The Splitting of the Atom: The US in the Nuclear Age

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The unleashed power of the atom has changed everything, save our modes of thinking and thus we drift toward unparalleled catastrophe.

—Albert Einstein

INTRODUCTION

Sometimes this is how I see the world as a science teacher: there is a continuous exploration by the students towards achieving something that no one in history ever did. However we all walk through life everyday like ordinary people, not conscious of the fact that perhaps this continuous exploration leads some people somewhere in the world to hide in secret laboratories that study what has yet to be seen by the future generation. They could be developing something beneficial or something that could be used as a weapon which, when placed in the hands of a leader, may end the world. Other times though, I just reflect on the fact that as a teacher I have the responsibility to teach my kids good humanitarian practice along with scientific knowledge.

When people are asked about what they think of the nuclear threat or the nuclear age, most of them consider it as something with "no reason to talk about" (Greenwald and Zeitlin 3). That is exactly the title of the book by Greenwald and Zeitlin where they recount the survey they had when they interviewed families about how it feels to be in the nuclear age.

Since when did the nuclear age start? The answer to that varies, in my view. Radioactivity was discovered by Henry Bequerel in the late 1800s. However I would consider the threatening nuclear age started when some of us lived through or read about the bombing of Hiroshima in 1945. When we realize the causes and the effects of such actions, we take heed, we become aware of the fact that the "continuous exploration" may lead us to something more destructive and fatal. Indeed it has led us somewhere worse than that. A single bomb destroyed Hiroshima but by current standards it was a small nuclear weapon. A single three-megaton hydrogen bomb equals all the conventional bombs dropped in World War II" (Joseph Nye 1).

"Even before World War I, when drinkers consumed radium cocktails that glowed in the dark Paris and New York night clubs, a few visionaries anticipated the coming of the nuclear age" (Williams and Cantelon 1). The splitting of the atom did not start in America: the American atom has its origins in Europe at the turn of the century, in 1938 when German physicists Otto Hahn and Fritz Strassmann working in a Berlin laboratory discovered that when neutrons are fired into a heavy element uranium, the atom would split, or fission, into lighter metals and as a consequence produced a high amount of energy and additional neutrons. They figured that this could be a source of a chain reaction that can produce a tremendous amount of energy (Williams and Cantelon 2).

We have to remember that during those times, several refugee scientists fled Hitler's Germany and Stalin's Russia. Hitler's rise to power in 1933 legalized the discriminatory acts against Jews. Thus an exodus began when the Nazi party issued a " Cleansing of the Civil Service" decree which legally removed the "non-Aryans" from office. Non-Aryans were considered to be people having two or more Jewish grandparents. Even though Jews were only 1 percent of the German population, Jews held more than 12 percent of the chairs in the university system. Additionally, Jews won one-quarter of the Nobel Prizes that had gone to Germany. In effect, the decree forced many scholars from their positions. By the start of World War II, almost 40 percent of the university professors were dismissed, perhaps a third of them were scientists. Albert Einstein, the most famous scientist in the world, was one of them and fled to the U.S. where there were more job opportunities in universities (Badash 11). Earlier on in 1905, Einstein released his study on his famous equation $E=mc^2$, the underlying principle of the nuclear reaction, that matter can be changed to energy.

Many other scientists came to the U.S. as refugee scientists. One of the most important persons was Leo Szilard, a Hungarian physicist, who was then in New York, and who learned about the Hahn-Strassman fission experiment. Szilard correctly anticipated that a "new world of atomic weapons would be headed for grief, especially if such weapons came into the hands of Adolf Hitler's Nazi Germany" (Williams and Cantelon 2). Slizard was the one who persuaded Einstein, who was already famous at that time, to sign a letter to President Franklin Delano Roosevelt warning him of the dangers of nuclear weapons and the possibility that Hitler would soon acquire the uranium mines in Czechoslovakia. This letter was sent to Roosevelt shortly after World War II started with the German Blietzkrieg against Poland on September 1, 1939 (Williams and Cantelon 13).

In his book, *Nuclear Ethics* Joseph Nye asked these questions:

> Is it true that 'as long as there are nuclear weapons in the world we are compelled to choose between a position that is politically sound but immoral and one that is morally sound but politically irrelevant? Do we incur the full burden of guilt for extinguishing our species merely in preparing to do the deed, even without actually pushing the button? Have nuclear weapons "exploded" the social conventions such as the just war doctrine, that we have inherited from the past? Can we morally justify the possession of such weapons? (Nye 2)

Maybe this topic is even more relevant today with the increased measures to secure our national defenses. Therefore the questions presented above are still provoking some questions regarding the ethics on the weapons of war. Nye's answer to his own question can be summed up: “practical politicians might feel tempted to ignore such questions.” Or better yet, “our nuclear arsenal is being ‘shaken by a war of ideas about its purpose.’ Probably then we can just brush it off as simply ‘ideas.’ That is what is called ‘psychic numbing’” (Greenwald and Zeitlin 13).

As a teacher, I know I have a direct responsibility for my students’ learning. I would not want them to have that “psychic numbing” especially now when the growth of science and research are in their hands. In this unit, it is my goal to make my students realize how scientific knowledge can change the course of the world. The discovery of nuclear energy, for example, had an immediate result in the form of the first atomic bomb, which became a symbol of a nation’s power over all other nations. It created an atmosphere of threat. As Baracsh and Lipton wrote in *The Caveman and the Bomb*, “it is a never ending vicious cycle: The more insecure we feel, the more weapons we build, and the more we build, the more they (Russians) build, and the more they build, the more insecure we feel . . . ” (28).

