

## Class Reminders:

- Research Project #1 due in class on Friday, October 31
- Homework #8 now available, due next Wednesday
- Extra Credit #5 due November 7 (reminder)

Upcoming Panel Discussion: "Do we Need a 'Manhattan/Apollo Project' To Solve the Energy/Climate Problem?"

Thursday, October 30  
7:00 PM - 9:00 PM  
CU-Boulder, Easton Humanities Room 150  
Free and Open to the Public  
View Flyer: [http://sciencepolicy.colorado.edu/cu/research2\\_flyer.pdf](http://sciencepolicy.colorado.edu/cu/research2_flyer.pdf)

- Read all of Chapter 6

## Question on Nuclear Energy Production in Iran...

### Nuclear program of Iran

From Wikipedia, the free encyclopedia

This article is about Iran's nuclear power program. For information about allegations of Iran developing nuclear weapons, see Iran and weapons of mass destruction.

The nuclear program of Iran was launched in the 1950s with the help of the United States as part of the Atomic Energy program.<sup>[1]</sup> The support, encouragement and participation of the United States and the now European governments in Iran's nuclear program continued until the 1979 Islamic revolution that toppled the Shah of Iran.<sup>[2]</sup>

After the Islamic Revolution in 1979, the Iranian government temporarily discarded elements of the program, and then revived it with less Western assistance than during the pre-revolution era. Iran's nuclear program has included several research sites, a uranium mine, a nuclear reactor, and uranium processing facilities that include a uranium enrichment plant.

Iran's first nuclear power plant, *Buzayeh 1*, is expected to be operational in 2009.<sup>[3]</sup> There are six more plans to complete the Buzayeh 1 reactor, although the construction of 19 reactors or power plants is envisaged.<sup>[4]</sup> Iran has announced that it is working on a new 1000 MWe nuclear power plant to be located in Darkeyeh. Iran has also indicated that it will build more medium-sized nuclear power plants and uranium mines for the future.<sup>[5]</sup>

#### Nuclear program of Iran

- Timeline of nuclear program of Iran
- Atomic Energy Organization of Iran
- Nuclear facilities in Iran
- International treaties
  - Nuclear Non-Proliferation Treaty
  - Additional Protocol
- International organizations
  - International Atomic Energy Agency
  - Non-Aligned Movement
  - United Nations
  - United Nations Security Council Resolutions
    - Resolution 1803
    - Resolution 1737
    - Resolution 1747
- Industry
  - Uranium Mining and Refining

## What is the future of nuclear energy?

The screenshot shows the Constellation Energy website. The main heading is "POWER GENERATION" with a sub-heading "Nuclear Overview". The text describes Constellation Energy's commitment to nuclear power as a reliable, cost-effective, and environmentally friendly source. It mentions that nuclear power is the only source that can provide 24/7 power and that Constellation Energy is working to build new nuclear power plants. A sidebar on the right contains "Nuclear Information" links and "Related Pages" including "Calvert Cliffs 2" and "New York 2".

## What is the future of nuclear energy?

The screenshot shows a news article with the headline "EDF is concerned that Mr. Buffet's ownership of Constellation, through *Shukanta Holdings* Inc., could jeopardize a joint venture the French company has with Constellation to construct nuclear plants in the U.S. using nuclear technology developed by Paris-based *Areva* SA." The article discusses the U.S. Nuclear Regulatory Commission's permission to transfer nuclear operating licenses to MidAmerican and Constellation. It also mentions that Constellation's nuclear plans are "very" advanced and that one reason for EDF's concern may be its stake in General Electric Co. The article is from the Associated Press and includes a date of 10/27/08.



## Advantages:

- No CO<sub>2</sub> emissions → Small impact on global warming
- No SO<sub>2</sub>, CO, NO<sub>x</sub>, particulates, etc.
- Basically (air) pollution free.
- Less radiation leakage in normal operation than coal burning.
- Safety record in US better than fossil fuels (despite 3 Mile Island).
- Uranium relatively abundant, relatively inexpensive.
- Quantity needed to mine is relatively small (compared to coal).

Recall "R/P" = resource amount / current production rate  
~ "simple time to end"

It is about R/P ~ 150 years for Uranium fuel.

"Breeder" reactor technology would extend that to 1000's of years.

### Clicker Question

How long will our (US) Uranium reserves last if we ramp up nuclear energy to cover all our electrical needs, using present reactor technology?

- A) 30 years
- B) 300 years
- C) 1000 years
- D) 5000 years
- E) Even longer than that.

Using current extraction technologies, about 30 years.  
R/P ~ 150 but we only get about 20% of electrical from nuclear.  
If we can figure out how to efficiently get U from sea water, there's quite a bit there, the supply would last 100's of years then. (It'd be more expensive than it is now, but by less than a factor of 10, so this may happen some day!)  
Breeder reactors may be necessary.

### Disadvantages:

- Public fears
- "New" technology, hard to understand, unknown risks



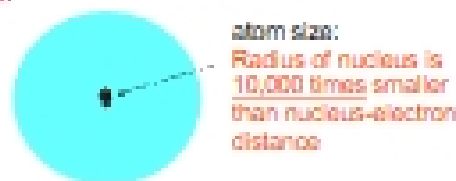
- Catastrophic failure can have severe consequences
- Radioactive waste disposal (how and where?)
- Nuclear weapon proliferation (fuel and waste can be reprocessed for bombs).
- Reactor construction costs more than coal burning plant (in the USA currently). Decommissioning is expensive.

