

# SCIENCE 1104

# ATOMIC STRUCTURE AND PERIODICITY

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## II. MODERN ATOMIC STRUCTURE

In Section I the Thomson model and Rutherford model were shown to be almost opposite one another. Thomson visualized a positive cloud with the negative particles. Rutherford's experiment

gave strong evidence that the atom must have a negative cloud with the positive particles in the nucleus. Rutherford's model with a dense, positively charged nucleus, is generally accepted today.

### SECTION OBJECTIVES

**Read these objectives.** When you have completed this section, you should be able:

3. To develop the theory of modern atomic structure.
  - 3.1 To use the Bohr representation of atoms.
  - 3.2 To use orbital representations.
  - 3.3 To describe the shape and meaning of *s* and *p* orbitals.

We know that the negative charges (-) in an atom are equal the positive charge (+) on the nucleus. In this section you will explore how the electrons are

arranged around the nucleus to make the volume of the atom about ten thousand times larger than the nucleus.



### VOCABULARY

**Study these words** to enhance your learning success in this section.

energy level

orbitals

photon

group

Periodic Table

sublevels

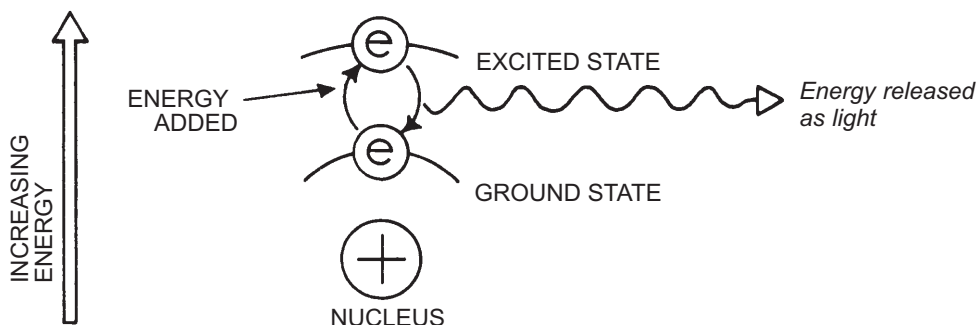
ionization energy

### ATOMIC SPECTRA

The exact model of the atom is still in question. But since a model is vital to your understanding of the concepts of chemistry, let's see what the presently proposed models are like.

**Quantum emission.** One might predict that the atom should collapse into a very tiny volume since

the negative charge on the outside is attracted to the positive center. This is not the case, however. You may recall that light is a form of energy. When a tube of gas under low pressure has a voltage put through it, it emits light like a neon sign. Energy is being given off. This emission of light occurs when electrons are migrating toward the nucleus.



**Figure 10: Quantized Energy Emission**

Nature often tries to lose energy to become more stable or to return to a previous *satisfied* state. For example, the liquid para-dichlorobenzene gave up heat energy to return to the stable solid state. In the

gas-filled tubes, electrical energy forces the electron out of its orbit. When the electron returns to its stable position near the nucleus (its ground state), it gives up energy in the form of light.

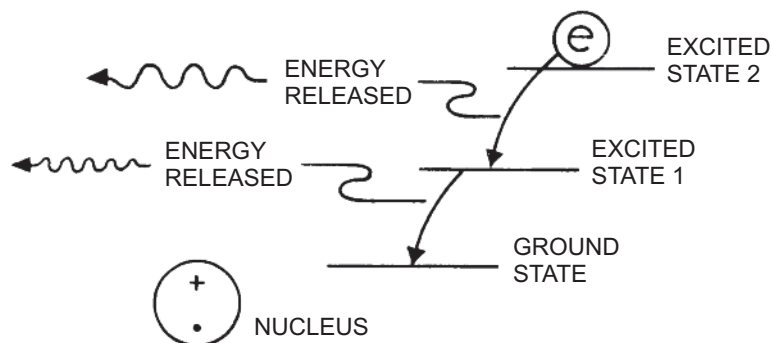


Figure 11: Photons of Energy Emitted by Returning Electrons



**Do these activities.**

- 2.1 Look carefully at Figures 10 and 11. Notice that the electron is normally in the ground state, and that electrons return to the ground state.
- What must be true of the amount of energy input compared to the light energy given off? \_\_\_\_\_
  - Why? \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_
- 2.2 Visualize two magnets with the north pole of one moving toward the south pole of the other. Because opposite poles attract, a steadily increasing opposing pull must be applied to resist the magnetic attraction. The force you apply is steady and not jerky. The attraction continually increases as distance between the magnets decreases.



