090501 Quiz 3 XRD

This week we studied x-ray detectors and some review of crystallography.

a) What is an image plate? Explain what happens when an x-ray impinges on the image plate as well as the mechanism for reading the image plate.

b) Explain what a Geiger Counter is and how it differs from an ionization guage and a proportional counter.

c) What is a scintillation counter?

d) Explain what the following mean: [111]; {100}; <110>; (120). Sketch in a crystal lattice if you can.

e) List the 7 crystal systems and what values the three angles and three lattice vectors take for each.

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a) The image plate is composed of a plastic backing and a film of BaFBr doped with Eu^{2+}. The Ba salt contains sites with missing halide that are called color centers. These can act as storage depots for free electrons. The x-ray ionizes Eu^{2+} to Eu^{3+} and an electron is injected into the conduction band of the Ba salt. Some of these electrons recombine with Eu to form Eu^{2+}. Some electrons (the number being proportional to the number of x-ray photons) are captured by the color centers. Irradiation of the image plate with a HeNe laser excites electrons from the color centers to the conduction band where they can decay and recombine with Eu^{3+} to lead to Eu^{2+} releasing 390 nm radiation (blue light) in the process. This blue light is detected in the reader as the proportional signal.

b) A Geiger counter is a gas detector that relies on a gas (P10 which is 10% methane in argon) to be ionized by an incident x-ray. The ions are collected by creating a large voltage gap in the gas chamber. Depending on the voltage gap the device can be an ionization gauge (200V), a proportional counter (1000V) or a Geiger counter (1500V). In an ionization gauge a single photon creates a single electron so it is proportional but has no signal amplification. These are used at synchrotrons to monitor the direct beam from the source as well as detectors for accurate quantification of sources on an absolute scale. With increasing voltage amplification of the signal occurs since one photon makes one electron which then collides with other gas atoms to react a cascade of electrons. In the proportional voltage range the signal is proportional to the number of photons incident on the gas. At very high voltages a single photon makes a huge number of electrons so the signal is very large but proportionality is lost between the number of incident photons and the number of detected electrons. This is a Geiger counter and it is useful as a survey meter such as the device we use in the lab to scan for x-ray leaks.

c) A scintillation counter consists of an x-ray phosphor screen attached to a photo multiplier tube. The phosphor can be thallium doped NaI that gives violet light when Tl^{+1} reverts to Tl. This light is converted to electrons when it hits a cesium-antimony intermetallic film on a glass window. The released electrons are amplified by a series of dynodes at about 100V drop per dynode leading to a gain of about 10^7. Scintillation counters are proportional and are commonly used in diffractometers. The typical brand name is Bicron and these are often referred to as Bicron detetctors.

d) [111] refers to the [111] direction (diagonal across the cube))
{100} refers to the family of (100) planes (all sides of a cube)
<110> refers to the family of [110] directions (all diagonals on the side of the cube so make an X on each side)
(120) is the plane that intersects the x-axis at 1 and the y-axis at ½.

e)

	a b c	α β γ
Cubic	$a = b = c$	$\alpha = \beta = \gamma = 90^\circ$
Tetragonal	$a = b \neq c$	$\alpha = \beta = \gamma = 90^\circ$
Orthorhombic	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90^\circ$

Rhombohedral	$a = b = c$	$\alpha \neq \beta \neq \gamma \neq 90^\circ$
Hexagonal	$a = b \neq c$	$\alpha = \beta = 90^\circ \quad \gamma = 120^\circ$
Monoclinic	$a \neq b \neq c$	$\beta = \gamma = 90^\circ \quad \alpha \neq 90^\circ$
Triclinic	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90^\circ$