Nuclear Power Plants and the Environment

Nuclear power plants use nuclear reactions in order to generate immense amounts of heat to boil water. The steam from the water is used to spin a turbine to generate electricity. For more background information, see the CoreChem page on Nuclear Power Plants.

Energy Behind Nuclear Power Plants

Nuclear Reactions

Nuclear reactions are high in energy and the energy associated with these types of reactions is described by Einstein’s famous equation,

$E = mc^2$

Where $E$ is energy, $m$ is mass and $c$ is the speed of light, $3.00 \times 10^8$ m/s.

Energy is therefore proportional to the mass of the particle emitted and even a small change in size relates to a large change in energy. In most chemical reactions, the mass lost is so small that mass is considered conserved. However, in nuclear reactions, the mass loss is much greater. The splitting of a heavy nucleus into smaller particles is called a fission reaction. The union of two lighter nuclei is called a fusion reaction. In either reaction, a large amount of heat and radiation is emitted. When mass is lost in the reaction, the reaction is exothermic, and when mass is gained, the reaction is endothermic.

Example : Fission Reaction

In this fission reaction, Uranium 238 degrades to Thorium 234 and an alpha particle.
U has the mass of 238.0003 g, Th, 233.9942 g and He, 4.0015 g. Find the mass change in this system and determine whether it is an exothermic or endothermic reaction.

**Solution**

\( \Delta \text{mass} \) is calculated by subtracting the mass of the reactants from the mass of the products.

\[
\Delta \text{mass} = (233.9942g + 4.0015g) - 238.003g = -0.0046 \text{ g}
\]

Because the change in mass is negative, the reaction is exothermic, as would be expected of any spontaneous nuclear reactions.

**Nuclear Power Plants and the Environment**

Nuclear power currently supplies about 16% of the world’s electricity supply. As fossil fuels continue to dominate our energy sector, there is growing concern as the impacts on the climate due to continued release of greenhouse gases including carbon dioxide. Unfortunately, complete conversion to nuclear power is not the solution to our problems with the climate but it does deserve serious consideration. The following analysis of Nuclear Power and its affects on the environment does not include a discussion of the mining, transporting and refining the uranium ore. While there is great controversy as to the consequences of such work, the following solely focuses on Nuclear Power Plants.

**Cons of Nuclear Power**

Each step of the process of designing, producing and testing nuclear reactions results in waste and byproducts. While the chemical separation of the Uranium-235 (the fission reaction) yields the greatest amount of high-level radioactive waste, there is waste of varying radioactive levels that are products of mining, uranium enrichment and operation. Nuclear waste and radioactive materials have been shown to be hazardous to human health and their contamination in not limited to the actual leftover byproducts but can permeate the surrounding soil. Waste is categorized as either, low-level waste, waste incidental to reprocessing, high-level waste and uranium mill tailings.

- **Low-Level Waste:** includes radioactive contaminated protective clothing, tools, etc
- **High-level Waste:** includes waste incidental to reprocessing, this waste is spent nuclear reactor fuel.
- **Uranium Mill Tailings:** the leftover residues after processing ore for uranium.

Nuclear waste is a long-lived result of a nuclear fission reaction. As many of the byproducts of the reaction are themselves radioactive, the spent fuel must be handled with extreme care. Currently, there are no designated sites for nuclear waste produced for civil purposes and waste that is produced for defense purposes is transported and buried in New Mexico. Transportation and disposal of nuclear waste is one of the biggest hurdles that nuclear energy faces for there is great fear associated with nuclear waste. This fear stems from the devastation of past nuclear disasters. (see link for more information.)
**Pros of Nuclear Power**

There are significant benefits to nuclear energy for the environment specifically relating to the zero emission of greenhouse gases or other noxious gases produced from combustion. Because the nuclear reaction is close celled (meaning there is nothing that escapes from the reaction) the emission into the air is water vapor. While water vapor’s characteristic as a greenhouse gas is clear, there is confounding evidence as to whether it promotes warming or promotes cooling.

Another large benefit of nuclear energy is the high energy density of uranium as compared to other currently used energy sources. Table 1 highlights the energy densities of our current energy sources.

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Joules Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pound of Gasoline</td>
<td>$2.2 \times 10^7$</td>
</tr>
<tr>
<td>Pound of Coal</td>
<td>$1.6 \times 10^7$</td>
</tr>
<tr>
<td>Pound of Oil</td>
<td>$2.4 \times 10^7$</td>
</tr>
<tr>
<td>Pound of Uranium-235</td>
<td>$3.7 \times 10^{13}$</td>
</tr>
</tbody>
</table>

Uranium stores in the United States are quite high and the most recent estimate in 2008 assumed uranium reserves of $\text{U}_3\text{O}_8$ at 1, 227 million pounds. This map shows the known uranium reserves in the United States.

**Nuclear Power Plants and Climate Change**

Greenhouse gases have been the focus of the climate change debate. Their source, their consequences and how to control them are highly debated. It is widely accepted that the most potent greenhouse gases include water vapor, carbon dioxide, methane, nitrous oxide and other synthetic molecules including fluorocarbons. Water vapor is the most abundant greenhouse gas and its source in the atmosphere is not solely from combustion reactions but also from evaporation due to warming trend. The consequences of increased water vapor is not clearly elucidated as higher concentrations can lead to cloud formation which blocks heat but also can lead to greater warming due to its greenhouse characteristics.

Nuclear power plants do not emit carbon dioxide from its plants but does emit water vapor. In the iconic symbol of nuclear power plants, the cooling towers, some see an answer to the climate change issue while others continue to fear movement to nuclear power. This will continue to be a debate for a long time to come.

From ChemPRIME: 19.14: Nuclear Power Plants
Contributors and Attributions

- Ed Vitz (Kutztown University), John W. Moore (UW-Madison), Justin Shorb (Hope College), Xavier Prat-Resina (University of Minnesota Rochester), Tim Wendorff, and Adam Hahn.