An X-Ray Refutation and Elaboration Activity

INTRODUCTION

Sunlight bursts through a tear in the dark clouds as a summer rainstorm recedes. You look toward the West and a brilliant rainbow stretches across the sky. It is so beautiful that you want to believe that a pot of gold might be found where the end touches the ground. X-rays, the topic of this activity, have many things in common with the light rays that produce a rainbow, and we shall explore them here. Perhaps at the conclusion of your research you will find that x-rays can also be appreciated as one of the marvels of our Universe.

THE TASK

Imagine that you are the student who submitted the essay below to your teacher. You knew that it was not your best effort and now your instructor has returned the paper to you with a note in red ink: “There are three errors in your opening sentence alone! Please resubmit your paper, with correct information, citing the sources which back up your corrections.”
To make your task more manageable the errors have been italicized. It is suggested that you read the essay, then explore the references included at the end to find the correct information. Some of the information is purely factual in order to set the stage, while other information is conceptual and will help you better understand the concepts as we proceed through this unit.

While simple factual corrections will accomplish the task, it is hoped that you will expand on the **boldfaced** topics with examples cited from the resources. Work together with a partner, discussing the ideas as you go along, and coming to consensus on what the corrections and elaborations should be.

As a safety note, one of the references tells how an amateur scientist made his own X-ray machine for about $20.00. If this is something that appeals to you, it would certainly make an excellent project. But remember that X-rays are high-energy radiation, and potentially very harmful to living tissue. Be sure to heed all safety precautions, and have an experienced person check over your apparatus to look for potential health risks. Good luck.

X-Rays

X-rays were *invented* by *Xavier Ray* in *1950*. Xavier was a German Professor who had been experimenting with the effects of high voltage electricity passed through glass tubes from which most of the air had been removed. Such tubes were known as *Thief* tubes. As he explained in an interview at the time:

> "I was working with a *Thief* tube covered by a shield of black cardboard. A piece of barium platino-cyanide paper lay on the bench there. I had been passing a *gas* through the tube, and I noticed a peculiar black line across the paper.” “…I assumed that the effect

must have come from the tube, since its character indicated that it could come from nowhere else. I tested it. In a few minutes there was no doubt about it. Rays were coming from the tube which had a ***heating*** effect upon the paper. I tried it successfully at greater and greater distances, even at two *miles*.

It seemed at first a new kind of invisible light. It was clearly something new, something unrecorded." [i]

The professor named the strange rays ***after himself*** in a moment of vanity. Dr. Ray experimented with the strange new rays by interposing various materials including wood, metal and glass between the source and a darkened chamber. On the wall of the chamber which faced the tube, hung a paper covered with platino-cyanide salt. The salt "lighted up with brilliant fluoresecence" in the presence of the rays. The rays were discovered to have the power to pass through nearly every material, but with varying strength. Dr. Ray states that the degree of "transparency" of a body to the rays is *not* simply the product of density and thickness. It is regrettable that Dr. Ray ***never experimented*** with exposing living tissues to his X-rays, as *this might have* advanced the cause of medical care by decades. In other experiments however he was able to demonstrate that lenses made of glass and ebony (a very dense wood) *had the ability* to focus the rays. Yet although *photographic plates were insensitive* to the rays, he had *conclusive* evidence that the rays might be refracted as a prism does with visible light. In other experiments Dr. Ray demonstrated that the rays *could distinctly be influenced* by the presence of a magnet. Dr. Ray **methodically experimented in every way imaginable** to understand the nature of his X-radiation, and most of his conclusions have been vindicated today.