Generally, students love science because of the thrill of discovery. Chemistry students experience the blasting sound of combustion as well as other sights and smells associated with chemical reactions. It comes to a point that whenever I schedule a laboratory experiment, the first thing my students ask excitedly is, “Are we going to blow up something today, Miss?” or “Can we make an A-bomb in the lab?” My students seem most motivated to work in the lab when they anticipate something might “blow up.” In my experience, students who actually witness the violent reaction of sodium metal to water seem to be genuinely inspired to learn more chemistry, anxious to discover a “breakthrough.” They love thrills, they love blasting sounds, and of course combustion. The classic chemical reactions with substances changing colors or formation of precipitates just don’t excite them at all as it used too.

One of the most interesting topics in the chemistry course outline is nuclear chemistry. Unfortunately, there are not a lot of laboratory activities on this topic that is feasible for the students to do that would best show them what a nuclear reaction is. This aspect of chemistry holds one of the most important uses in the world: as an alternative source of energy. How and where to use the energy has profound implications—for the good or bad for mankind. A very good example of this is using nuclear science to operate a nuclear power plant as a source of energy instead of relying on the oil industry to keep the economy running. This is putting the knowledge of nuclear science into better use than using it as a means for mass destruction. In this course outline however, we focus on the other form of nuclear energy: the atomic bomb which played a very vital role in the course of World War II. The bombings of Hiroshima and Nagasaki in 1945 by the US government is one segment of American history that left deep scars in the lives of the Americans as well as the innocent victims of the explosion. As James Patterson wrote, “It was obvious that advances in air power, rocketry, and atomic weapons ended America’s history of relatively free security.” Indeed after World War II, the United States was never the same again. The world looked up to it as the most powerful nation which could defend itself against all attacks and to be always ahead of every nation in national defense.

Teaching in a magnet high school for engineering professions here at Booker T. Washington, I try to make chemistry really challenging for my students. I consider writing this curriculum unit as a great opportunity to actually show the students how one's genius and love for science can bring a very strong impact to world history. Looking at nuclear chemistry in this manner will make the learning more meaningful to them since science played a major role in an actual event recorded in the pages of American history.

Since my students are pre-engineering students, building and designing models to "solve a problem" may be something they would love to spend more time on either by actual materials or computer programming. I remember one engineer who gave a speech to our graduating class, "The task of an engineer is to solve a problem. How much you make will depend on what kind of problem you want to solve." Posing a problem to them would be a challenge. This unit will bring them back in time before the first nuclear bomb was made.

As engineering students, they will be asked to present a model of an atomic bomb and explain how each of the parts works. Although it may be easy to simply tell them to create a project, I still want to instill in them the fact that it is not so important that we create or invent something from our mind but more importantly that we are forewarned of the possible consequences of such. In this light, they will be able to present the pros and the cons of a nuclear reaction and actually present to class what were the short term and long term effects of the bombing of Hiroshima.

In light of wanting my students to be aware of the causes and effects of nuclear reactions, I intend to broaden their scientific knowledge by reaching out to the social and historical events that led to the creation of the atomic bomb.

HISTORICAL ACCOUNTS ON THE BOMBING OF HIROSHIMA AND NAGASAKI

International Laws on the Bombing of Civilians

International laws on the conduct of war and the protection of civilians caught in any conflict have been enacted and ratified by participating nations as early as the turn of the nineteenth century. This concern, stemming from the emergence of new weapons attempted to delimit the means with which any belligerent army can use. The international convention held in The Hague on July 29, 1899 on the Laws and Customs of War on Land specifically provided that "the rights of belligerents to adopt means of injuring the enemy is not unlimited" (Article XXII, Laws and Customs of War on Land). Furthermore, it was specifically forbidden to employ poison or poisoned weapons, to attack or bomb towns, villages, dwellings or buildings which are undefended (Article XXV). In fact it is the duty of the officer in command of an attacking force to warn the authorities before commencing a bombardment (Article XXVI). As far as possible, buildings dedicated to religion, art, science, or charitable purposes, historic monuments, hospitals, are to be spared from sieges and bombardments (Article XXVII). The Laws and Customs of War on Land was ratified by the U.S. Senate on March 10, 1908.

In a further move to spare civilian casualties in war, another convention held in The Hague in February, 1923 drafted the rules of Aerial Warfare which provided, among others, that bombardment is legitimate only when it is directed exclusively to military targets. In the event that the area to be bombarded would pose any danger to the civilian population, the aircraft must abstain from bombardment. Unfortunately, the rules on the conduct of aerial warfare provided for in this draft, which would have been the basis for an international treaty and whose enactment was supported by the United States, were never formally adopted (*Draft Rules of Aerial Warfare*).

On September 30, 1938, the League of Nations Assembly unanimously passed a resolution entitled "Protection of Civilian Populations Against Bombing From the Air in Case of War." This important resolution declared illegal the intentional bombing of a civilian population and that the use of chemical or bacterial methods in the conduct of war is contrary to international law. A year later, on September 1, 1939, President Franklin D. Roosevelt appealed to the Governments of France, Germany, Italy, Poland and England not to resort to aerial bombardment of civilian populations. He was very emphatic in saying that the "ruthless bombing from the air of civilians in unfortified centers of population . . . has sickened the hearts of every civilized man and woman, and has profoundly shocked the conscience of humanity" (*Appeal of Pres. F.D. Roosevelt on Aerial Bombardment of Civilian Population*).

