Science of Nuclear Energy and Radiation

Nuclear has been a required unit in the grade 12 physics course and from the looks of things it will continue to be part of the course if the Ministry of Education approves the submitted course outlines. Nuclear physics is usually an area that invokes much student interest and questions: some of which I can't answer. Along with this interest however, goes a lot of fear invoked by the words radiation, nuclear reaction, chain reaction. Part of our job as teachers is to rationalize this fear for them and provide the students with enough background so they can understand what they should fear and what is possible when used with care. I hope this course has given you some information that will help you and thus your students make these decisions. Many of the students that you are teaching will have a close encounter with nuclear medicine in their life times and any background you can provide them with will certainly be useful to them when and if this should happen.

I have tried to package up some activities and demonstrations that I have found useful and hopefully you can use some of them. I have found that hands on activities go a long way to alleviating that fear in the students. So if you will find something here to use that you aren't already feel free. I left any headers off so that you an just photocopy and use, in addition I have provided you with a disk for PC's that have the shareware software and all the pages from this unit. The material is done in Word 97 and if you try to use it in a prior version you might run into formatting problems especially with the graphics.

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9. Student Cloud Chamber

Cloud chambers are one type of radiation detector that show the paths of the emitted particles as they pass through the air and cause ionizations as they travel. Below are the instructions for making a simple chamber, which we will use in class.

Day 1

The bottom of the petri dish needs to be painted. To prepare the dish for painting, separate the halves and put the top away for later. Wrap a layer of adhesive tape around the side of the dish to protect from over spray. Take the bottom to the painting area and place the dish bottom up and spray paint the bottom. Use a few light passes of the can so the paint is uniform and doesn't run. Take the dish to the drying area and leave to dry.

Day 2

Cut a 1.0 cm wide strip of construction paper to fit around the circumference of the bottom half of the dish. Wet this strip with alcohol and place on the inside of bottom dish. Use tweezers to handle the strip and avoid contact of the alcohol with your hands. Using the tweezers, place the radioactive ore in the center of your chamber and place the top on. Put a layer of the crushed dry ice on the Styrofoam plate and place the covered chamber on this layer. ***Do not touch the dry ice with your hands, as it is very cold and will cause frostbite.*** Illuminate your cloud chamber with the light source slightly from the side and wait about 4 to 5 minutes. At this time you may have to gently wipe away any condensation that has formed on the outside of the top. (Do not open the chamber) Looking down from above you should now be able to see tracks like small jets being emitted from the source. If you can't see them try moving the light source at various angles to get better illumination.

When you have answered the questions below disassemble your chamber, use the tweezers to put the source back in the container specified. Place the top back on the dish and leave the dish where instructed.

Questions

1. Write a short description of the tracks. Be sure to state if all are the same length, width or if there seems to be any connection between the characteristics.
2. Is there any pattern to the rate of emission of the particles?

Teachers notes for the 10 minute Student Cloud Chamber

Student's interest is increased when they make their own equipment. These are instructions for making a simple cloud chamber in class. The cost is cheap especially if compared to the cost of purchasing a similar device, for example, in the 1998 VWR catalogue (Sargent Welch) the cloud chamber #WL6829-A the cost is $67.40.
For a class set of 15 to 20 you would need:

- One order of petri dishes which for the top of the line Premium clarity 100 x 20 would cost $10.10 /20 (VWR page25 WLS26028-30)
- A class set of radioactive sources such as the one offered in the VWR catalogue on page 706, #WL5542A @ $2.60 each.
- A can of black spray paint.
- ~ 15 small Styrofoam plates.

On the first day when there is painting there are a couple of options. We do ours in a large cardboard box to catch the over spray. A fume hood could also be used but make sure to use some paper to catch the over spray. Another option is the shop in your school may have an actual paint room you could use for a half-hour.
On the second day you will need to pick up some dry ice to cool the chambers. In Oakville I use Praxair, they usually donate the small amount we need. The cost is low anyway, under $4.00 / kg and you only need 2-3 kg. You will need to crush the dry ice, a brick works nicely. Wear gloves to avoid bites. A small non-metallic scoop for the students to use when placing the Dry ice on the plate is useful.

