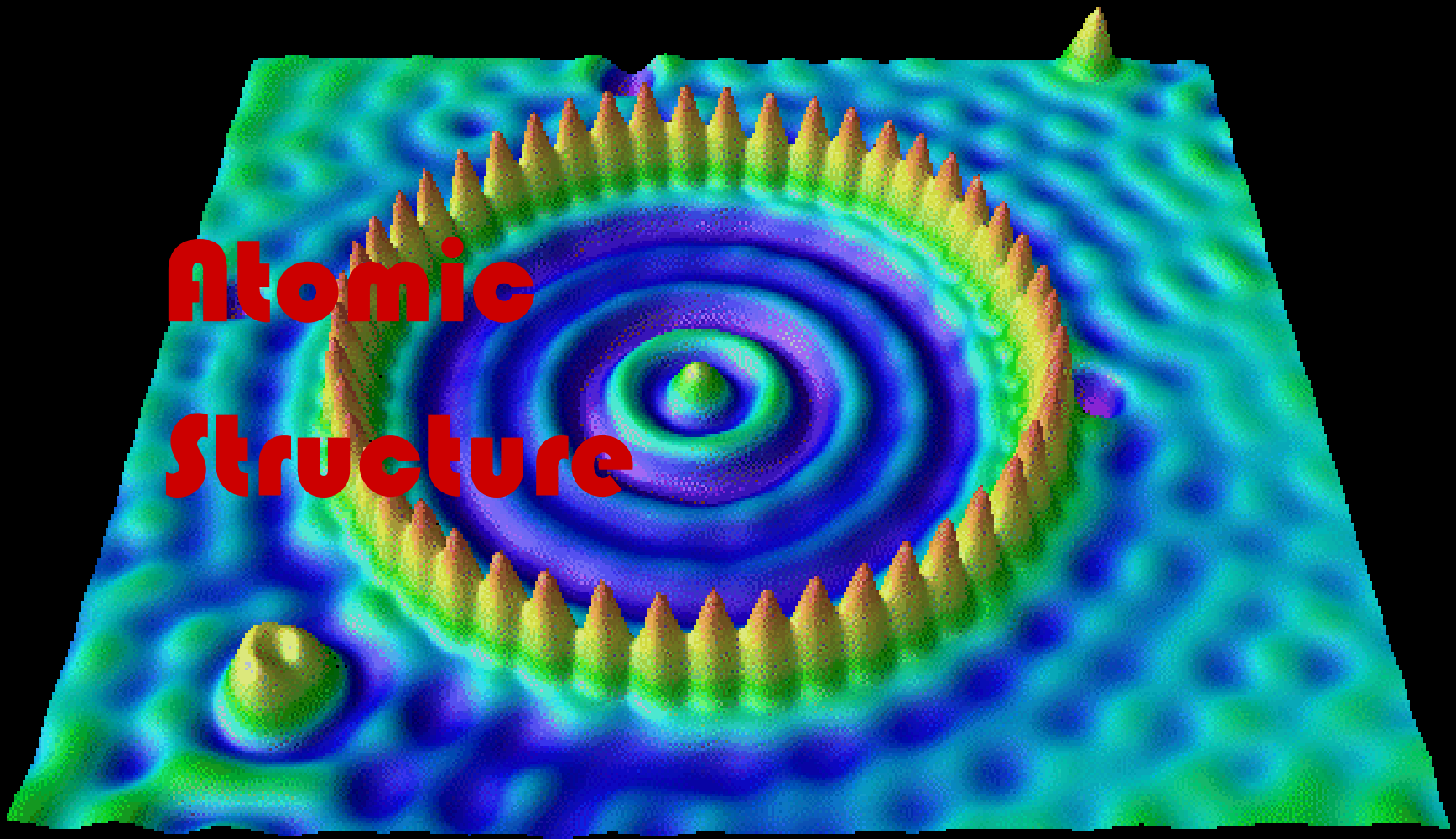
Chapter 4

Atomic Structure



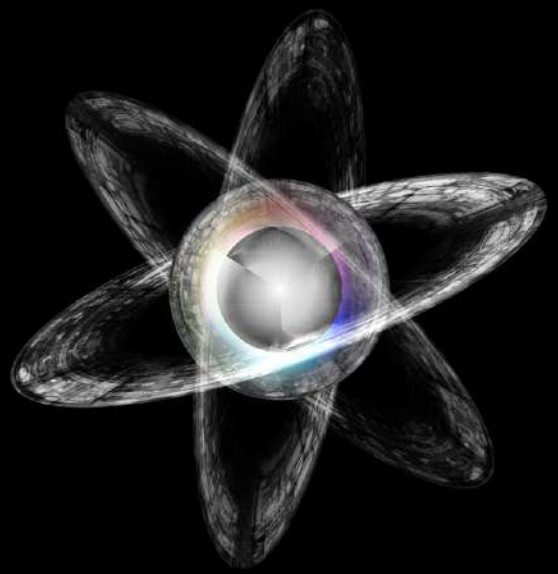
IRON ATOMS

Warm-Up Sept. 11 (Pre-Chapter 4)