Nevertheless, in spite of the legal and moral stand against bombardment of civilian targets, the United States, on the orders of President Truman on August 6, 1945, dropped "Little Boy," a uranium based atomic bomb, on the heavily populated Japanese city of Hiroshima. Three days later in Nagasaki another bomb was dropped – the "Fat Man," a plutonium based atomic bomb much more powerful than the first. Ironically, on August 8, 1945, two days after the bombing of Hiroshima and just one day before the bombing of Nagasaki, the United States was one of the signatories (together with the USSR, Britain, and France) of the Nuremberg Principles "Charter of the International Military Tribunal." The Nuremberg Principles defined "crimes against peace," "war crimes," and "crimes against humanity." Leaders and organizers of such crimes even when acting on orders of his government shall be held responsible for such crimes (The Nuremberg Principles).

What led the United States to make that critical decision to use the atomic bomb on the heavily populated cities of Hiroshima and Nagasaki? What factors were considered to justify the bombing of defenseless people? Was it necessary to make the Japanese surrender and end the war? Is it true that the bombing saved more lives than it destroyed?

Atomic Bomb Decision

Why President Truman decided on August of 1945 to drop the world's first atomic bomb in Hiroshima is still a very intense debate after more than forty years. In later years, Truman himself justified his action by citing the U.S. military estimate that defeating Japan by conventional means would have resulted in as many as 1 million additional American casualties. Revisionists, however, justify this decision as a means to scare the Russians, not to win the war (Halperin 5).

The bombing of Hiroshima and Nagasaki has been justified with the explanation that it was necessary to force the Japanese to surrender and bring the war in the Pacific to an end. Information contrary to this has been made unavailable to the general public for many years. Considered as classified information or withheld as private papers and diaries, many of the documents that have recently been uncovered reveal that even after the bombing of Hiroshima and Nagasaki, the Japanese government still refused to surrender (Long). It appears that the U.S. leaders at that time did not understand the "samurai doctrine" so closely interwoven into the Japanese culture and psyche. This doctrine, which influenced the "kamikaze" suicide bombers, made the Japanese prefer "death before dishonor" (Long). Doug Long explains this cultural factor in these words:

> Even after Japan was being helplessly destroyed by U.S. conventional bombing, Japan's hawks refused to surrender. Although the atomic bombings made it more apparent that Japan would be defeated, their hawks again refused to surrender. The samurai believed that honor and the survival of Japan's way of life could be preserved if a great battle could achieve peace terms short of a surrender. So for the samurai, hopelessness in battle was no reason to surrender. This is an important reason why so few Japanese surrendered in battle during WWII and why, after both atomic bombs were dropped, Japan refused to surrender.

Another factor that was clearly a cultural one and therefore not understood or given importance by the Allied Leaders was the belief of the Japanese that their Emperor was infallible, divine even (Long). The fear that an unconditional surrender demanded by the Allied leaders (U.S., Britain, Russia) would remove the Emperor from power was the one controlling factor that made the Japanese refuse to surrender. The Potsdam Proclamation, made on the evening of July 26, 1945 in San Francisco, was a message from the Allies broadcast to the Japanese on the morning of the 27th. It demanded the "unconditional surrender" of the Japanese and made no mention of the vital consideration for the Japanese: the retention of the Emperor's position (Long). Furthermore, the implied reference to the Emperor as "the authority and influence of those who have deceived and misled the people of Japan" and as one included among "war criminals" who will have to face the court and be "eliminated . . . for all time from authority and influence" was untenable to the Japanese (Long).

Nine days after the Potsdam Proclamation on August 6, 1945, the Enola dropped the first atomic bomb on the city of Hiroshima. In the early hours of August 9, the Soviet Union entered Manchuria. A few hours later the U.S. dropped the second atomic bomb on Nagasaki. Threats of making Tokyo, the capital city and seat of government, the next target began to circulate among the Japanese military. Still the upper-members of the Japanese government refused to surrender. On the 13th, the Japanese Supreme Council For the Direction of the War, also known as the "Big 6," met to discuss the Allies' call for surrender. Caught in a deadlock, the Council could not arrive at a decision (Long).

The Japanese Cabinet, which had the power to decide as to whether Japan should surrender or not, met later that day. However, for their decision to be binding, it had to be unanimous. The Cabinet adjourned without arriving at a decision: 12 were for surrender, 3 against and 1 undecided. The next day while the generals were still arguing that victory could still be achieved, the Cabinet, at the request of Emperor Hirohito, unanimously agreed to surrender. How this was done is actually the root of contention. The Emperor was considered to be above politics. But documents now reveal that the "doves"—those in favor of peace—among the Japanese decided to take the move, to bring the Emperor into the decision making, in order to save the Emperor system of Japan (Long).

It was not the bombing of Hiroshima and Nagasaki that forced the doves to make the move. It was, rather, the greater danger of the imminent loss of the Emperor. The Potsdam Declaration had made no provisions for the retention of the Emperor's position. It was demanding instead for the "unconditional surrender" of Japan. Citing the documents from the Pacific War Research Society, Long explains this particular cultural construct:

> But *unconditional* surrender would still leave the doves' central issue unanswered: would surrender allow Japan to retain the Emperor? Prime Minister Suzuki spelled out the problem of "unconditional surrender" well for doves and hawks alike when he publicly announced on June 9, 1945, "Should the Emperor system be abolished, they [the Japanese people] would lose all reason for existence. 'Unconditional surrender', therefore, means death to the hundred millions: it leaves us no choice but to go on fighting to the last man." (Long)

The documents further reveal that the Allies knew beforehand that the throne was the primary issue for Japan. Yet the Potsdam Declaration was emphatic on the term "unconditional surrender." In effect, this refusal to view the Japanese reluctance to surrender at that point was actually delaying the war.