Demonstration - Collection of Radon Daughter Products

When I first introduce the topic of radioactivity the students find in hard to believe that there is radioactive materials in their environment and that they are exposed to the radiation from these sources. One of the most convincing demonstrations for the students is the following.

- Take an ordinary balloon and place it under the G-M tube and take a 1-minute reading.
- After that blow up the balloon and tie a knot in the end.
- Charge the balloon negatively by rubbing with fur, get a good charge by rubbing vigorously for 30 to 60 seconds.
- Suspend the balloon in the room somewhere where it won't touch anything and leave it for 30 to 45 minutes.
- After this time remove the balloon and use a pin to let the air out of it. It seems to work better if you can let the air out without popping the balloon.
- Fold the balloon up and place it under the G-M tube the same distance away as for the first reading and take another reading. We consistently get readings around 10x background.

Radon-222 is a radioactive gas that is one step in the decay chain of Uranium hence it is constantly being produced as Uranium goes through its natural decay sequence. Bricks and concrete contain some Uranium and thus are a source of the Radon. Radon is breathed in and usually back out since the half-life is just under 4 days. However the daughter products of Radon are solids and will cling to dust particles in the air. The dust is attracted to the large charge on the balloon and will accumulate in the 30 minutes or so.

The collection can also be done using a vacuum cleaner with a piece of filter paper over the intake. I haven'' tried this and I'' not sure I want to listen to the vacuum for 30 minutes. Another method I.V. tried and did get results is to use a piece of filter paper to wipe the front of a TV screen about 30 minutes after is was turned off,

A possible extension is to take a series of measurements of the collected sample and see if you can determine the half-life and perhaps the product that is being collected. Apparently some of the daughter products have sufficiently short half-lives that this can be done. See reference below.

References

Thomas A. Walkiewicz, Physics Teacher.33,345 (1995)

Web Search Assignment for Nuclear Energy

This is a two-day assignment. During the first day you will be given a topic. Your group is to research this topic by visiting at least 5 sites on the web and reading about your topic, As you do this you are to make up three questions on your topic that will be given to another group tomorrow to find the answers. Try to make up questions that would force the next group to learn about the topic and would also make them visit at least three sites to be able to answer all the questions, Fill in the information below and ***rewrite only your questions*** on the back then turn in the sheet at the end of the period.

Names of group members:

1._____ 3._____

2._____ 4._____

Topic: _____

Search Engine(s) used ? _____

Key words searched for **(i) initial**_____

_____

(ii) Refined _____

_____

Site	Address	Question	Answer
1 rating 1 2 3 4 5			
1 rating 1 2 3 4 5			
1 rating 1 2 3 4 5			

For each site circle the rating with 1 being very useful and 5 being not very useful.

Web Search Assignment for Nuclear Energy Day 2

Find the answer to the following questions on the WWW. Fill in the address and the answer that you have found.

Names of group members:

1._____ 3._____

2._____ 4._____

Topic: _____

Search Engine(s) used ? _____

Key words searched for **(i) initial** _____

_____

(ii) Refined _____

_____

Site	Address	Question	Answer
1			
2			
3			

Web Search Assignment for Nuclear Energy

This is a two-day assignment. During the first day you will be given a topic. Your group is to research this topic by visiting at least 5 sites on the web and reading about your topic, As you do this you are to make up three questions on your topic that will be given to another group tomorrow to find the answers. Try to make up questions that would force the next group to learn about the topic and would also make them visit at least three sites to be able to answer all the questions, Fill in the information below and ***rewrite only your questions*** on the back then turn in the sheet at the end of the period.

