NUCLEAR ENERGY		
Teacher: Alfonso Raspi (Physics/Maths specialist) - ITC Antonio Zanon, Udine (Italy)		
UNIT FEATURES		
Students' age	17 years old	
Students' language level (CEFR)	B1/B2	
Subject	Physics	
Module topic	Energy Production	12 hours
Unit title	Nuclear Energy	3-4 hours
Comments	The unit has been constructed entirely with net resources and devised as a first introduction to the concept of WebQuest, with a view to enhancing students' IT skills. It also provides teachers with an example of how even language and comprehension exercises may either be found directly on line or derived from downloaded texts (Internet "milking" prompts provided in an appendix).	
Unit description	Nuclear power plants are often presented as the answer to the world's ever-increasing need for energy. This unit focuses on how nuclear energy is presently produced, and what counter-effects its exploitation might bring.	
Goals	1. Understanding the principles on which nuclear energy is based. 2. Learning the pros and cons of nuclear energy production.	
Objectives	1. To enounce the equation for nuclear fission 2. To enounce Einstein's equation concerning energy and mass 3. To understand how a chain reaction takes place 4. To understand how a nuclear power plant works 5. To understand the risks of nuclear power plants	
Contents	Equation for nuclear fission – Einstein's equation $e=mc^2$ – Chain reaction and critical mass – Nuclear power plants and their components – How a nuclear plant produces electricity – Some accidents that have occurred – Nuclear wastes	
Student workload	1. In groups, students report according to objectives listed above. 2. Individually, students do a test after each group's presentation to the class.	
Resources and materials		
Teacher resources	Internet, DVD / Video	
Teacher-produced or -distributed materials	Printouts of basic text on topic - Internet WebQuest prompt sheets - Nuclear fission worksheet (terminology and comprehension text) - Glossary - Plan of a nuclear power plant (labelling exercise) - Final test (multiple choice)	
Student resources	Internet - Science dictionary (on line)	
Student-processed or –produced materials	Worksheets, reports, test.	
Learning environments	Students spend one or two sessions in the computer room searching the Net for information and two sessions in their own classroom (one to prepare materials and one for the oral presentations).	

Assessment	1. Oral presentation (in groups). 2. Tests on each presentation (individually). Presentations will be assessed according to the following criteria: a) Accuracy and detail of the information provided. b) Amount of information provided and use of adequate and sufficient sources. c) Organisation and structure of the presentation. d) Capacity to communicate the information successfully.
Lesson plan	Session 1. Getting Net research under way. 1. Presentation of the topic to the class and distribution of background printouts. 20' 2. Guided instructions for Internet use, including prompts on keywords, search and discrimination criteria for sites, material and URL saving techniques. 10' 3. Research work is assigned, individually or in pairs, on the five objectives listed above. 25' (A supplementary session may be planned if students' IT skills should require it). Session 2. Group work. 1. Group work for development of presentation. 55' (Allow an extra session if computer presentations are opted for, instead of transparencies, posters etc.) Session 3. Presentations and assessment. 1. Oral presentations, followed by written assessment. 55'
Learning activities	Session 1: Students take notes on teacher's explanation. 15' Students receive instructions for their work. 15' Students carry out targeted individual research on the Net. 25' [Students review printout as homework, before completing exercise assigned.] Session 2: Students divide in five groups, according to objectives, and prepare reports. 55' Session 3: Oral group presentations to the class. 45' Unit assessment quiz 10'
Materials provided	• **<u>Basic text</u>**: printouts of necessary background material taken from http://www.dummies.com/WileyCDA/DummiesArticle/id-1669.html (adapted from **Chemistry For Dummies**) In the 1930s, scientists discovered that some nuclear reactions can be initiated and controlled. Scientists usually accomplished this task by bombarding a large isotope with a second, smaller one — commonly a neutron. The collision caused the larger isotope to break apart into two or more elements, which is called *nuclear fission*. Figure 1 shows the equation for the nuclear fission of uranium-235. $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{142}_{56}Ba + ^{91}_{36}Kr + 3\,^{1}_{0}n$ **Figure 1:** The equation for nuclear fission. Reactions of this type also release a lot of energy. Where does the energy come from? Well, if you make *very* accurate measurement of the masses of all the atoms and subatomic particles you start with and all the atoms and subatomic particles you end up with, and then compare the two, you find that there's some "missing" mass. Matter disappears during the nuclear reaction. This loss of matter is called the *mass defect*. The missing matter is converted into energy. You can actually calculate the amount of energy produced during a nuclear reaction with a fairly simple equation developed by Einstein: $E = mc^2$. In this equation, E is the amount of energy produced, m is the "missing" mass, or the mass defect, and c is the speed of light, which is a rather large number. The speed of light is squared, making that part of the equation a *very* large number that, even when multiplied by a small amount of mass, yields a *large* amount of energy.

