Questions

1. What are the world’s biggest suppliers of Uranium?

2. Explain the process of leaching!

3. Why is yellowcake being converted to uranium-hexafluoride?

1. List the two main enrichment processes for $^{235}$U!
New kids on the block?

North Korea & Iran
TREATY ON THE NON-PROLIFERATION OF NUCLEAR WEAPONS

(Preamble & XI articles)

Article I
Each nuclear-weapon State Party to the Treaty undertakes not to transfer to any recipient whatsoever nuclear weapons or other nuclear explosive devices or control over such weapons or explosive devices directly, or indirectly; and not in any way to assist, encourage, or induce any non-nuclear weapon State to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices, or control over such weapons or explosive devices.

Article II
Each non-nuclear-weapon State Party to the Treaty undertakes not to receive the transfer from any transferor whatsoever of nuclear weapons or other nuclear explosive devices or of control over such weapons or explosive devices directly, or indirectly; not to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices; and not to seek or receive any assistance in the manufacture of nuclear weapons or other nuclear explosive devices.

Article IV
1. Nothing in this Treaty shall be interpreted as affecting the inalienable right of all the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes without discrimination and in conformity with articles I and II of this Treaty.
2. All the Parties to the Treaty undertake to facilitate, and have the right to participate in, the fullest possible exchange of equipment, materials and scientific and technological information for the peaceful uses of nuclear energy. Parties to the Treaty in a position to do so shall also cooperate in contributing alone or together with other States or international organizations to the further development of the applications of nuclear energy for peaceful purposes, especially in the territories of non-nuclear-weapon States Party to the Treaty, with due consideration for the needs of the developing areas of the world.

Rogue States as Threat to the World

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In the aftermath of the Japanese occupation Korea was divided at the 38th parallel in accordance with a UN arrangement. North Korea was formally founded as the Democratic People's Republic in 1948. Tensions escalated to Korean War 1950-1953. The war was triggered by North-Korean invasion of South Korea, followed by UN supported US intervention and counter attack, stopped by the intervention of China. Since the Armistice in 1953 a tense relationship of deep mistrust on both sides developed and overshadows diplomatic relations.
Possible motivation for Nuclear Proliferation

- Pakistan supplied North Korea with the initial assistance, critical equipment, and technology to develop a nuclear reactor and nuclear weapon program.
- Historical fears in context of Korean War.
- With the collapse of the Soviet Empire, North Korea had to invest in another source of power.
- A combination of attention-seeking behavior and political chest-banging?
Nuclear relationships

North Korea joins the NPT, but there are beliefs that plutonium in reactors are being used for nuclear weapons

In the process of building a 200MWe reactor at Taechon until it agreed with the U.S. to freeze building and research efforts

U.S. proposes that the U.N. security council place sanctions on North Korea - banning exports and imports and worldwide financial dealings


After many refusals, North Korea allows the IAEA to conduct inspection of their reactors -- U.S. intelligence judged that the plutonium at Yongbyon was enough for 1-2 nuclear weapons

Inspection results turn up discrepancies, NK refuses IAEA special inspections and withdraws from the U.S. treaty, citing “protection of supreme national interests”
The demolition of the 60-foot (18 m)-tall cooling tower was a positive response to U.S. concessions after the North delivered a declaration of its nuclear programs to be dismantled. The United States paid the US$2.5 million demolition fee.
### Nuclear Facilities in North Korea

#### Power Reactors

<table>
<thead>
<tr>
<th>Name/Location of Facility</th>
<th>Type/Status</th>
<th>IAEA Safeguards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinpo-1 Kumho1</td>
<td>Light-water, PWR, 1,040 MWe, construction suspended</td>
<td>No</td>
</tr>
<tr>
<td>Sinpo-2 Kumho</td>
<td>Light-water, 1,000 MWe, construction suspended</td>
<td>No</td>
</tr>
<tr>
<td>Yongbyon</td>
<td>Gas-graphite, nat. U, 5 MWe, operating</td>
<td>No</td>
</tr>
<tr>
<td>Yongbyon</td>
<td>Gas-graphite, nat. U, 50 MWe, construction halted, no evidence that it has resumed</td>
<td>No</td>
</tr>
<tr>
<td>Taechon</td>
<td>Gas-graphite, nat. U, 200 MWe, construction halted, no evidence that it has resumed</td>
<td>No</td>
</tr>
</tbody>
</table>

#### Research Reactors

<table>
<thead>
<tr>
<th>Name/Location of Facility</th>
<th>Type/Status</th>
<th>IAEA Safeguards</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRT</td>
<td>Pool-type, HEU (80 percent), 8 MWt, operating</td>
<td>No2</td>
</tr>
<tr>
<td>Yongbyon</td>
<td>Critical assembly, 0.1 MWt</td>
<td>No</td>
</tr>
<tr>
<td>Pyongyang</td>
<td>Subcritical assembly</td>
<td>No</td>
</tr>
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</table>