Figure 12: Movement of Magnets

- From our investigations in Section I would you predict that unlike electrical charges would attract with steadily increasing attraction or jerky attraction? \_\_\_\_\_  
 \_\_\_\_\_
- Give a reason for your prediction. \_\_\_\_\_  
 \_\_\_\_\_

If this prediction that the nucleus-electron attraction is similar to the opposite magnetic pole attraction is correct, then as the electron returns to its stable position near the nucleus it should give off energy continually and steadily. We should then have a continual emission of white light with all energies. Each element, however, gives off a different color. Observation contradicts prediction. A more detailed study of this energy idea should be

carried out before the prediction is totally checked. Let's see if we can find out how the energy is given off if not in a continuous way.

One way of considering light is to say that light travels from one place to another in bundles or packets. These packets are called **photons**. The size of the photon depends upon the characteristic of the light waves (its wavelength or frequency) in that particular packet.



### Try this experiment.



#### These supplies are needed:

Slinky or long coil spring



Follow these directions and complete the activities. Place a check in the box when the step is completed.

- 1. Fasten one end of the spring to some stationary object on a workbench or on an uncarpeted floor. It works well to slip an end loop under a chair leg.
- 2. Stretch the spring to twice its relaxed length (a Slinky to 30 times its relaxed length). *Do not overstretch.* With one hand hold the free end fixed. With the other hand pull some coils to the side about 20 centimeters. Release. Shorten or lengthen the free end until a pulse so generated will return to your fixed hand.

2.3 Sketch the general form you observe.

- 3. Now give the Slinky two side-to-side shakes with moderate energy.

2.4 Describe your observations. \_\_\_\_\_  
\_\_\_\_\_

- 4. This time move the Slinky from side to side with as much energy as you can.

2.5 Describe your observations. How are they different from Step 3? \_\_\_\_\_  
\_\_\_\_\_

Wave motion is described in various ways. However, certain terms are used to describe its shape and motion. The wavelength is symbolized by  $\lambda$ .

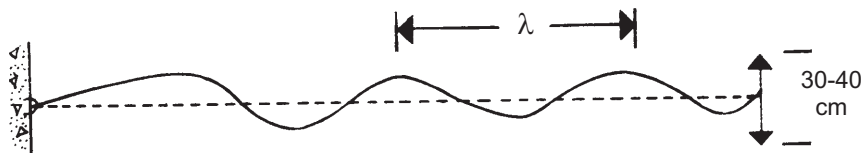


Figure 12: Wavelength

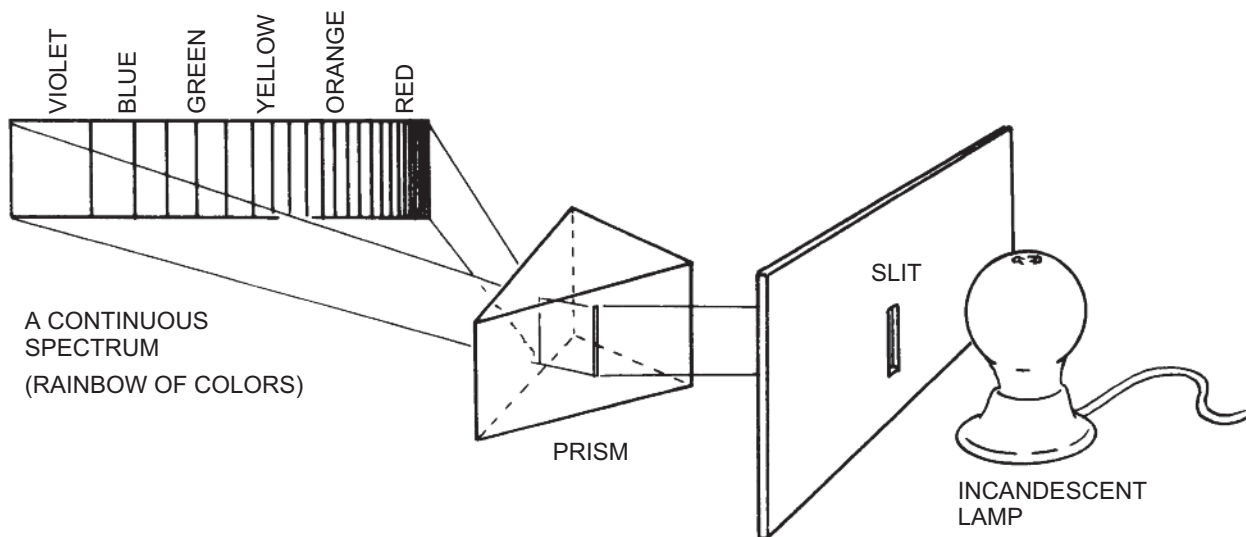
2.6 Order your three observations in 2.3, 2.4, and 2.5 in terms of a. longest  $\lambda =$  \_\_\_\_\_  
b. medium  $\lambda =$  \_\_\_\_\_ c. shortest  $\lambda =$  \_\_\_\_\_