1. What are the 3 parts of an atom?
2. What particles make up the nucleus?
3. Draw a picture of an atom. Label the parts.

Section 4.1 – Defining the Atom

- All matter is composed of atoms.
- An atom is the smallest particle of an element that retains its identity in a chemical reaction.
- Democritus believed that atoms were indivisible and indestructible.

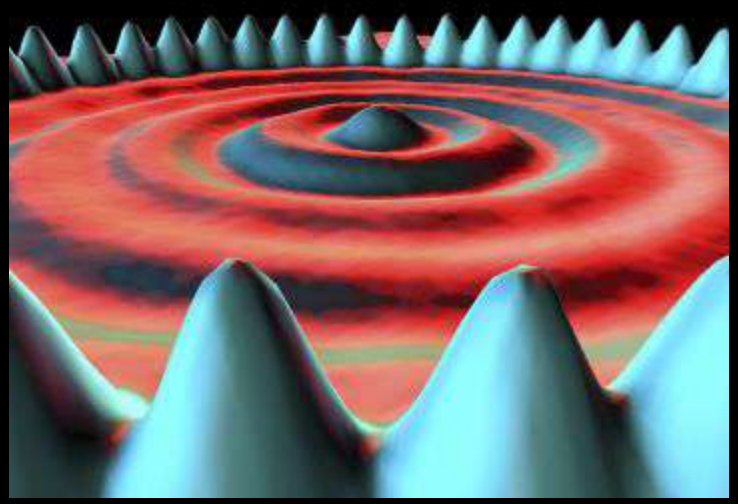


Dalton's Atomic Theory

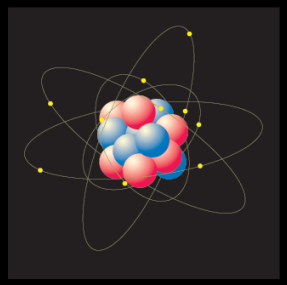
- All elements are composed of tiny indivisible particles called atoms.
- Atoms of the same element are identical. The atoms of any one element differ from those of any other element.
- Atoms of different elements can physically mix together or can chemically combine in simple whole-number ratios to form compounds.
- Chemical reactions occur when atoms are separated, joined, or rearranged. Atoms of one element, however, are never changed into atoms of another element as a result of a chemical reaction.

Sizing up the Atom

- The radii of most atoms fall within the range of 5×10^{-11}m to 2×10^{-10}m.
- If you could line up 100,000,000 copper atoms side by side, they would produce a line only 1 cm long!!
- Despite their small size, individual atoms are observable with instruments such as scanning tunneling microscopes.



IRON ATOMS



4.1 Section Assessment

1. In your own words, state the main ideas of Dalton's atomic theory.
2. According to Dalton's atomic theory, is it possible to convert atoms of one element into atoms of another?
3. A sample of copper with a mass of 63.5g contains 6.02×10^{23} atoms. Calculate the mass of a single copper atom.

$$1 \text{ Cu atom} \times \frac{63.5\text{g}}{6.02 \times 10^{23} \text{ Cu atoms}} = 1.05 \times 10^{-22} \text{ g}$$

Warm-Up Sept. 12

1. Can we see atoms? What instrument does the book say we can use to "observe" them?
2. Who was the first person to come up with the idea of atoms?
3. When can atoms of one element turn into atoms of another element?