Militarily, Japan's impending defeat began with Germany's losing the war in Europe and followed by the fall of the Mariana Islands, including Saipan to the U.S. in July 1944.

From November 1944 onwards, large-scale non-nuclear bombing raids were conducted over Japan. President Roosevelt was even informed by his chief of Staff Admiral William Leahy that "by the beginning of September [1944], Japan was almost completely defeated through a practically complete sea and air blockade" (Long).

When Germany surrendered in May 1945, the Allies were more capable of concentrating their forces in the Pacific War. Japan had been suffering from many losses and in particular, the loss of the strategic Marianas. This meant that the Allies had bridged Japan's defense perimeter and left her vulnerable to the conventional bombing raids the Allies launched from their Pacific bases. The invasion of Japan by U.S. forces seemed to be the next move. At this point, the question was raised as to whether it was better to risk the lives of thousands (even estimated at 500,000) of American soldiers or use the A-bomb. It was assumed that either the use of nuclear weapons or the invasion of mainland Japan would be necessary to end the war. Moreover, the Allies' official policy of "unconditional" surrender could not factor in the retention of the Emperor.

On the other hand, did the U.S. know of the Emperor's importance to the Japanese surrender? Undersecretary of State Joseph Grew who had been U.S. Ambassador to Japan for 10 years and was therefore familiar with Japanese culture had explained the importance of the Emperor to President Truman on May 28, 1945. Truman was informed about the obstacle to the unconditional surrender. The Japanese belief, he told Truman, is that this (the unconditional surrender) would "entail the destruction or permanent removal of the Emperor and the institution of the throne" (Long).

From other sources cited by Long (Mills 70-71, Giovanitti and Freed, 134-136), it appears that in a meeting with Truman in June 18, 1945, Assistant Secretary of War John McCloy had argued for the retention of the Emperor and had asked that Japan be warned of the planned use of the atomic bomb. On June 28, 1945, Under Secretary of the Navy Ralph Bard sent a memo to Secretary of War Stimson recommending the suggestions made by McCloy. Furthermore, he suggested that Japan be informed of Russia's entry into the war against Japan (Long).

Thus when Secretary of War Stimson and President Truman were discussing the proposal for Japan to surrender, Stimson proposed that provisions for the retention of the constitutional monarchy would substantially add to the chances of its being accepted by Japan. However, this important condition was not included in the surrender demand, known as the Potsdam Declaration. Truman had listened to other advisers who were not as familiar with the Japanese culture (Long).

Janet Bloomfield, Chair of the Campaign for Nuclear Disarmament, believes that the "atomic bombings of Hiroshima and Nagasaki, when considered in a historical perspective, were undoubtedly unnecessary and barbarous acts." She adds that those who supported this view include Prime Minister Winston Churchill, Field Marshall Bernard Montgomery and Gen. Dwight Eisenhower. In fact, Bloomfield quotes Eisenhower saying " Japan was at that very moment seeking some way to surrender with a minimum loss of 'face' . . . It wasn't necessary to hit them with that awful thing."

At this point, it is perhaps important to recall the event and its horrendous aftermath. Bloomfield describes the impact of the atomic bombs in this manner:

> The uranium bomb exploded over Hiroshima on 6 August 1945 and the plutonium bomb used on Nagasaki on 9 August killed tens of thousands instantly and had claimed 350,000 lives by 1950. Those not killed or vaporized immediately by the blast were horribly burned by the intense heat of the explosion. Eye-witness accounts describe traumatised people wandering with their skin trailing from their bodies 'like walking ghosts'. All recorded pregnancies within a two-mile radius of the centre of the blast resulted in miscarriage or stillbirth. Even today, survivors live with the fear that they may be struck down by a radiation-related disease.

The series of events leading to the bombing showed that Japan would have surrendered even if the atomic bombs were not used. Bloomfield lists these events leading to the Japanese capitulation. In April of that year, General Curtis le May (US Air Force) had predicted that the war could end by September or October without an invasion of Japan. On May 12, William Donovan, Director of the Office of Strategic Studies, reported to President Truman that Japan's Minister to Switzerland, Shuichi Kate was trying to arrange for a cessation of hostilities. In mid-June, Admiral Leahy declared that "a surrender of Japan can be arranged with terms that can be accepted by Japan and that will make fully satisfactory provision for America's defense against future trans-Pacific aggression." On July 16, the U.S. exploded a nuclear bomb secretly in the New Mexico desert. On July 18, Truman is informed by Stalin of a telegram from the Emperor seeking peace. On August 10, a day after the second bomb was dropped in Nagasaki the Japanese publicly broadcast an offer of surrender. Truman, however, orders the continued conventional military operations. On August 14, the Japanese surrender was accepted (Bloomfield).

An important detail has to be considered at this point: if Japan was ready to surrender and there was no need for the bombs or for an invasion, then what made the U.S. decide to drop the bombs? Bloomfield, Long and other military analysts and historians point to the Russian factor. Long suggests that Russia, who had remained neutral until the last moment, had its eyes set on claiming Japanese territory along its borders. In fact, on August 9, very early in the morning, it invaded Manchuria, just a few hours before "Fat Man" would be dropped in Nagasaki. Bloomfield sees this as a political move by the U.S. to prevent Russia from claiming territory won. According to Bloomfield, Vannevar Bush (Chief aide for atomic matters to Stimson, the Secretary of War) confirmed this when he said that the bomb was "delivered on time so there was no necessity for any concessions to Russia at the end of the war."