2.7 The frequency with which the wave moves side-to-side is symbolized by  $\nu$  or  $f$ . Order your observations in 2.3, 2.4, and 2.5 according to a. greatest  $\nu =$  \_\_\_\_\_  
b. medium  $\nu =$  \_\_\_\_\_ c. lowest  $\nu =$  \_\_\_\_\_ .

2.8 Make a statement relating  $\lambda$  to  $\nu$  for your three trials. \_\_\_\_\_  
\_\_\_\_\_

**Emission spectra.** Let's apply the ideas of this section to the structure of the atom. Light that we see from the sun or from an incandescent light bulb is

called *white light*. When white light is passed through a prism, or diffraction grating, it is separated into a continuous spectrum in which all colors are shown.

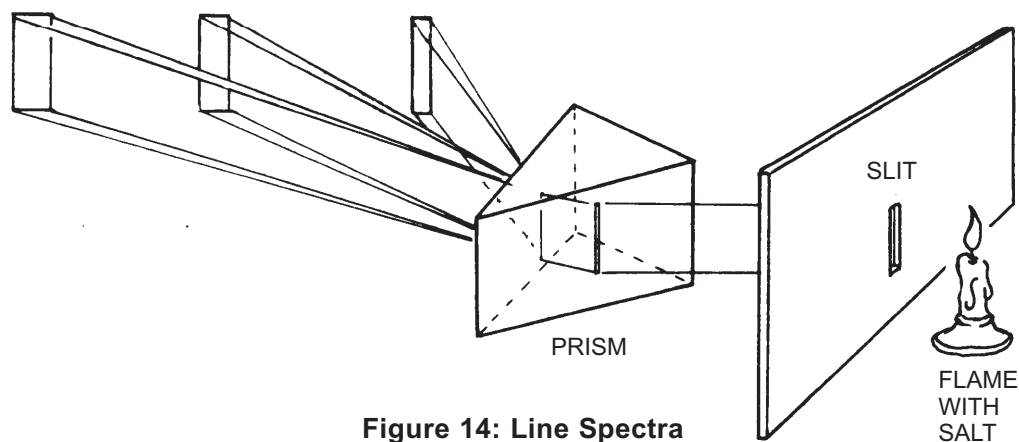


**Figure 13: White light is separated into a continuous spectrum.**

On the other hand, when the light from a flame containing salts such as sodium chloride are passed through the prism, only specific narrow lines of light (a *line spectrum*) can be seen on the screen. According to Max Planck, each line—that is, each color or wavelength or frequency—corresponds to a definite energy, which means that atoms can radiate (give off) light of only certain energies. *Each element has its own unique line spectrum and this spectrum*

*can be used as an identifying characteristic of that element. Look in a reference textbook for a color chart of emission spectra.*

**Scientists have used line spectra to determine the chemical composition of stars and atmospheres. Crime detectives use this spectral analysis as a way of determining if certain substances match those at the site of the crime.**