#### Reprocessing (Plutonium Extraction)

<table>
<thead>
<tr>
<th>Name/Location of Facility</th>
<th>Type/Status</th>
<th>IAEA Safeguards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiochemical Laboratory Yongbyon1</td>
<td>Operational1</td>
<td>No</td>
</tr>
<tr>
<td>Pyongyang</td>
<td>Soviet-supplied laboratory-scale hot cells, status unknown2</td>
<td>Nu</td>
</tr>
</tbody>
</table>

#### Uranium Processing

<table>
<thead>
<tr>
<th>Name/Location of Facility</th>
<th>Type/Status</th>
<th>IAEA Safeguards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyongsan</td>
<td>Uranium ore processing, status unknown</td>
<td>No</td>
</tr>
<tr>
<td>Sanchon-Wolbingston mine</td>
<td>Uranium ore processing, status unknown</td>
<td>No</td>
</tr>
<tr>
<td>Pakchon</td>
<td>Uranium ore processing, status unknown</td>
<td>No</td>
</tr>
<tr>
<td>Pyongsan</td>
<td>Uranium ore processing, status unknown</td>
<td>No</td>
</tr>
<tr>
<td>Pakchon</td>
<td>Uranium ore processing, status unknown</td>
<td>No</td>
</tr>
<tr>
<td>Yongbyon</td>
<td>Uranium purification (UO2) facility, operating</td>
<td>No</td>
</tr>
</tbody>
</table>
US “stick and carrot” politics

Threats and accusations “axis of evil” are followed by humanitarian offers “food and supplies” in response to the extremely poor North Korean economy.
Under President Clinton the leaders meet and surprisingly, Kim Il Sung agrees to freeze the nuclear program if the U.S. resumed high-level talks, leading to the 1994 “Agreed Framework”

“Agreed Framework”
North Korea would stop all plutonium separation and hand over its spent fuel in exchange for two light water reactors and 500,000 tons of heavy oil for heating and electricity

The agreement meant to promote better relations between the U.S. and North Korea

The Korean Peninsula Energy Development Organization (KEDO), a consortium of the United States, South Korea, Japan, and various other states was responsible for implementing the agreement. North Korea would repay KEDO over a 20-year interest-free period after the completion of each LWR plant.
US politics

It was reported that US officials agreed to the plan only because they thought that the North Korean government would collapse before the nuclear power project was completed because of Kim Il Sung’s death.

Soon after the agreement U.S. Congress control changed to Republican Party, who regarded KEDO as appeasement. The promised supplied were delivered with substantial delays or not at all. The economic sanctions were not lifted. KEDO's first director, commented "The Agreed Framework was a political orphan within two weeks after its signature".

The North Korean Government had ambitious nuclear energy plans which never got realized due to significant delays of LWR components. Foundation were poured in 2002.
Increasing disagreement between North Korea and U.S. on scope and implementation of treaty. When by 1999 economic sanctions had not been lifted and full diplomatic relations between U.S. and North Korea had not been established, North Korea warned that they would resume nuclear research unless the U.S. kept up its end of the bargain. The U.S. repeatedly stated that further implementation would be stalled as long as suspicions remained that the North Korean nuclear weapons research program continued covertly.
The North Korean Bomb

On January 10, 2003, North Korea announced its withdrawal from the Nuclear Non-Proliferation Treaty. On February 10, 2005, North Korea declared that it had manufactured nuclear weapons as a "nuclear deterrent for self-defence". On May 31, 2006, KEDO decided to terminate the LWR construction project. On October 9, 2006, North Korea conducted a nuclear test. US intelligence agencies believe that North Korea has manufactured a handful of simple nuclear weapons.
North Korea is a nuclear state, its decision was driven by mistrust, fueled by US politics failure. Lack of US willingness of communication and acceptance of the North Korean regime is typically answered by military demonstrations of strength even after Kim Jong Il’s death. The Kim family plays hardball!
Another Member of the Axis of Evil

IRAN
History of Iran-United States Interaction

Relations between the Iran and the United states began in the later nineteenth century, a period when Iran felt threatened by British and Russian colonial interests (Great Game).

After World War II the US became worried about growing Soviet influence, in particular in view to the Chinese revolution of 1949 and the Korea War. When the democratically elected government of Prime Minister Mohammad Mossadeq announced plans to nationalize the Anglo-Iranian Oil Company because it withheld their financial records from the Iranian government. In response Mossadeq was overthrown by a coup organized by MI6 and aided by the CIA and the Shah was installed as absolute ruler. This is considered “the crucial turning point both in Iran's modern history and in U.S. Iran relations”.

This coup was followed by an era of close alliance between Shah Mohammad Reza Pahlavi's regime and the American government, which was in turn followed by a dramatic reversal and hostility between the two countries after the 1979 Iranian Revolution.
Military Aid and Nuclear Developments

The US spend lavishly in military aid to the Shah as part of cold war strategy to encircle Soviet Union. The Shah invested in modern weapon systems. During the period of 1972-1977 the value of US military sales to Iran amounted to $16.2 billion. The number of US military advisors reached to 35000. The Shah dreamed of a role as leader in the Middle East world and expressed interest in the development of a nuclear program.