Names of group members:

1._____ 3._____

2._____ 4._____

Topic: RADON

Search Engine(s) used ? Alta vista

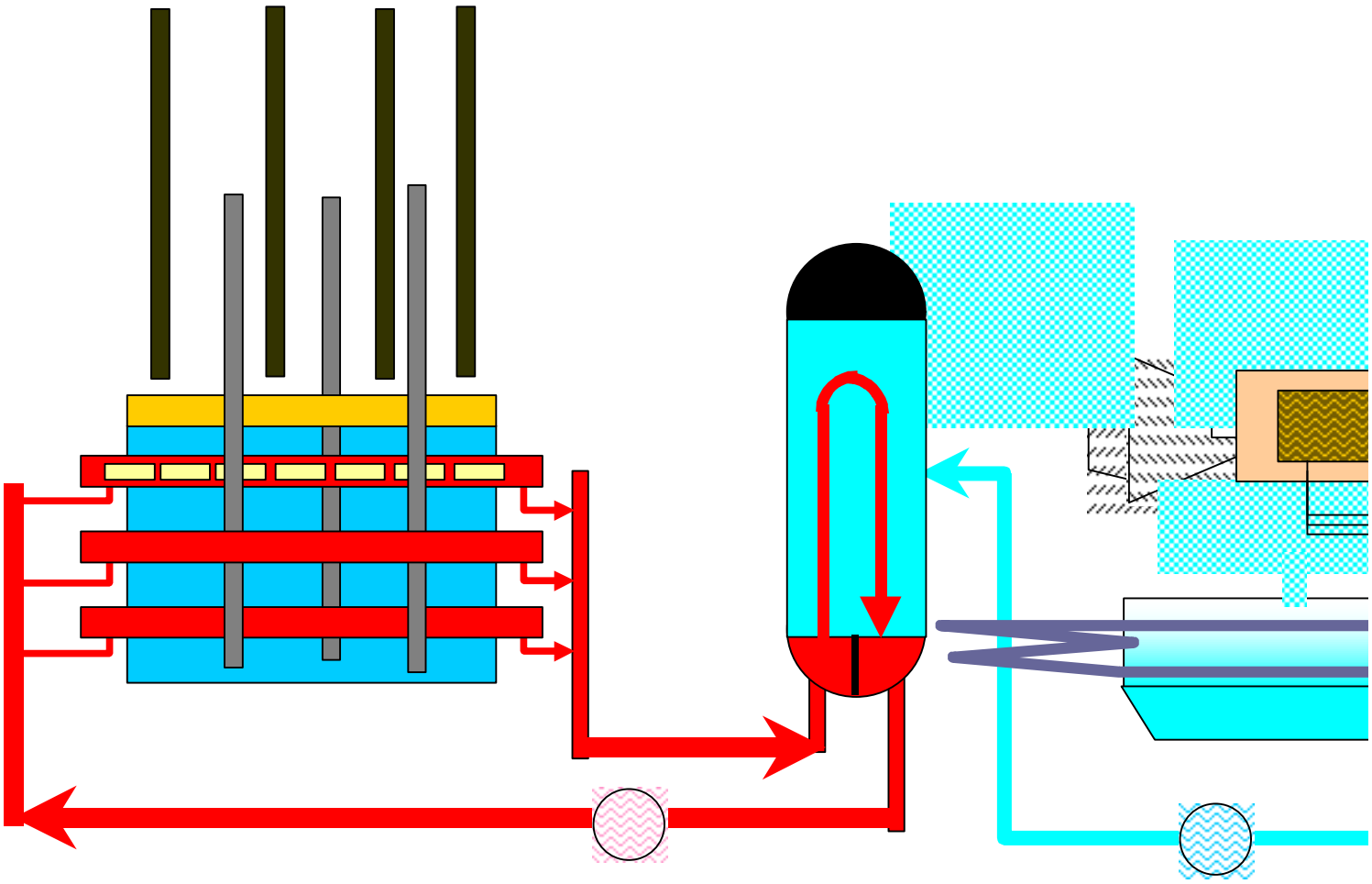
Key words searched for **(i) initial** radon

(ii) Refined radon, health effects
radon,properties

Site	Address	Question	Answer
1 rating 1 2 3 4 5	www2.inetdirect.net/~ecoindy/chems/radon#top	What is the primary pathway by which you are exposed to radiation from radon ?	By breathing in dust that has radon and its daughters attached to it
2 rating 1 2 3 4 5	WWW.atral.com/U238.html	What are the following 4 daughters of radon 222 and their half-lives ?	Po-218 –3.05 minutes Pb- 214 – 26.8 minutes Bi – 214 – 19.7 minutes Po –214 – 1.5 x 10^{-4} s
3 rating 1 2 3 4 5	www.in-search-of.com/frames/periodic/elements/86.html#iso	What is the unusual property of radon when it is cooled below the freezing point.	A brilliant phosphorescence that is yellow at first then becoming red-orange as the temperature approaches that of liquid air.