**Figure 14: Line Spectra**



**Try this experiment.**



**These supplies are needed:**

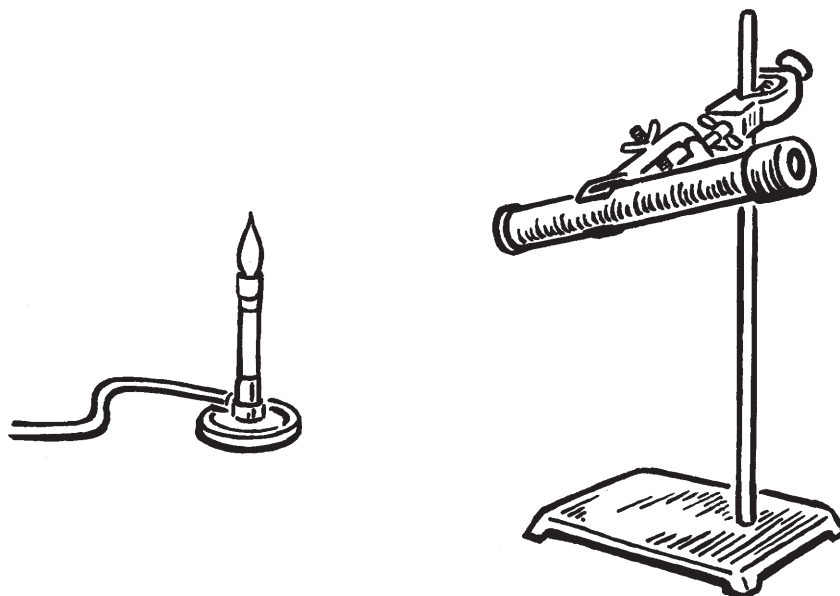
- |   |   |
|---|---|
| <ul style="list-style-type: none"> <li>six clean, dry milk jug lids or small test tubes</li> <li>Nichrome wire with handle (inoculating loop)</li> <li>Bunsen burner or propane torch</li> <li>Solid samples of chemicals such as compounds of sodium (table salt), copper, potassium, calcium, lithium, and strontium</li> </ul> | <ul style="list-style-type: none"> <li>hand spectroscope</li> <li>distilled water</li> <li>dropper</li> </ul> |
|---|---|

**Note:** The spectroscope from the kit is a tubular instrument that has a diffraction grating in the eyepiece and a narrow slit in the front for light to enter the tube. The diffraction grating is a plastic disk with 13,400 grooves per inch that separate light into its colors.



**Follow the directions.** Place a check in the box when the step is completed.

- 1. Aim the slotted end of the spectroscope at a light source.
- 2. Look through the eyepiece toward the inside wall of the spectroscope until you see the light spectrum.
- 3. Rotate the spectroscope until the light spectrum is on the side of the tube.
- 4. While holding the tube still, rotate the slotted end-cap to get the widest spectrum. Repeat Steps 1-4 with each different light source in the following steps.
- 5. Aim the spectroscope at the sunlight, BUT NOT DIRECTLY AT THE SUN. Record your data in Data Table 5 on the next page.
- 6. Hold your spectroscope toward a fluorescent bulb. This is the spectrum of mercury (Hg) since the light tube contains mercury vapor. Record your data in Data Table 5.
- 7. Set up the apparatus as in Figure 15. Aim the spectroscope just to the left of the flame. Adjust the spectroscope position and rotation until a line spectrum (NOT a continuous spectrum) is visible.



**Figure 15: Identifying Line Spectra**

- 8. Using samples of chemicals put a few crystals in separate milk jug lids or small test tubes.
- 9. Put 1/3 dropper of distilled water in each and mix to dissolve crystals. Prevent cross-contamination.
- 10. Heat the Nichrome wire in the burner until no more color can be seen except for the flame.
- 11. It will be much easier if you have a helper do this step while you make the observations. Dip the Nichrome wire into one sample to fill the loop with a drop of salt solution. Hold the loop in the flame. Observe the spectrum in the spectroscope. Repeat as often as necessary to get a good test and record your results in Data Table 5.
- 12. Wash the wire in distilled water and repeat Steps 10 and 11 for each of the samples.