Since the time of Dr. Ray, X-ray science has come a long way. Today we realize that X-rays, like radio waves and the sunlight we are so familiar with, are all forms of *mechanical* energy. This energy travels through space in "waves" which have something in common with the simple waves of the ocean. These waves have a characteristic distance between one wave and the next. This is known as the *cycle*, and often measured in *inches*. Such waves expand outwards from their source. The number of these waves passing a given point in one second is the *refractive index*. For example green light has a *cycle* of ……and a *refractive index* of ……It has been demonstrated that in empty space—a vacuum -- radiant energy travels at about *500* meters/second "the speed of light," Frequency and wavelength are *inversely* related according to the formula: $\lambda = C / f$, where λ is the wavelength in meters, f the frequency in Hz / second, and C refers to the speed of *sound*. We can imagine all the wavelengths of radiant energy as upon a giant radio-dial. We can segment this dial by wavelength. In one region are the waves of the familiar radio stations; in another, with shorter wavelengths, are the visible waves, those we can actually receive or see with our eyes. If we explore the more distant end of this dial or properly speaking, the *quantic*-magnetic spectrum, we encounter the extremely short waves, about one ten-thousandth that of visible light (about 250 millionths of an inch); these are the x-rays. And beyond X-rays there are still shorter waves known as *krypton* radiation.

The penetrating power of X-rays seems magical to us. The ability for something to pass through "solid" matter contradicts our intuition. Yet it is really not so mysterious;

after all, doesn't ordinary, visible, light pass through a pane of glass, and radio wave effortlessly pass through the walls of buildings? But how is this accomplished?

Atoms consist primarily of open space. It may help to compare an atom with our own solar system. At the center, or "nucleus," lies the sun, and circling at varying distances, the "electrons" or planets. In between is a vast empty space, 93 million miles for example between Earth and the Sun: surely plenty of room for something to pass in between! What really matters is the size of the object you wish to pass through. An object greater than 93 million miles in diameter would never make it. In the case of atoms, waves of X-ray size often can. As you might imagine, sometimes a given ray is on a collision course with the nucleus or perhaps one of the electrons of an atom. In this case the wave will be absorbed; its energy transformed into longer, often visible, wavelengths and re-radiated. This effect was what caught Ray's attention and led him to his discovery. To quote again Dr. Ray:

"**Rays were coming from the tube which had a luminescent effect upon the paper….It seemed at first a new kind of invisible light. It was clearly something new, something unrecorded.**" [ii]

When X-rays are directed at some object of varying thickness or density, some of the rays may pass through unimpeded. If they should reach a photographic film the energy is usually sufficient to cause the same chemical changes as ordinary light would; the film is "exposed." But if some rays are absorbed the film will show less exposure. This contrast between areas of absorbed X-rays and those that are not, presents the image of bones or even cancers in medical X-rays. In Industry X-rays are used to look for cracks in welds of pipelines, not to mention guns in airline luggage.

How can X-rays be generated?

To understand how the electromagnetic waves are generated, recall the structure of the atom. According to the Bohr model the electrons circling the nucleus occupy discrete energy "shells." When these electrons absorb energy they are forced into more distant but unstable orbits. Typically they drop back to their original positions and emit the surplus energy as *quantico*magnetic waves, waves that are characteristic for the particular kind of atom involved. Such radiation, which can be in the form of radio waves, visible light, X-rays and gamma rays, is extremely useful as it can inform scientists about the composition of substances on Earth or of distant stars and other stellar artifacts.

Energy can be applied to atoms by electric currents, as in radio transmitters, light bulbs and X-ray tubes. An environment of high temperature is also effective in producing *quantico*magnetic radiation. On a local level the flames one sees in a crackling fire exhibit this effect. The solar radiation that sustains our planet is generated by the intense heat of nuclear fusion within our sun. Likewise when stars implode or explode massive amounts of *quantico*magnetic energy stream into space. When instruments such as the Chandra X-ray Observatory are focused on distant objects in space brilliant images of X-ray energy are revealed. Some of these intense X-ray emitters are believed to be of clouds super hot gasses generated by exploding stars or supernovas as they are called. Such study is certain to enhance our understanding of the evolution of the Universe. We should

appreciate that X-radiation, like visible light, “can be reflected, refracted, diffracted and polarized” [2]

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[i] http://www.cc.emory.edu/X-RAYS/century_09.htm
[ii] http://www.cc.emory.edu/X-RAYS/century_09.htm
[2] http://www.noah.org/science/x-ray/index.html