Chain reactions and critical mass

Take a look at the equation for the fission of U-235 in the preceding section. Notice that one neutron was used, but three were produced. These three neutrons, if they encounter other U-235 atoms, can initiate other fissions, producing even more neutrons. It's the old domino effect. In terms of nuclear chemistry, it's a continuing cascade of nuclear fissions called a *chain reaction*. The chain reaction of U-235 is shown in Figure 2.

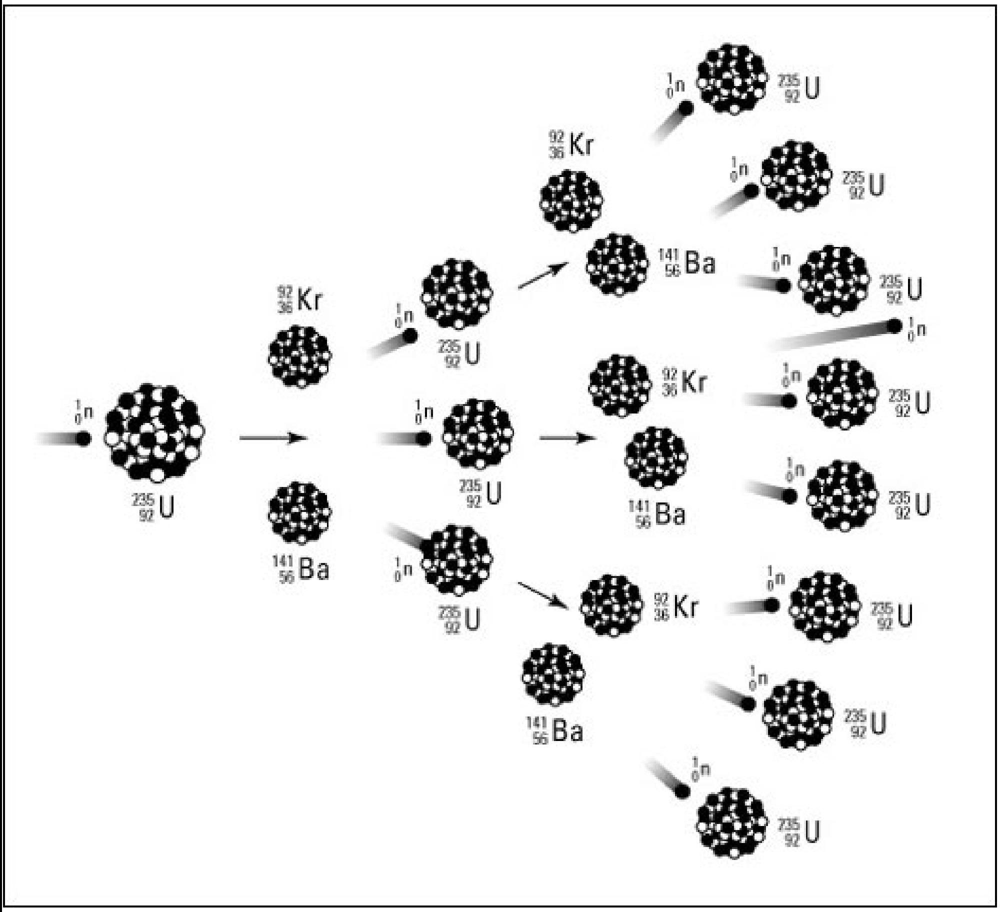


Figure 2: Chain reaction.

This chain reaction depends on the release of more neutrons than were used during the nuclear reaction. If you were to write the equation for the nuclear fission of U-238, the more abundant isotope of uranium, you'd use one neutron and only get one back out. You can't have a chain reaction with U-238. But isotopes that produce an *excess* of neutrons in their fission support a chain reaction. This type of isotope is said to be *fissionable*, and there are only two main fissionable isotopes used during nuclear reactions — uranium-235 and plutonium-239.