During the 1960ies the US supplied a 5MW reactor. During the 1970ies plans were developed despite US discouragement for the construction of 22 nuclear reactors with 23 GW total power output. The two reactors for the Bushehr nuclear power plant were delivered by the German Kraftwerk Company (Siemens), fuel in form of yellowcake was purchased from South Africa.
Ayatollah Khomeini

After the revolution Ayatollah Khomeini halted further construction. He stopped the nuclear program because he felt that nuclear power was evil and certainly nuclear bombs were evil. It's forbidden in Islam to murder innocents, and it's certainly forbidden in Islam to kill large numbers of civilians in the course of warfare.

The long war with Iraq 1980-1988, may have caused a change of mind. The Iraqi surprise attack was thought to be motivated by US/CIA activities — in remembrance on the CIA sponsored Mossadeq coup from 1953.
Hostile Encirclement?
Iranian Aggression?
Revitalization of Nuclear Program

Completing the Bushehr reactor plant for nuclear energy production
Iran’s Nuclear Arsenals 2002

<table>
<thead>
<tr>
<th>Name/Location of Facility</th>
<th>Type/Status</th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>POWER REACTORS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bushehr I</td>
<td>Light-water, LEU, 1,000-MWe; damaged by Iraqi air strikes (1987, 1988). Currently under construction.</td>
<td>Planned</td>
</tr>
<tr>
<td>Bushehr II</td>
<td>Light-water, LEU, 1,300-MWe; damaged by Iraqi air strikes (1987, 1988). Facility remains unfinished, and project is currently suspended.</td>
<td>Planned</td>
</tr>
<tr>
<td><strong>RESEARCH REACTORS</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tehran</td>
<td>Light-water, HEU, 5-MWe; operating¹</td>
<td>Yes</td>
</tr>
<tr>
<td>Esfahan</td>
<td>Miniature neutron source reactor (MNSR), 900 grams of HEU, 27-kW operating</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>URANIUM ENRICHMENT</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tehran</td>
<td>Alleged uranium centrifuge research program, Sharif University of Technology</td>
<td>No</td>
</tr>
<tr>
<td><strong>REPROCESSING (PLUTONIUM EXTRACTION)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tehran</td>
<td>Laboratory-scale hot cells; may not be operational²</td>
<td>No</td>
</tr>
<tr>
<td><strong>URANIUM PROCESSING</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yazd Province</td>
<td>Discovery of uranium deposits announced in 1990</td>
<td>N/A</td>
</tr>
<tr>
<td>Tehran</td>
<td>Uranium-ore concentration facility; incapacitated.</td>
<td>N/A</td>
</tr>
<tr>
<td>Esfahan</td>
<td>Planned uranium conversion plant that could produce UF₆, UF₆, and UO₂. China cancelled its assistance in this area in 1997.</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Fueling the Nuclear Reactors

Officially for peaceful purposes, allowed by Article IV of Non-Proliferation treaty

Bushehr reactors started operation in October 2011 with Russian produced uranium fuel returning spent fuel elements back to Russia.
Iran’s Nuclear Industrial Complex

Secret measures to halt the program!

- Attack by Stuxnet computer codes
- Murder of Iranian nuclear scientists
- Threat of military air strikes
- Nuclear attack
  By bunker-buster
Iran Nuclear Arsenals 2012
Uranium Enrichment Plant
Is there direct evidence?

**Fuel Enrichment plant (FEP)**

*Annual capacity:*
About 150 t SWU (UF₆/year) for 54000 centrifuge machine

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The Pressure Transducer

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The supreme Leader
Ayatollah Khameini
Israeli Army Chief Says He Believes Iran Won’t Build Bomb

By JODI RUDOREN

Published: April 26, 2012

JERUSALEM — The Israeli military chief described the Iranian government as “rational” in interviews published Wednesday and said he did not believe it would build a nuclear bomb, appearing to put some distance between himself and Prime Minister Benjamin Netanyahu and Defense Minister Ehud Barak.

“I believe he would be making an enormous mistake, and I don’t think he will want to go the extra mile,” the chief of staff of the Israeli Defense Force, Lt. Gen. Benny Gantz, told the left-leaning newspaper Haaretz, referring to Ayatollah Ali Khamenei.

“I think the Iranian leadership is composed of very rational people,” General Gantz added. “But I agree that such a capability, in the hands of Islamic fundamentalists who at particular moments could make different calculations, is dangerous.”

“What he said,” said George Perkovich of the Carnegie Endowment for International Peace in an Associated Press article, is “consistent with the views of the U.S. military leadership, the U.S. intelligence community. What’s interesting is why he said it out loud.”