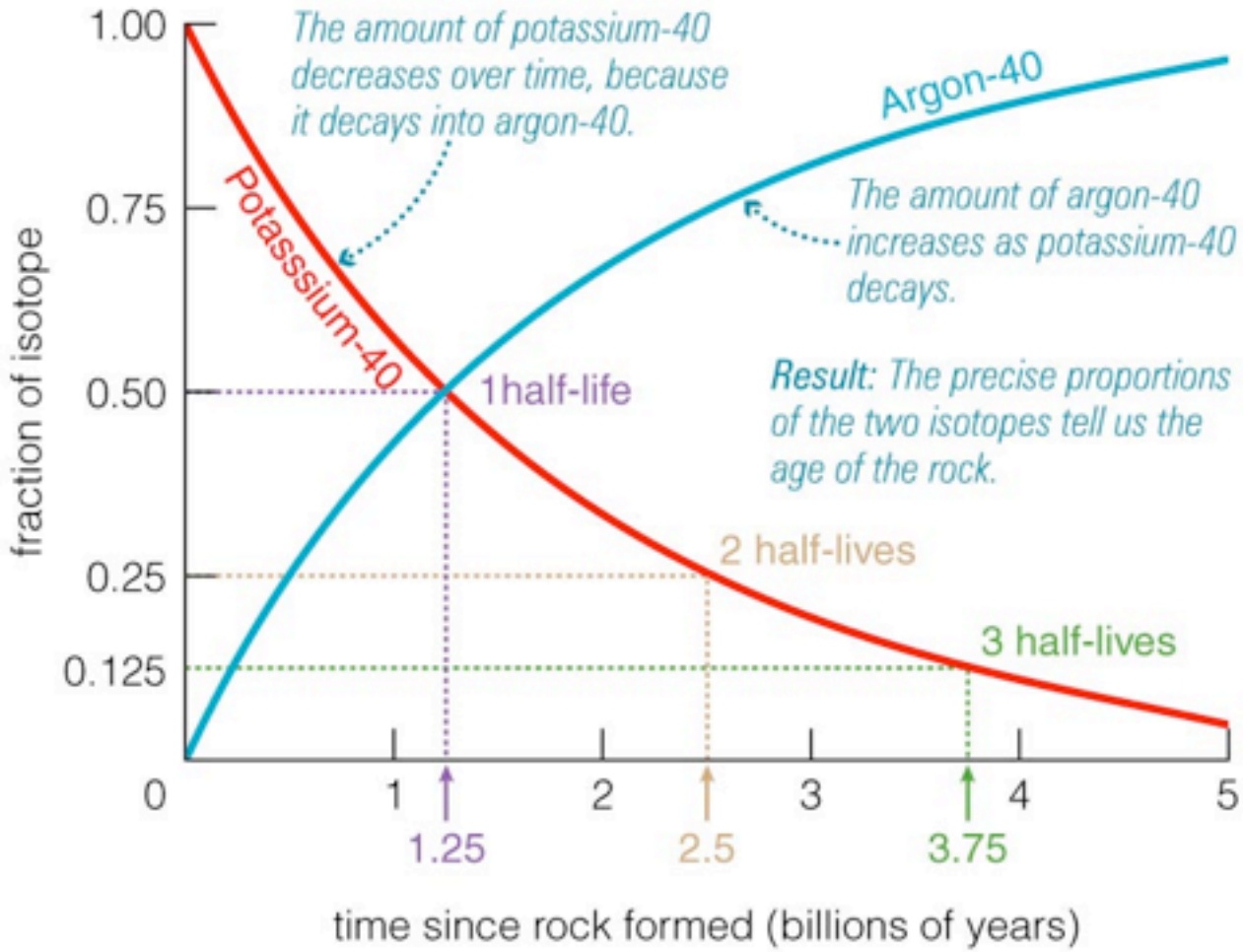
Radioactive “clocks” extremely useful!

Procedure:

- Collect radioactive nuclei from meteor
- Measure both parent and daughter
- Find out how long since sample formed!

Example: The Potassium-Argon Method

- Potassium (K)-40 decays to Argon (Ar)-40 with a half-life of 1.25 billion years
- A rock that contains 7 Ar-40 atoms for every 1 K-40 atom is 3 half-lives old or 3.75 billion years old