A certain minimum amount of fissionable matter is needed to support a self-sustaining chain reaction, and it's related to those neutrons. If the sample is small, then the neutrons are likely to shoot out of the sample before hitting a U-235 nucleus. If they don't hit a U-235 nucleus, no extra electrons and no energy are released. The reaction just fizzles. The minimum amount of fissionable material needed to ensure that a chain reaction occurs is called the *critical mass*. Anything less than this amount is called *subcritical*.

Atomic bombs (big bangs that aren't theories)

Because of the tremendous amount of energy released in a fission chain reaction, the military implications of nuclear reactions were immediately realized. The first atomic bomb was dropped on Hiroshima, Japan, on August 6, 1945.

In an atomic bomb, two pieces of a fissionable isotope are kept apart. Each piece, by itself, is subcritical. When it's time for the bomb to explode, conventional explosives force the two pieces together to cause a critical mass. The chain reaction is uncontrolled, releasing a tremendous amount of energy almost instantaneously.

The real trick, however, is to control the chain reaction, releasing its energy slowly so that ends other than destruction might be achieved.

Nuclear power plants

The secret to controlling a chain reaction is to control the neutrons. If the neutrons can be controlled, then the energy can be released in a controlled way. That's what scientists have done with nuclear power plants.

In many respects, a nuclear power plant is similar to a conventional fossil fuel power plant. In this type of plant, a fossil fuel (coal, oil, natural gas) is burned, and the heat is used to boil water, which, in turn, is used to make steam. The steam is then used to turn a turbine that is attached to a generator that produces electricity.

The big difference between a conventional power plant and a nuclear power plant is that the nuclear power plant produces heat through nuclear fission chain reactions.

How do nuclear power plants make electricity?

Most people believe that the concepts behind nuclear power plants are tremendously complex. That's really not the case. Nuclear power plants are very similar to conventional fossil fuel plants.

The fissionable isotope is contained in fuel rods in the reactor core. All the fuel rods together comprise the critical mass. Control rods, commonly made of boron or cadmium, are in the core, and they act like neutron sponges to control the rate of radioactive decay. Operators can stop a chain reaction completely by pushing the control rods all the way into the reactor core, where they absorb all the neutrons. The operators can then pull out the control rods a little at a time to produce the desired amount of heat.

A liquid (water or, sometimes, liquid sodium) is circulated through the reactor core, and the heat generated by the fission reaction is absorbed. The liquid then flows into a steam generator, where steam is produced as the heat is absorbed by water. This steam is then piped through a steam turbine that's connected to an electric generator. The steam is condensed and recycled through the steam generator. This forms a closed system; that is, no water or steam escapes — it's all recycled.

The liquid that circulates through the reactor core is also part of a closed system. This closed system helps ensure that no contamination of the air or water takes place. But sometimes problems do arise.

In the United States, there are approximately 100 nuclear reactors, producing a little more than 20 percent of the country's electricity. In France, almost 80 percent of the country's electricity is generated through nuclear fission. Nuclear power plants have certain advantages. No fossil fuels are burned (saving fossil-fuel resources for producing plastics and medicines), and there are no combustion products, such as carbon dioxide, sulfur dioxide, and so on, to pollute the air and water. But problems are associated with nuclear power plants.

One is cost. Nuclear power plants are expensive to build and operate. The electricity that's generated by nuclear power costs about twice as much as electricity generated through fossil fuel or hydroelectric plants. Another problem is that the supply of fissionable uranium-235 is limited. Of all the naturally occurring uranium, only about 0.75 percent is U-235. A vast majority is nonfissionable U-238. At current usage levels, we'll be out of naturally occurring U-235 in fewer than 100 years. A little bit more time can be gained through the use of breeder reactors. But there's a limit to the amount of nuclear fuel available in the earth, just as there's a limit to the amount of fossil fuels.

However, the two major problems associated with nuclear fission power are accidents (safety) and disposal of nuclear wastes.

Accidents: Three Mile Island and Chernobyl

Although nuclear power reactors really do have a good safety record, the distrust and fear associated with radiation make most people sensitive to safety issues and accidents. The most serious accident to occur in the United States happened in 1979 at the Three Mile Island Plant in Pennsylvania. A combination of operator error and equipment failure caused a loss of reactor core coolant. The loss of coolant led to a partial meltdown and the release of a small amount of radioactive gas. There was no loss of life or injury to plant personnel or the general population.