It was both a military and political move by the U.S. not to allow the Soviet Union to take part in the "anticipated 'last push' land invasion of Northern China, since this would put it in a good position to exert influence in the area once hostilities ceased" (Bloomfield). The U.S. had to win the war with as little help as possible from Russia. Bloomfield further analyzes the situation by factoring in the move by Truman to postpone meeting Churchill and Stalin to discuss post-war territorial control until after July 16, the day when the U.S. first tested the atomic bomb in the desert of New Mexico. It was important for the U.S. to send the message that it had the most powerful weapon in its arsenal. Russia must take note of this. Bloomfield points out the possible motives of the U.S.:

> The Hiroshima bomb was dropped on August 6. The message to the Japanese must have been unmistakable and it is difficult to imagine why a second one should have been used on August 9. Except that the Soviet Union was due to enter the war in that week and the US wanted to demonstrate to the Soviets the awesome power that they would be dealing with once the war was over.

This is a disturbing piece of information. Was it because Truman waited for the bomb to be ready and tested that he ignored earlier advice from Acting Secretary of State Grew that the war could be ended earlier if the terms are changed? Did the U.S., in fact, prolong the war and cost more lives than it should have? According to Long, Truman's own diaries reveal that he knew of the Japanese messages deciphered by American intelligence. He knew that the Emperor had talked to Stalin asking for peace. Long questions the actions taken by Truman:

> In passing up this possible opportunity for an earlier and less deadly peace, Truman was not deliberately trying to prolong the war so the atomic bomb could be used on Japan to intimidate the Soviets. Briefly stated, it is likely that Truman *believed* [highlighting by Long] the use of atomic bombs on Japan was necessary primarily for the reasons he always gave: "We have used it in order to shorten the agony of war, in order to save the lives of thousands and thousands of young Americans."

Nevertheless, the claim that the atomic bombings saved lives is disputed by some quarters. Gar Alperovitz (*The Decision to Use the Atomic Bomb* 342, cited by Long) notes that the claim that the use of atomic bombs saved more lives than conventional bombing raids (which had been on-going before and after the atomic bombings) does not hold water because by early August very few significant civilian targets remained to be bombed. Moreover, the need for an invasion of mainland Japan became unnecessary at that point due to the weakened military position of Japan after having lost the strategic Mariana Islands and after the war in Europe was coming to an end and American forces were consolidating in the Pacific front. Surrender feelers had in fact been given except for the hesitance of the Japanese to accede to an unconditional surrender which was unacceptable for fear of losing their Emperor. Thus many other alternatives could have been chosen if they had truly wanted to end the war without resorting to the use of the atomic bombs. On June 27, 1945, Undersecretary of the Navy Ralph Bard, wrote that the use of the bomb without warning was contrary to the position of the United States as a "great humanitarian" especially since Japan was already close to surrender.

Several petitions were made to make President Truman not resort to using the atomic bomb. The famous Szilard petition drafted on July 3, 1945 called the atomic bombs, "a means for the ruthless annihilation of cities." The petition was asking for the President not to resort to the use of the atomic bombs "in the present phase of the war." This same petition was sent to his colleagues at Oak Ridge and Los Alamos discussing the need for scientists to take a moral stand on the use of the bomb. This petition inspired the Oak Ridge Petition which was asking for the bomb to be adequately "described and demonstrated" before use. Based on eyewitness accounts, even 32- kilometers away, scientists felt the heat of the explosion on exposed skin.

At the beginning of WWII, bombing of civilians was considered a barbaric act. Several documents and petitions were made before the crucial decision was made. On June 11, 1945, seven scientists at the University of Chicago wrote the Franck Report urging that the bomb be demonstrated "before the eyes of representatives of all United Nations, on the desert or a barren island." However, on June 16, 1945, despite this opposition, a panel composed of four scientists namely: Oppenheimer, Fermi, Compton, and Lawrence stood by the statement that there is no acceptable alternative to direct military use.

In view of the untold sufferings of the victims of the bombings, international laws on the protection of civilian populations from nuclear weapons and other weapons of mass destruction were decreed by the United Nations on November 24, 1961. It has been declared among others that "any State using nuclear or thermo-nuclear weapons is to be considered as violating the charter of the United Nations, as acting contrary to the laws of humanity and as committing a crime against mankind and civilization" (*The Franck Report*).

Damages Caused by the Atomic Bombing

Eyewitness accounts of the bombing of Hiroshima and Nagasaki reveal the degree of devastation of an atomic bomb. The first bomb had a power equal to twenty thousand tons of dynamite. When it was dropped over Hiroshima from the Enola Gay at precisely 8:15 in the morning of August 6, 1945, "it exploded with unbelievable force and power 1850 feet above the ground" (Pittock et al 1). Within the 1.5 mile radius the force created by the winds destroyed most of the buildings. As the wind reflected off the nearby mountains, it doubled back, striking the city with another forceful blow. The wind generated by Little Boy caused the most serious damage to the city and the people. The heat and light were so strong that when the heat wave reached the ground it burned all before it including people. The heat generated by the blast was so intense, it killed thousands of people. (Pittock et al 6) About eighty thousand people died in the initial blast. Another seventy thousand died within the year. Two hundred thousand people have been estimated to have died as the result of the bombing of Hiroshima. Children yet unborn died in their mother's wombs and in years to come more horrifying effects of atomic radiation would cause various types of cancer. The exposure to the radiation had long-term effects: it caused genetic problems, which resulted in people having malformed babies or being unable to have babies at all.