For each site circle the rating with 1 being very useful and 5 being not very useful.

CANDU REACTOR



Primary Coolant, Heavy Water

Calandria, full of heavy water
As a moderator

Steam Turbines

electrical generator

steam generator

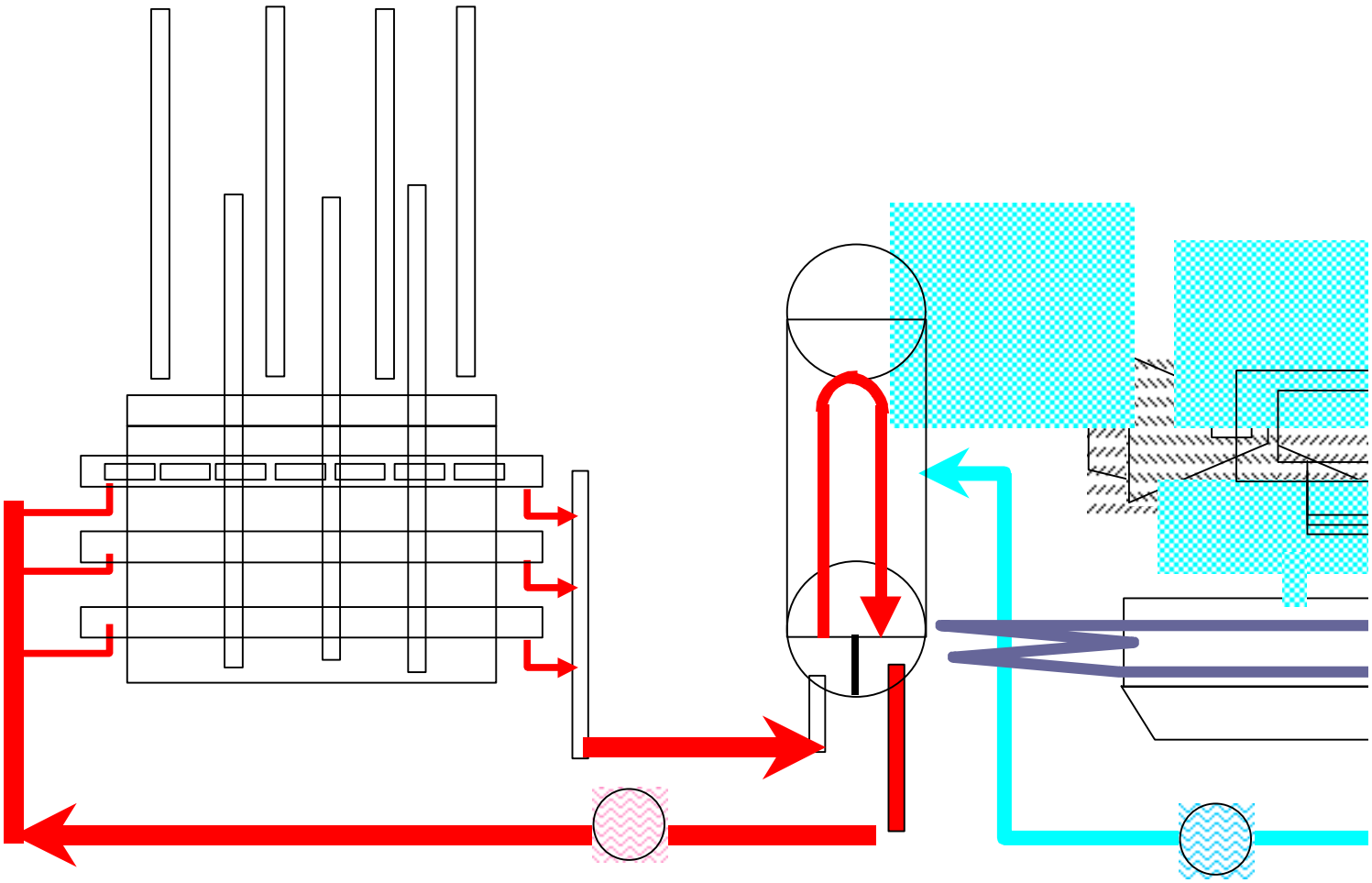
lake water

control rods

shut off rods

fuel bundles

CANDU REACTOR



Primary Coolant, Heavy Water

Calandria, full of heavy water as a moderator

Steam Turbines

electrical gen