Section 4.2 – Structure of the Nuclear Atom

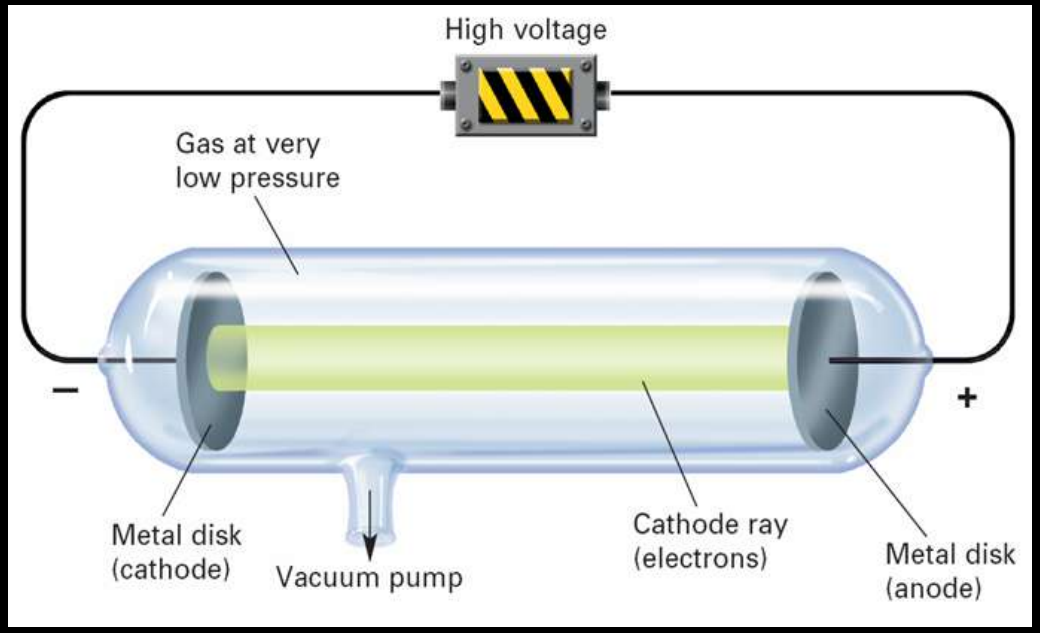
- Three kinds of subatomic particles are electrons, protons, and neutrons.

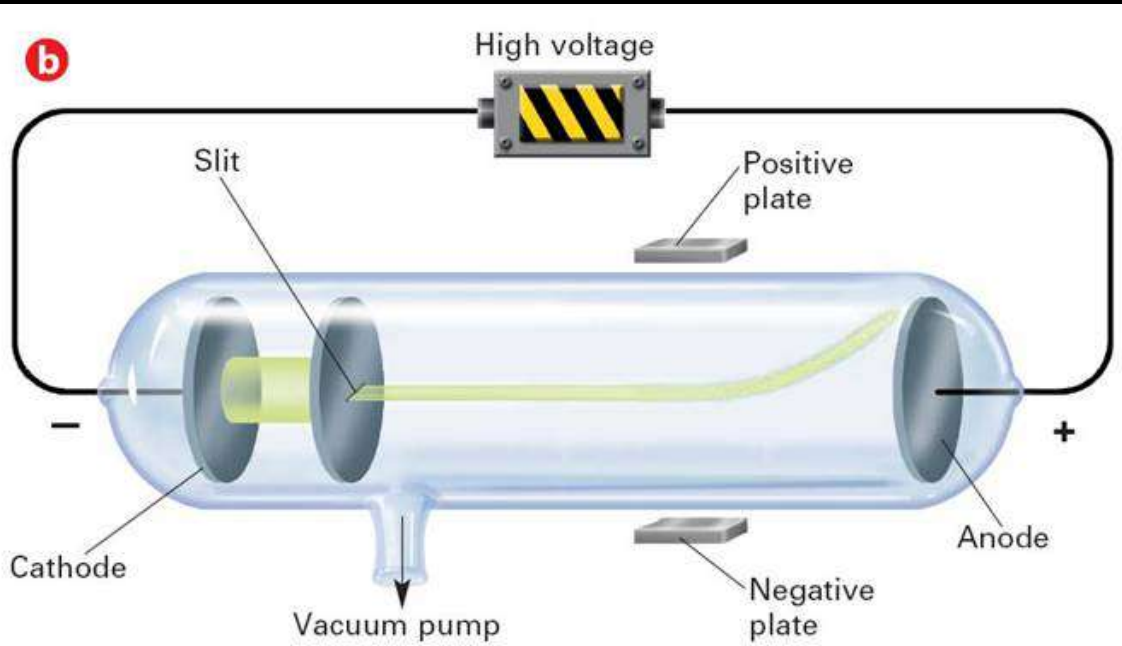
Subatomic Particle	Symbol	Charge	Relative Mass	Location
Electron	e^-	-1	1/1840	Electron Cloud
Proton	p^+	+1	1	Nucleus
Neutron	n^0	0	1	Nucleus