The first bomb "Little Boy," was a uranium based atomic bomb. It used a high explosive to send a uranium wedge down a gun barrel and into the Uranium core. This caused the chain reaction that produced the devastating effect on the people of Hiroshima. The second bomb dropped on Nagasaki was almost twice as big as "Little Boy" and was a plutonium bomb. It had a beryllium core followed by a layer of explosives and plutonium shell. It was more powerful than the first but it caused less damage due to the geographic structure of the city.

War indeed kills. In the aftermath of Hiroshima and Nagasaki, the information generated by studies on the atomic bomb, its use and effects and the moral issues involved may hopefully be used to never allow the same thing to happen again.

THE SCIENTIFIC ASPECT

Timeline of the Nuclear Age

A simple thought of energy and matter started the birth of nuclear science. In the early 1930s Albert Einstein proposed with his popular formula, $E=mc^2$, that energy and matter are equivalent. In other words, during some special reactions, matter changes into energy.

Not long after Chadwick discovered the neutrons in 1932, scientists have begun to use the neutrons as chemical bullets—bombarding them on atoms of other elements. One particular atom, Uranium, was fired with neutrons and an amazing thing happened. They found out that the mass of the products of this reaction is LESS than the total mass of the original reactants and that this reaction was accompanied by a remarkable amount of energy. They called this reaction a **nuclear fission**. The following reaction shows how much energy is released by the fission of one atom of uranium.

$$^{235}U_{92} + {}^{1}n_{0} \text{ --> fission products + (about 2.5)}{}^{1}n_{0} + \text{ 200 MeV of Energy}$$

The fission products are a mixture of atomic nuclei of other, lower molecular weight elements and neutrons, which means that the products are of lower mass. Einstein's proposal that energy and matter are interconvertible was proven true. Instead of producing a different type of matter that is of equivalent mass, the reaction produced energy from matter, energy which perhaps can be useful (Dr. Frank Settle, *Nuclear Chemistry: the Biological Effect of Nuclear Radiation*).

Looking at the equation above, one can tell that for every neutron used to fire at Uranium- 235, 2.5 neutrons are formed. Theoretically, if these newly produced neutrons were designed to react with another Uranium atom, a series of controlled and sustaining source of energy could be created. This was made possible when they developed the chain reaction, which was first demonstrated in 1942 by Enrico Fermi, an Italian scientist, at the University of Chicago. This controlled chain reaction moderates the amount of reacting uranium by using the neutron absorbers that could be added or removed to be sure that the reaction did not release huge amounts of energy from fission caused by too many neutrons.

Because of the impact of this result, a Hungarian physicist, Leo Szilard, alerted Albert Einstein prior to World War II that this may be a possible source of weapons of mass destruction far beyond their imagination. They figured out that condensing the chain reaction to a millisecond burst of fission produces a tremendous amount of energy. Einstein then communicated this to President Roosevelt and thus the Manhattan Project was established which basically demonstrated weapon feasibility that soon led to the use of two weapons on Japan.

How exactly did this work? Looking at it through a series of reactions (nuclear transformations), even though the only fissionable isotope was $^{235}{}_{92}U$, the more commonly available one is U-238 which itself is not fissionable. The latter plays an important role though in a series of nuclear transformations. It reacts with neutrons and results in a production of a new element, plutonium, Pu, together with an emission of a beta particle. The following is an account of a transmutation of $^{238}{}_{92}U$ with the corresponding half-life ($t_{1/2}$):

$$^{238}U_{92} + {}^{1}n_{0} \dashrightarrow {}^{239}U_{92}$$
$$^{239}U_{92} \dashrightarrow {}^{239}Np_{93} + ß^{-1} \quad t_{1/2}=23.5 \text{ min.}$$
$$^{239}Np_{93} \dashrightarrow {}^{239}Pu_{94} + ß^{-1} \quad t_{1/2}=2.33 \text{ days}$$

This newly produced plutonium is itself fissionable and as such, it was isolated from the neutron bombardment of $^{238}{}_{92}U$. Isolation of the Pu became one of the goals of the Manhattan Project because it could also be used as a source for nuclear weapons. After World War II, Pu has been the source of most fissionable nuclear devices (Dr. Frank Settle, *Nuclear Chemistry: the Biological Effect of Nuclear Radiation*).

Though the exploration of the power within the nucleus may be astoundingly relevant and useful, certain aspects of it must be well taken into consideration. When a nucleus degrades, energy and matter are released in the form of radiation. Other than the neutron emission, three other types of radiation are involved in radioactive decays:

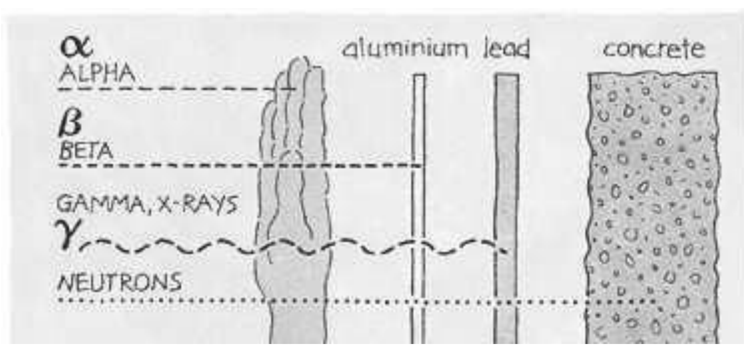
1. alpha radiation (α^{+2})
2. beta radiation (β^-)
3. gamma radiation (γ)

The beta and the gamma radiations are considered as high-energy radiation and are known to cause damaging chemical transformations in living organisms.