## Nuclear Physics

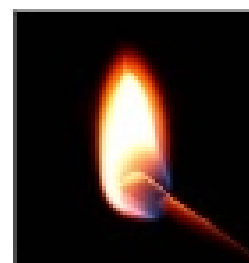
What are atoms? What are nuclei?

Atoms are made of a central nucleus (composed of protons and neutrons). These protons and neutrons are bound together by the strong force (also called the nuclear force).

In "orbit" around the nucleus are electrons. These electrons have a negative electrical charge and are thus attracted ("bound") to the nucleus (which has positive charge) by the electric force.



atom size:  
Radius of nucleus is 10,000 times smaller than nucleus-electron distance



Chemical Reactions involve atomic electrons.

Typical energy per reaction ~  $10^{-18}$  Joules (or 10 eV)



Nuclear Reactions involve the nucleus.

Typical energy per reaction ~  $10^{-11}$  Joules (or 200 MeV)

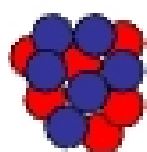
Nine orders of magnitude difference in energy !

## Nuclear Notation

Z = "atomic number" = # of protons

N = "neutron number" = # of neutrons

A = N+Z = "atomic mass number"



Example = Carbon

Z = 6 protons

N = 6 neutrons

A = 12 protons + neutrons

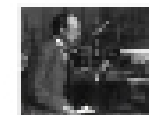


Note there are other "isotopes" of carbon. These have similar chemical properties (same electron configuration), but just a different number of neutrons in the nucleus.

## Discoveries

The basic pieces of the atom were discovered in the early 20<sup>th</sup> century.

1897 – Discovery of the electron



1911 – Discovery of the nucleus (i.e. proton)



1932 – Discovery of the neutron

On the same time scale in history, radioactivity was discovered.



Also, in 1905 Einstein related mass to energy  $E=mc^2$  !

## X-Ray!

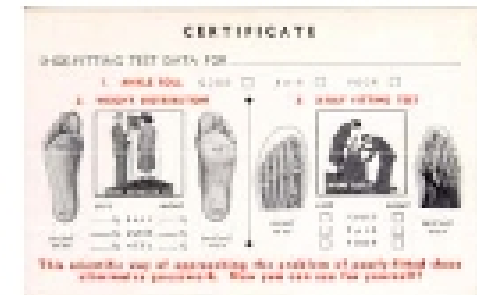
At the time, there were many strange phenomena observed. They did not know what these things really were (e.g. particles, light, other...).



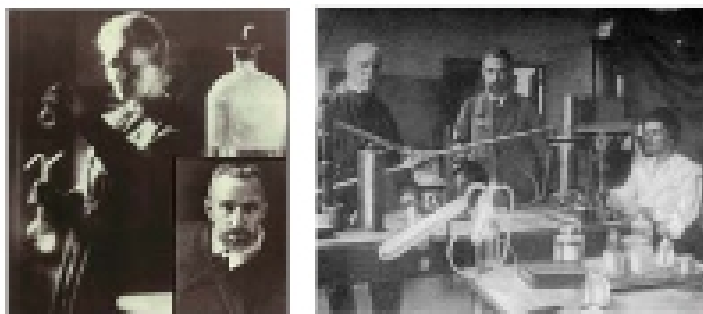
Wolfram Design via AP/Wide World Photos: Radiograph of Prof. Röntgen's hand

Interesting names ( $\alpha$  particle,  $\beta$  ray, X-ray, ...)

X-ray's to see how well the bones in your foot fit into that new shoe.



Marie Curie discovered "radium" (a new element at that time, and it was naturally radioactive or unstable).



In 1938, Lise Meitner discovered that Uranium nuclei spontaneously fission (split into smaller pieces).



Interestingly she did not get the Nobel Prize for this discovery. It went to Otto Hahn?

Another notable item is that the radiation many of these people were using was also killing them. Health impact were not understood at the time.

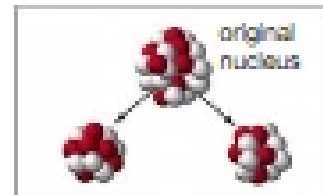
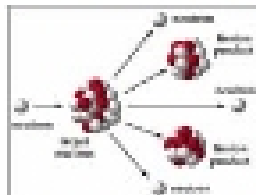


Clicker Question

## Fission!

Some isotopes of elements are inherently unstable and will just spontaneously split after some amount of time.

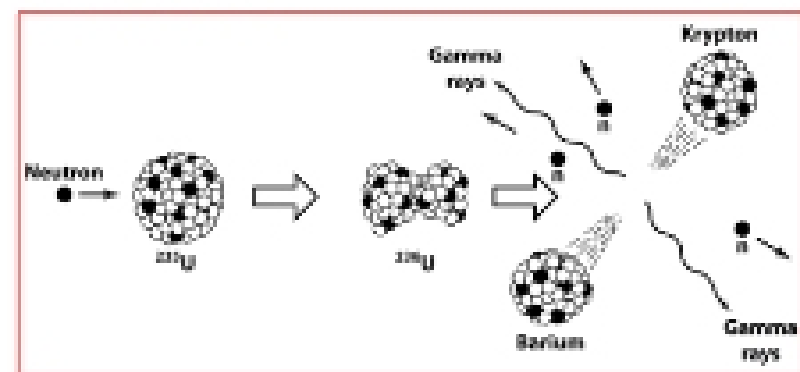
Some other elements only undergo fission if it is induced.



Which of the following are true?

- A) The left figure is of spontaneous fission
- B) The right figure is of spontaneous fission
- C) Both figures are induced fission
- D) Both figures are spontaneous fission

## Induced Fission



Neutron = n

Gamma rays =  $\gamma$  = photons or electromagnetic energy (light).