Electrons

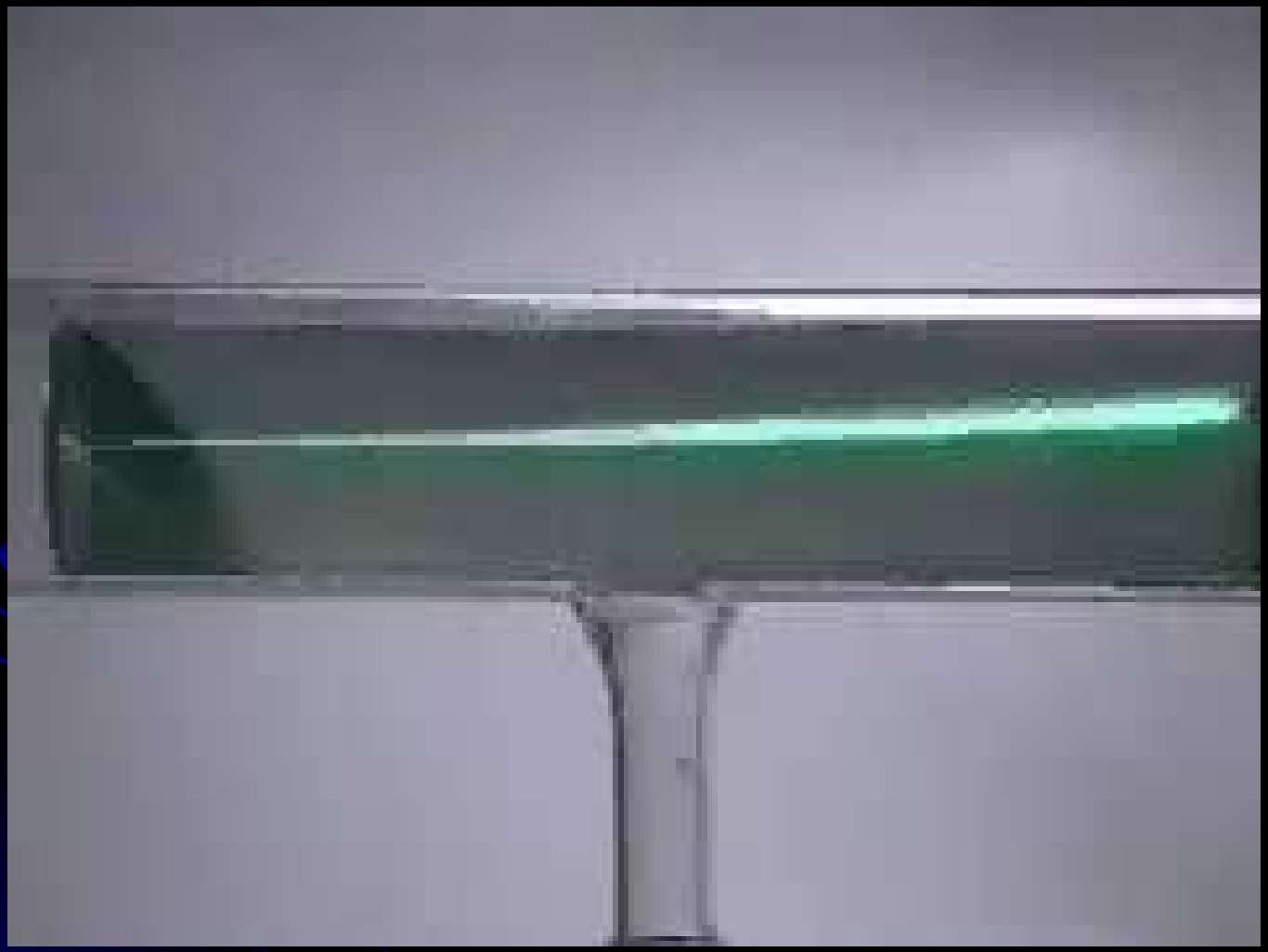
- In 1897, the English physicist J. J. Thomson discovered the electron.
- Electrons are negatively charged subatomic particles.
- Thomson discovered electrons by studying a cathode ray tube.
- A cathode ray is a glowing beam that travels from a cathode to an anode.