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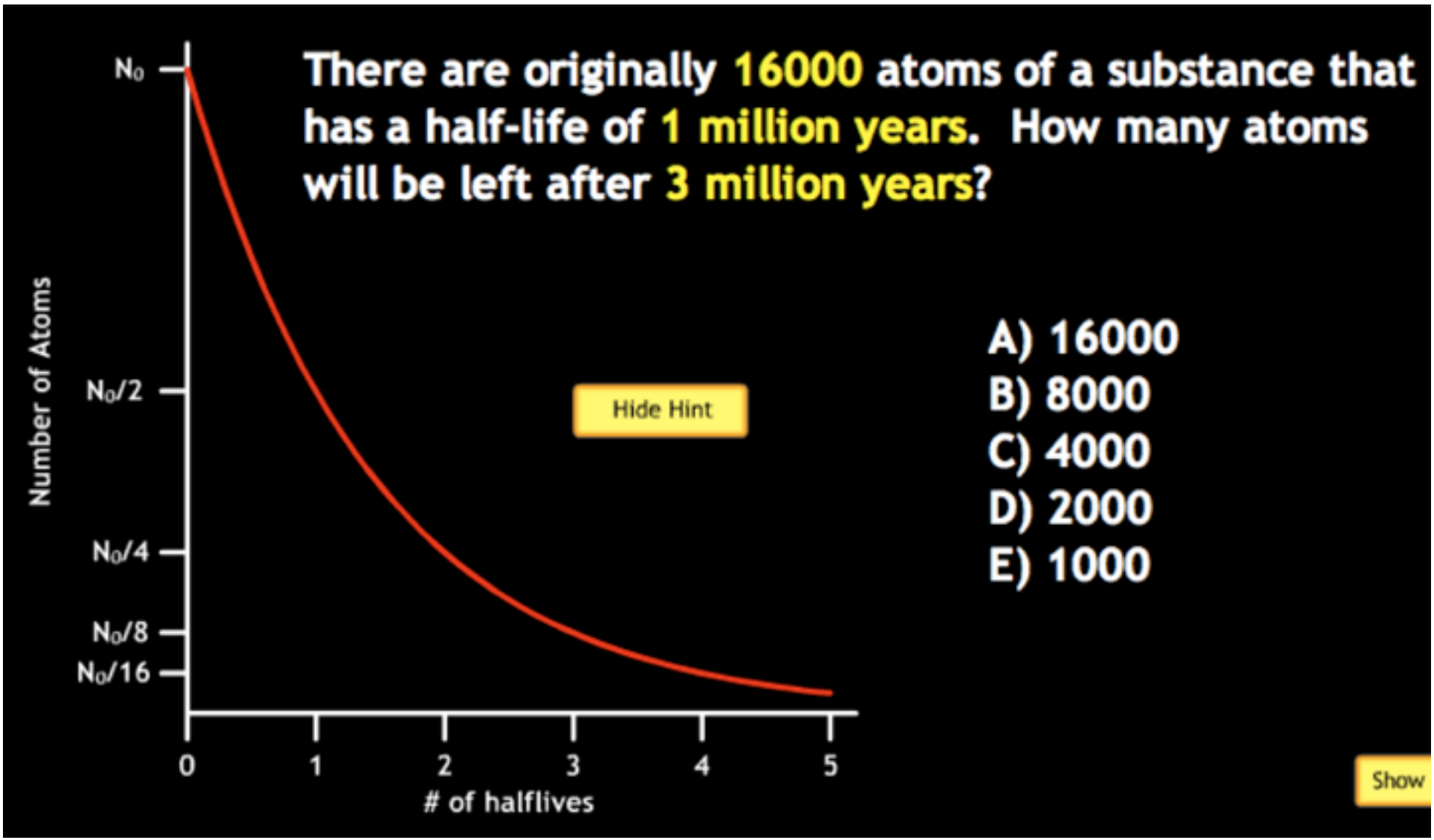


Meteorites are Ancient

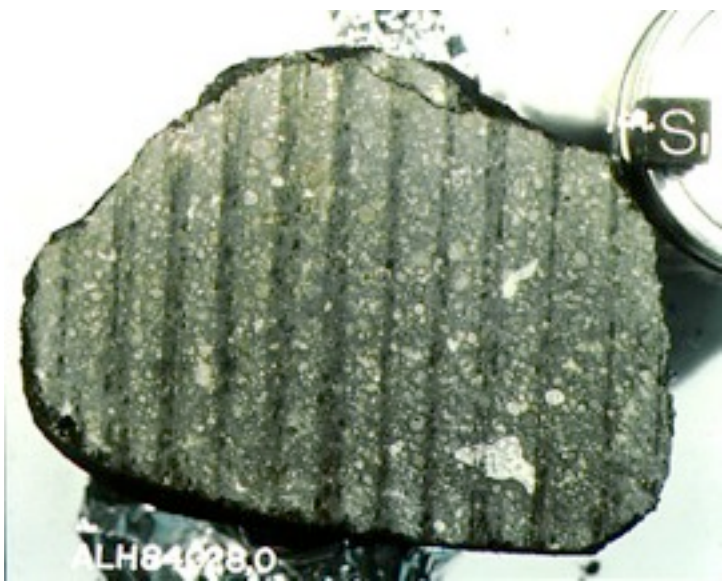
Meteorites are the oldest objects in the Solar System

Oldest are the carbonaceous chondrites (a type of stony)

- Abundant in carbon and water
- Contain amino acids - biochemical ingredients of DNA = building blocks of life!
- 4.56 billion years old

Some have diamonds produced by interstellar shock waves!

Clues to the ancient solar system!



Carbonaceous chondrites