This was not the case at Chernobyl, Ukraine, in 1986. Human error, along with poor reactor design and engineering, contributed to a tremendous overheating of the reactor core, causing it to rupture. Two explosions and a fire resulted, blowing apart the core and scattering nuclear material into the atmosphere. A small amount of this material made its way to Europe and Asia. The area around the plant is *still* uninhabitable. The reactor has been encased in concrete, and it must remain that way for hundreds of years. Hundreds of people died. Many others felt the effect of radiation poisoning. Instances of thyroid cancer, possibly caused by the release of I-13, have risen dramatically in the towns surrounding Chernobyl. It will be many more years until the effects of this disaster will be fully known.

How do you get rid of this stuff: Nuclear wastes

The fission process produces large amounts of radioactive isotopes, and some of the half-lives of radioactive isotopes are rather long. Those isotopes are safe after ten half-lives. The length of ten half-lives presents a problem when dealing with the waste products of a fission reactor.

Eventually, all reactors must have their nuclear fuel replenished. And as we disarm nuclear weapons, we must deal with their radioactive material. Many of these waste products have long half-lives. How do we safely store the isotopes until their residual radioactivity has dropped to safe limits (ten half-lives)? How do we protect the environment and ourselves, and our children for generations to come, from this waste? These questions are undoubtedly the most serious problem associated with the peaceful use of nuclear power.

Nuclear waste is divided into low-level and high-level material, based on the amount of radioactivity being emitted. In the United States, low-level wastes are stored at the site of generation or at special storage facilities. The wastes are basically buried and guarded at the sites. High-level wastes pose a much larger problem. They're temporarily being stored at the site of generation, with plans to eventually seal the material in glass and then in drums. The material will then be stored underground in Nevada. At any rate, the waste must be kept safe and undisturbed for at least 10,000 years. Other countries face the same problems. There has been some dumping of nuclear material into deep trenches in the sea, but this practice has been discouraged by many nations.

- **Webquest Input: prompts supplied to students**

All groups: general Internet search criteria.

Locating information:

- use a general purpose search engine such as Google (www.google.com);
- type in appropriate keywords (no more than 3-4 expressions at a time);
- if you search for the exact match of an expression, use inverted commas (e.g. “nuclear fission”);
- try to stick to sites originating in English language countries (**.edu** or **.org** sites are generally very useful; **.com** sites may be too commercial).

Saving material(s):

- create a separate folder on your HD, preferably on the desktop, to save documents, images, etc.;
- create one or more Word documents, cutting and pasting as required, for texts;
- right click on images, choose the “save images as…” option from the drop-down menu, and type in the name of the folder you’ve previously created.

Group one: the equation for nuclear fission.

Search the net (by using the underlined keywords) for further information on:

- a short history of nuclear energy;
- other equations for nuclear fission, using different isotopes.

Group two: Einstein's equation concerning energy and mass.

Search the net (by using the underlined keywords) for further information on:

- calculations for the quantity of energy released, compared to conventional fuels (nuclear energy calculations);
- Einstein explaining his equation (voice).

Group three: how a chain reaction takes place.

Search the net (by using the underlined keywords) for:

- simulations of a nuclear chain reaction;
- history of atomic bombs.

Group four: how a nuclear power plant works.

Search the net (by using the underlined keywords) for further information on:

- different kinds of nuclear power plants;
- simulations of a nuclear power plant.

Group five: the risks of nuclear power plants.

Search the net (by using the underlined keywords) for further information on:

- accidents that have occurred at nuclear power plants;
- the disposal of nuclear waste in various countries.

- **Language exercises related to the topic (given as homework after Session 1):**

Fill in the blanks, choosing one word from the following group:

control rods – critical mass - fissionable - fossil fuel - fuel rods- half-lives- mass defect - neutrons

The loss of matter in a nuclear reaction is called the ______ .

Isotopes that produce an excess of neutrons in their fission support a chain reaction and are called ________.

The minimum amount of fissionable material needed to ensure that a chain reaction occurs is called the _________ .

To control a chain reaction the number of ______ must be regulated, so that the energy can be released as desired.

In a conventional power plant, a ______ is burned, and the heat is used to boil water, which, in turn, is used to make steam. The steam is then used to turn a turbine that is attached to a generator that produces electricity.

The fissionable isotope is contained in ______ in the reactor core.