steam generator

lake water

control rods

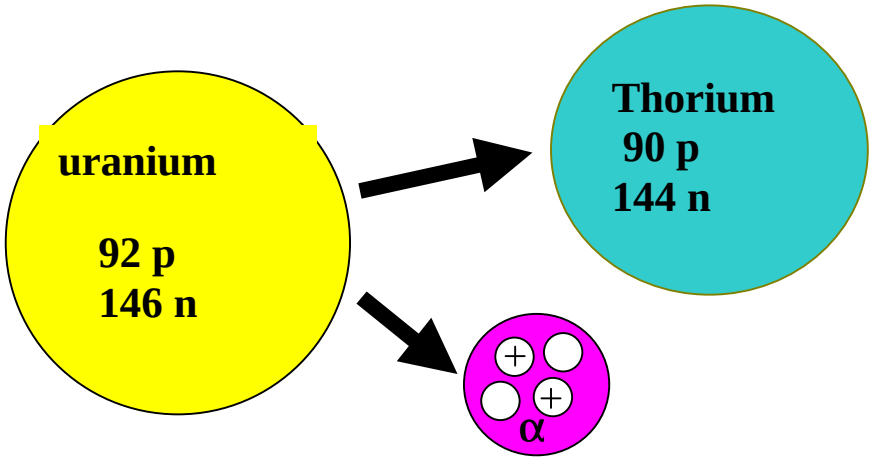
shut off rods

ALPHA DECAY

The emission of an alpha particle (helium nucleus), for example:

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

parent nucleus daughter nucleus alpha particle



In general alpha decay can be summed up with the following equation.

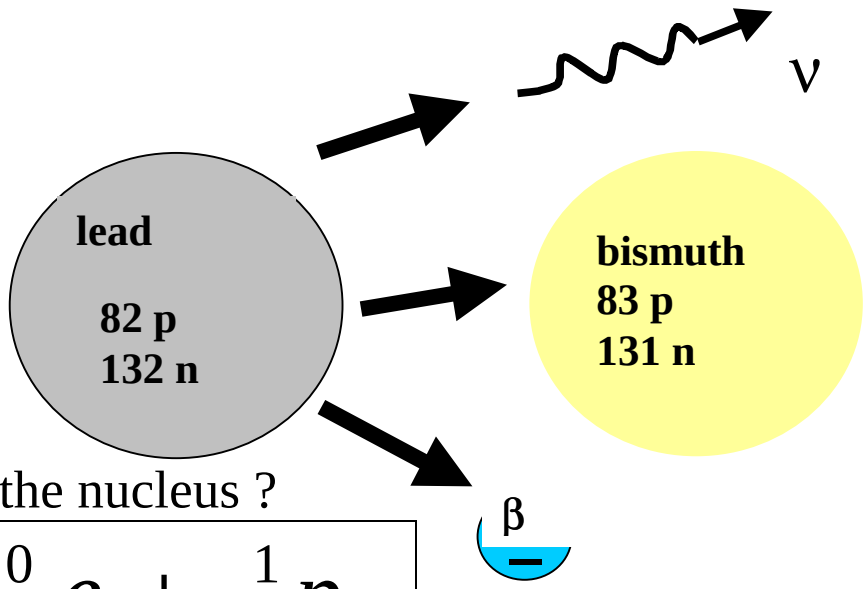
$$^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$$

