Workshop Tutorials for Introductory Physics

QI2: **Atomic Structure**

A. Review of Basic Ideas:

Use the following words to fill in the blanks:
electrons, shape, matter, electronics, quantum, planets, uniform, pudding, discrete, solar, indivisible, nucleus, spectra

The evolving model of the atom

The word "*atom*" comes from Greek, and means indivisible (*a*- not, *tom*- divisible). In about 450 BC Democritus postulated that _____ was made up of tiny individual atoms, and that the _____ of the atoms determined the properties of the material. It took more than another 2 millennia for this theory to be seriously advanced on.

The first modern model is Thompson's plum _____ model. In this model the atom is described as a lump of material with a _____ positive charge and uniform low density, with little bits of negative charge (_____) speckled throughout. Thompson measured the charge/mass ratio of the electron, the first sub-atomic particle. But even though this showed that the atom wasn't quite _____, atoms weren't renamed "*toms*"

The next big change to the model came from Rutherford. He discovered that the atom wasn't a uniform lump, but actually had a little _____ where the positive charge was, and the electrons were outside this. In fact, he showed that the nucleus was actually really small compared to the size of the atom. He suggested that the atom was like a _____ system, with a nucleus in the middle like a sun, and electrons orbiting around like _____.

There were some problems with this model. But at about the same time Planck and others were developing the _____ theory. Bohr incorporated the quantum theory into Rutherford's model, which solved a lot of the problems and explained not only why atoms show _____, but predicted where the lines for hydrogen would be. Unfortunately it didn't work very well for bigger atoms.

The currently accepted model of the atom is that the electrons exist in clouds around the nucleus, and have _____ energies which can be determined from quantum mechanics, although the calculations can be very difficult. While this model is bound to change a bit, it seems to work pretty well. In fact, all modern _____is based on it. Everything that has a transistor in it, from a digital watch to a computer, is based on quantum mechanics and the quantum model of the atom.

B. Activity Questions:

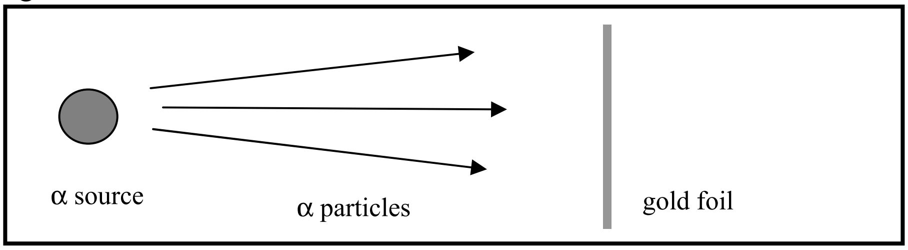
1. Hydrogen Spectrum
The hydrogen lamp has a tube which contains lots of hydrogen atoms, which have been excited so that their electrons occupy different energy levels.
Describe what you see when you look at the lamp. Now look at the lamp through the spectroscope. What do you see? Draw a sketch of the spectrum you observe.

2. Emission spectra
Use the spectroscope to observe light from other sources, including the lamps, fluorescent tubes and sunlight. Why are the spectra from these sources different?
How do you think scientists can tell what stars are made from without actually collecting samples?

3. Identify the element
Use the spectra chart and the spectroscope to identify the element contained in fluorescent lights.

C. Qualitative Questions:

1. In 1911 Ernest Rutherford, a New Zealand physicist and winner of the 1908 Nobel prize in chemistry, had his friend Hans Geiger (of Geiger counter fame), fire alpha particles (helium nuclei) at a very thin sheet of gold.



a. Draw a diagram showing where you expect the majority of alpha particles to go.
b. Where do the remainder go?
Most of the α particles went straight through, but a few bounced back. Given the model of the atom at the time, the plum pudding model, this was a very surprising result.
c. What do these results tell you about the structure of the atom?
d. What would have happened had Geiger accidentally used a neutron source rather than an α source?

2. In 1913 Niels Bohr proposed a modification to Rutherford's atomic model. He envisioned specific discrete energy levels (shells, numbered n=1,2,3…) for electrons bound to a nucleus.
a. What does discrete mean?
b. What else comes in discrete quanta?
c. How do we know that there are discrete energy levels?
d. Would you expect the energy levels to be the same or different for hydrogen and helium?
e. How are the levels distinguished in the current atomic model?

D. Quantitative Question:

The effective radius of a nucleus can be calculated using $R = R_o A^{1/3}$, where $R_o = 1.2$ fm $= 1.2 \times 10^{-15}$m, and A is the atomic mass number of the nucleus. The atomic mass number of gold is 197.
a. Calculate the size of a gold nucleus.
b. What is the density of a gold nucleus?
A gold atom has an effective radius of around 2 nm. Imagine making a model of a sheet of atoms with nuclei 1cm in diameter (marbles, for example), and spacing them so that the atoms were just touching.
c. How far apart would the nuclei need to be positioned?
d. How hard would it be to hit the nuclei with thrown marbles from several atomic radii away?

By convention there is colour,
By convention sweetness,
By convention bitterness,
But in reality there are atoms and space.
-Democritus (c. 400 BCE)