Another aspect to be explored in this area is the spent fuel, which is somehow scavenged from the fuel rods as the uranium is fissioned. This process produces a small amount of Pu in the spent fuel rods. This Pu is used in an attempt to make weapons. Control of spent fuel has created a rising concern in the efforts to limit the proliferation of nuclear weapons. There must be a control of the spent fuel rods and they must have a safe disposal.

Effects of the radiation

Depending on the type of radiation, the living tissues are susceptible to damage caused by the emissions of the nuclear reaction products. The following is a diagram taken from the Uranium Information Center. It shows the different penetration of the different radiation in the human body and other materials.



(Courtesy of the Uranium Information Center)

It clearly shows that the beta, gamma, and emitted neutrons have very high penetrating power. Since the tissues are mostly water with the light elements hydrogen, carbon, nitrogen, and oxygen, and some quantities of phosphorus and sulfur, the abundance of these affects the interaction of nuclear radiation with living tissue. The radiation can actually remove valence electrons of these elements and change the chemical reactivity of the affected atoms.

The worst effect this radiation could have is the incidence of cancer and genetic mutation. This is a long-term risk of radiation exposure. Although several other factors such as cigarette smoking, diet, and sunlight exposure can cause the same thing, an analysis of approximately, 100,000 survivors of Hiroshima and Nagasaki shows a slight increase on genetic mutations over what would be expected for a normal population. (Dr. Frank Settle, *Nuclear Chemistry: the Biological Effect of Nuclear Radiation*)

In addition to this, higher doses of radiation can affect the central nervous system which makes the person lose his coordination which unfortunately includes difficulty in breathing. Death may occur within 1 or 2 days. Even higher doses can damage the gastrointestinal tract, which can lead to dehydration and eventually to death.

The list of the biological effects can go on and on, however there are other aspects of nuclear science that can both be destructive or beneficial. For instance, radiation is used in some therapy to treat cancer or kill tumor cells. It is only when it is used intelligently that this becomes beneficial rather than destructive.

On historical accounts, the Hiroshima bomb (Little Boy) had an energy yield of about 15 kilotons (one kiloton is equivalent in energy release to the detonation of about 1000 tons of TNT). The Nagasaki bomb (Fat Man) had an energy yield of 21 kilotons (A.B. Pittock et al).

Given this information, it is pertinent to know that today's nuclear weapons have yields of hundreds of kilotons or more. If detonated, the following are the effects:

1. Thermal radiation and blast waves would result in death and devastation over an area of 500km^2 per megaton of yield (area typical of a major city).
2. The thermal radiation coupled with the accidental ignition caused by blasts would ignite fires in urban/industrial areas.
3. Smoke and toxic chemicals will be released into the atmosphere.
4. Explosions that contact land surfaces, large amounts of dust, soil, and debris are drawn up with the fireball which all fall back to the surface contaminating hundreds of square kilometers of land. This fallout can exceed the lethal dose level.
5. All of the radioactivity would be lofted on very small particles into the upper troposphere by the rising fireballs and contribute to longer term radioactive fallout on a global scale.
6. Nuclear explosions high in the atmosphere would generate an intense electromagnetic pulse which can induce strong electric currents that could damage electronic equipment and communications networks over continent-size regions.

These are some of the direct effects of nuclear explosions. However some effects are overshadowed by these. One important example of this is the health effects of prompt ionizing radiation. The atmospheric chemistry will be greatly changed since the chemicals in the explosion may alter the composition and radiative fluxes, the biosphere and the climate (Pittock et al 6-17).

The Engineering of the Atomic Bomb

In the late 1944, fissionable materials, solid uranium tetrafluoride and plutonium paste began to arrive at a secret library in Los Alamos, New Mexico. The chemists purified the two metals while the metallurgists shaped them into forms suitable for the weapons.

The physicists had to answer two fundamental questions: How much fissile material would be required for the weapons and how much time would be needed for an effective detonation?

The following is an account of the calculations and analysis the group of scientists went through in building up the bomb. This was taken from a website: <http://www.chemcases.com/2003version/nuclear/nc-09.htm>.

They wanted a 20-kiloton explosion (equivalent to 20,000 tons of TNT), so:
20 kilotons TNT = 1×10^{13} cal = 8.4×10^{13} joules

If each fission produces 3.2×10^{-11} joules, then the number of fissions (N) required is:
N = (8.4×10^{13} joules)/(3.2×10^{-11}joules per fission) = 2.6×10^{24} fissions

Thus, the mass of U-235 required would be:
$moles_{235}$ = 2.6×10^{24} atoms(1 mole U-235/6.02×10^{23} atoms) = 4.3 moles U-235

The physicists calculated a 10% efficiency for the weapon so:
m_{235} = 4.3 moles (235 g/mole)/0.10 @ 10 kg U-235

The basic equation for neutron production is exponential:
$N_n = N_0 e^{(k-1)n}$
If $N_0 = 1$ and k – 1.693, then $N_n = N_0\, e^{.693n} = 2^n$ (1)

One might expect that k, the number of neutrons produced per fission, to be larger. Neutron absorption by U-238 and leakage of neutrons from the supercritical mass, however, reduce the number of neutrons available to sustain the chain reaction.