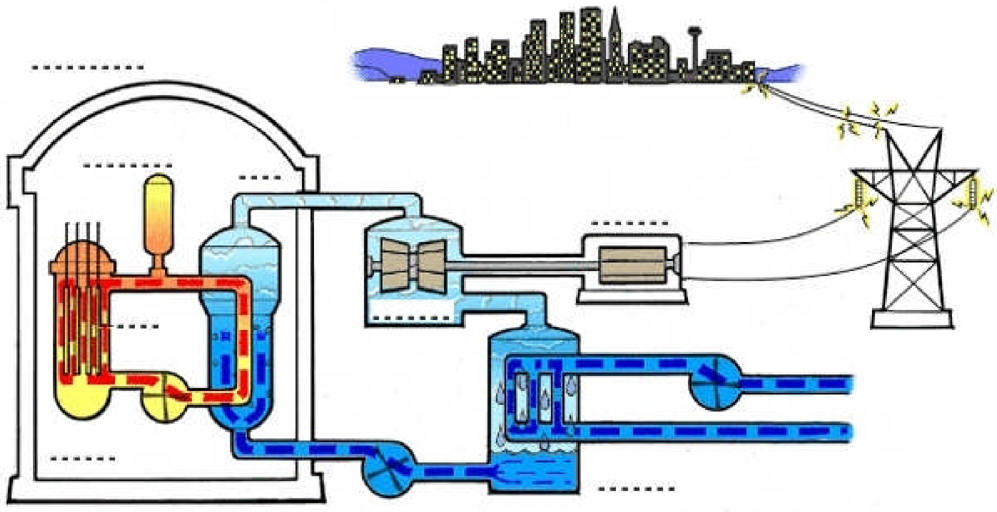
Operators can stop a chain reaction completely by pushing the _____ all the way into the reactor core, where they absorb all the neutrons.

The fission process produces large amounts of radioactive isotopes, and the most dangerous ones to deal with are the ones with longer ______ .

- **Labelling exercise**

Label the parts of the power plant given below with the following words:

condenser - containment structure - control rods - generator - pressurizer - reactor vessel - steam generator – turbine



- **Glossary**

chain reaction	*reazione a catena*
condenser	*condensatore*
containment structure	*struttura di contenimento*
control rods	*barre di controllo*
coolant	*liquido di raffreddamento*
core	*nocciolo*
critical mass	*massa critica*
fission	*fissione*
generator	*generatore*
fossil fuel	*combustibile fossile*
fuel rods	*barre del combustibile*
generator	*generatore*
half-life	*emivita*
isotope	*isotopo*
mass defect	*difetto di massa*
meltdown	*fusione*
pressurizer	*pressurizzatore*
rate of radioactive decay	*tasso di decadimento radioattivo*
reactor	*reattore*
steam	*vapore*
turbine	*turbina*
vessel	*serbatoio*

Assessment

(a few sample questions downloaded from the Net [see Sitology])

Multiple choice test:

In a fusion reaction, reacting nuclei must collide. Collisions between two nuclei are difficult to achieve because the nuclei are

1. both negatively charged and repel each other
2. both positively charged and repel each other
3. oppositely charged and attract each other
4. oppositely charged and repel each other

Fissionable uranium-233, uranium 235, and plutonium-239 are used in nuclear reactors as

1. coolants
2. control rods
3. moderators
4. fuels

Control rods in nuclear reactors are commonly made of boron and cadmium because these two elements have the ability to

1. absorb neutrons
2. emit neutrons

	3. decrease the speed of neutrons 4. increase the speed of neutrons
Sitography	Search engine http://www.google.it The WebQuest Page http://webquest.sdsu.edu Chemistry: Gone (Nuclear) Fission http://www.dummies.com/WileyCDA/DummiesArticle/id-1669.html Control The Nuclear Power Plant (Demonstration) [Java-script enabled: contact your school net administrator] http://www.ida.liu.se/~her/npp/demo.html#instructions Nuclear Reactors http://www.fact-index.com/n/nu/nuclear_reactor.html Multiple-Choice Questions http://regentsprep.org/Regents/core/questions/topics.cfm?Course=CHEM Doc Brown's Chemistry Clinic http://www.wpbschoolhouse.btinternet.co.uk/ Diagram of a nuclear power plant http://www.nrc.gov/reading-rm/basic-ref/students/reactors.html Wolfram Research (as an on-line dictionary, click on any section and then on the *alphabetical index* link) http://scienceworld.wolfram.com/
Bibliography	*Oxford Dictionary of Science,* Oxford University Press, 2003
DVD / VHS resources	*The China Syndrome*, Dir. James Bridges, Columbia/Tristar Studios, 1979
Appendix	Prompts for teachers: “Milking the Net”