BETA DECAY

The emission of a beta particle (electron) for example:

$$^{214}_{82}Pb \rightarrow {}^{214}_{83}Bi + {}^{0}_{-1}e + \bar{n}$$

parent nucleus	daughter nucleus	beta particle
anti-neutrino		



What happens in the nucleus ?

$$^{1}_{1}n \rightarrow {}^{0}_{+1}e + {}^{1}_{0}p$$

In general beta decay can be summed up with the following equation.

$$^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}b + \bar{n}$$

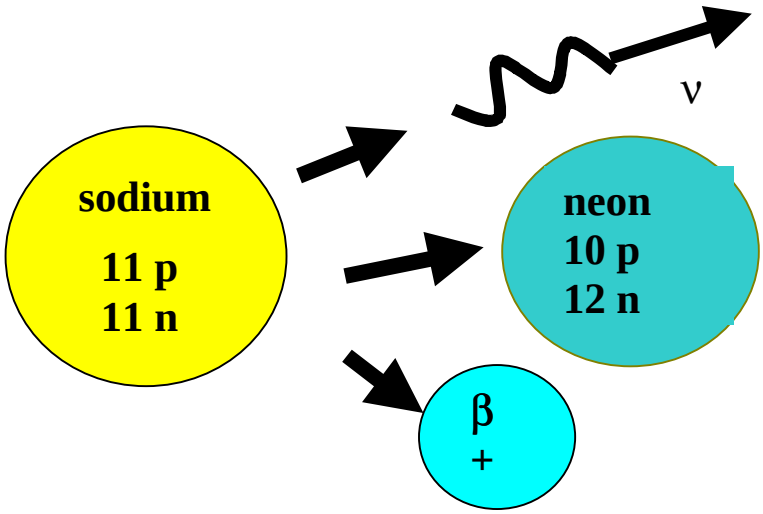
BETA DECAY

Positron Emission

The emission of an positron (positive electron), for example:

$$^{22}_{11}Na \rightarrow {}^{22}_{10}Ne + {}^{0}_{+1}e + n$$

parent nucleus — daughter nucleus — positron — neutrino



What happens in the nucleus ?

$$^{1}_{1}p \rightarrow {}^{0}_{+1}e + {}^{1}_{0}n$$

In general bets positive decay can be summed up with the following equation.

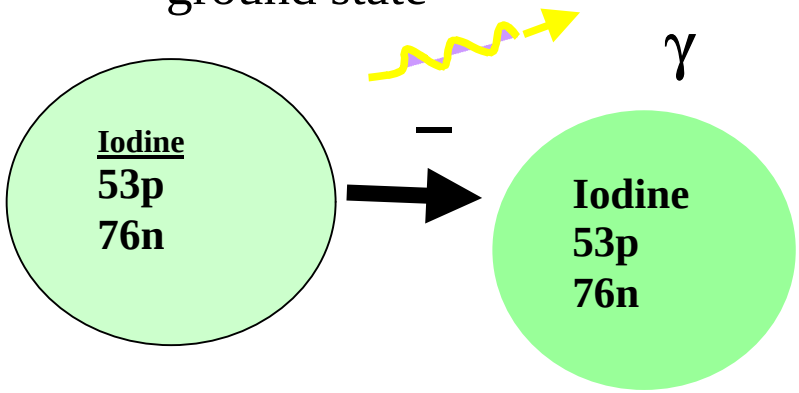
$$^{A}_{Z}X \rightarrow {}^{A}_{Z-1}Y + {}^{0}_{1}b + n$$

GAMMA DECAY

The emission of gamma radiation) for example:

$$^{129}_{53}I^{*} \rightarrow {}^{129}_{53}I + g$$

nucleus in excited state | nucleus in ground state | gamma photon



In general gamma decay can be summed up with the following equation.

$$^{A}_{Z}X^{*} \rightarrow {}^{A}_{Z}X + g$$

Gamma is always proceeded with a radioactive decay (usually beta) see below