This exponential equation generates the following data. Remember that the total number of neutrons produced at the time of a particular generation is the sum of all of the neutrons from all generations. Thus, in the 4th generation (n = 3), 15 neutrons have been produced.

n=generation; N=# of fissions per generation

n	N	Total # neutrons produced	n	N	Total # neutrons produced
1	1	1	10	1024	1.28×10^3
2	2	3	20	1.05×10^6	1.05×10^6
3	4	7	30	1.07×10^9	1.07×10^9
4	8	15	40	1.10×10^{12}	1.10×10^{12}
5	16	31	50	1.13×10^{15}	1.13×10^{15}
6	32	63	60	1.15×10^{18}	1.15×10^{18}
7	64	127	70	1.18×10^{21}	1.18×10^{21}
8	128	255	80	1.24×10^{27}	1.24×10^{27}

How long will it take to generate the number of fissions required to produce the energy equivalent to 20 kilotons of TNT? First, we need to calculate the number of generations. Substituting into Equation 1:

$(½)\ 2.6 \times 10^{24} = 2^n$

$\ln(1.34 \times 10^{24}) = (n)\ln 2$

n = 80 generations

How long will it take to release this energy? The time period for one generation is the time required for a neutron to travel across the diameter of the critical mass. We need to calculate the diameter of the critical mass assuming a sphere.

Density = mass/volume Volume = (4/3) P r^3

r = 3 m/(4P d) = 0.05 m, where d = density of uranium = 1.87×10^4 kg/m^3

Physicists experimentally determined the velocity (v) of neutrons to be 1×10^7 m/sec, so the time (t) required for a single generations is:

$t = 2r/v = 0.1\ m/10^7 = 10^{-8}$ sec for one generation

Thus, the time for 80 generations is approximately 80×10^{-8} sec or 1 microsecond. The exponential growth of neutrons means that the last 10 generations produce approximately 99.9% of the energy in the explosion. Thus, it is important to keep the supercritical mass together long enough to release the desired amount of energy.

LESSON PLANS

In the implementation of the following activities, it is assumed that the students already know the following concepts:

1. Atomic structure
2. The concept of radioactivity

3. The law of conservation of mass and energy
4. The concept of the mole and a balanced equation.

They must understand these things in order to be successful in obtaining the objectives of these lessons. I usually teach these pre-required lessons earlier in the school year. In this unit the most basic nuclear chemistry lesson they will learn is writing balanced **nuclear** reactions which involves the three different emissions mentioned above.

There are four flexible activities that can be done in this unit. I will start with the time lining of the development of the atomic bomb and then a follow up activity on the socio-political aspect. After this is an activity on the content mastery on nuclear chemistry followed by the building up of the model.

Activity I: Creating a Timeline of the Nuclear Age

This activity is very helpful in establishing a firm foundation in the understanding and appreciation of the development of the nuclear age. It is indeed more meaningful when students explore the very origin of this development and realize how long it took for the ultimate product to be materialized and put into use.

Objective
Students will be able chronologically to arrange the scientific breakthroughs that led to the development of the atomic bomb from the discovery of the radio active particles to Einstein’s energy theory ($E=mc^2$) up to the bombing of Hiroshima and the development of the Hydrogen Bomb in the early 1950s.

Materials
Poster paper, markers, information magazines, reference books, computer and Internet access

Procedure
1. The class will be divided into eight groups and each group will be assigned a decade between 1890 to 1950.
2. Each group will be provided with a poster paper where they will present their researched information on the development of the atomic bomb during the decade assigned to them.
3. They will be allowed to research using magazines, computer and Internet access, and reference books from which they will gather information relevant to the decade assigned to them. (Note to teacher: If materials are not accessible to the class, this can be done as an advanced assignment and presentation can be done on the next meeting.)
4. Each group will be allowed five to ten minutes to present to the class what they have written on their poster paper.

Activity II: Justifying the Act

Objectives
1. Identify factors that led to the bombing of Hiroshima and Nagasaki.
2. Realize the consequences of the action.

Procedures
Initially, this is a whole class grouping activity where the students will watch several documentary films from CNN or PBS on the effects of the Hiroshima and Nagasaki bombing. After the film presentation, the students will be grouped into smaller groups to answer the following questions:

1. What do you think were the reasons why President Truman ordered the bombing of Hiroshima and Nagasaki?
2. Do you think the grounds for bombing were justified by this action?
3. What are the short-term effects of the nuclear weapon?
4. What are the long-term effects of the nuclear weapon?

Activity III: Effects of the Nuclear Explosion

Objective
To identify the long and short term effects of the nuclear explosion

Procedure
The class will be grouped into four sections and each is assigned one topic from among the following areas that are affected by a nuclear explosion:

1. Physical environment and biological processes
2. Agriculture
3. Natural Ecosystems
4. Air and Water resources

The students will present to the class a depiction of these aftermaths of a nuclear explosion through a poster presentation.

Activity IV: Building an A-bomb Model

Objective
To enhance students' analytical ability by presenting to class how an atomic bomb is built and how each part of the bomb works.

Procedure
This activity enhances the engineering ability of the students by building and designing models. Students will research on a model of any type of atomic bomb. They will then

make a blue print of the structure using computer modeling programs. Together with the blue print, they will make a miniaturized model of the atomic bomb with all parts identified. In class they will be asked to explain to their classmates how each part works.

The following area topics can be assigned to each group. Four groups in a class will be enough because this will require more students to help build the model.

1. Little Boy model
2. Fat man model
3. Chain reactor
4. Particle accelerator

Activity IV: Group Investigation

Objective
To role play the event that led to the bombing of Hiroshima and Nagasaki

Procedure
Assign the following roles to the students:

1. Adolf Hitler
2. Stalin
3. President F. D. Roosevelt
4. Japanese government
5. Slizard
6. Einstein
7. President Truman
8. Henry Bequerrel
9. Fermi

In the instance that a student does not know one of these persons and what their roles are in the history, the student should research on this. This activity may be done per group or as a whole class. Students will present the positions of the different historical figures, thereby illuminating their role in the events leading to the US bombing of Japan.

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