Cathode Ray Tube





Cathode Ray Tube Video

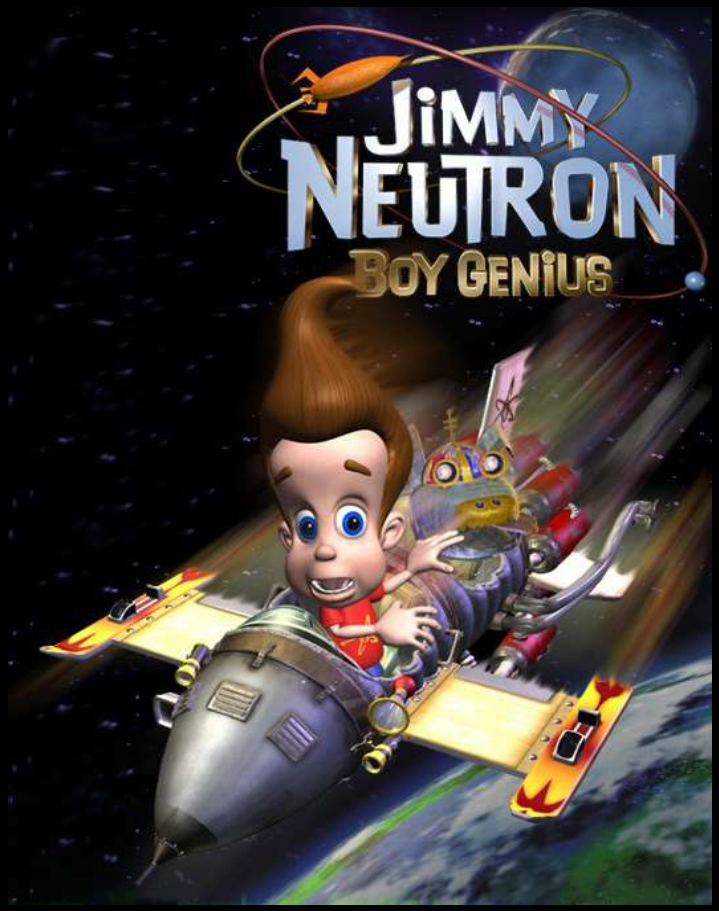


Protons

- Atoms have no net electric charge; they are electrically neutral.
- In 1886, Eugen Goldstein found evidence for positively charged particles with he found rays traveling in the opposite direction of the cathode ray.
- In 1911, Ernest Rutherford “rediscovered” them in his gold foil experiment and named them protons.

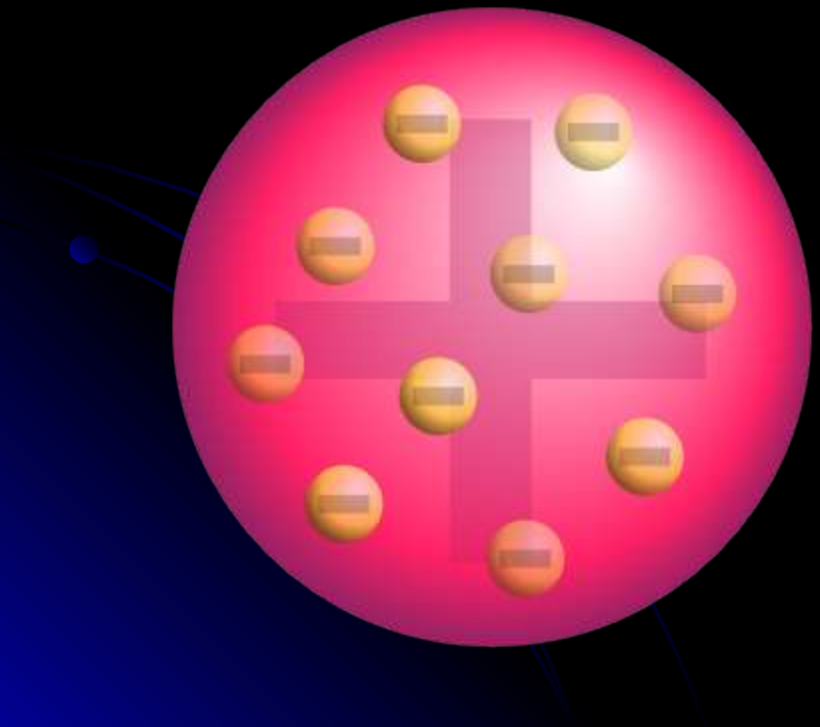
Neutrons

- In 1932, the English physicist James Chadwick confirmed the existence of neutrons.
- Neutrons are subatomic particles with no charge.



Plum Pudding Model

- The plum pudding model shows electrons dispersed in a large positively charged area.



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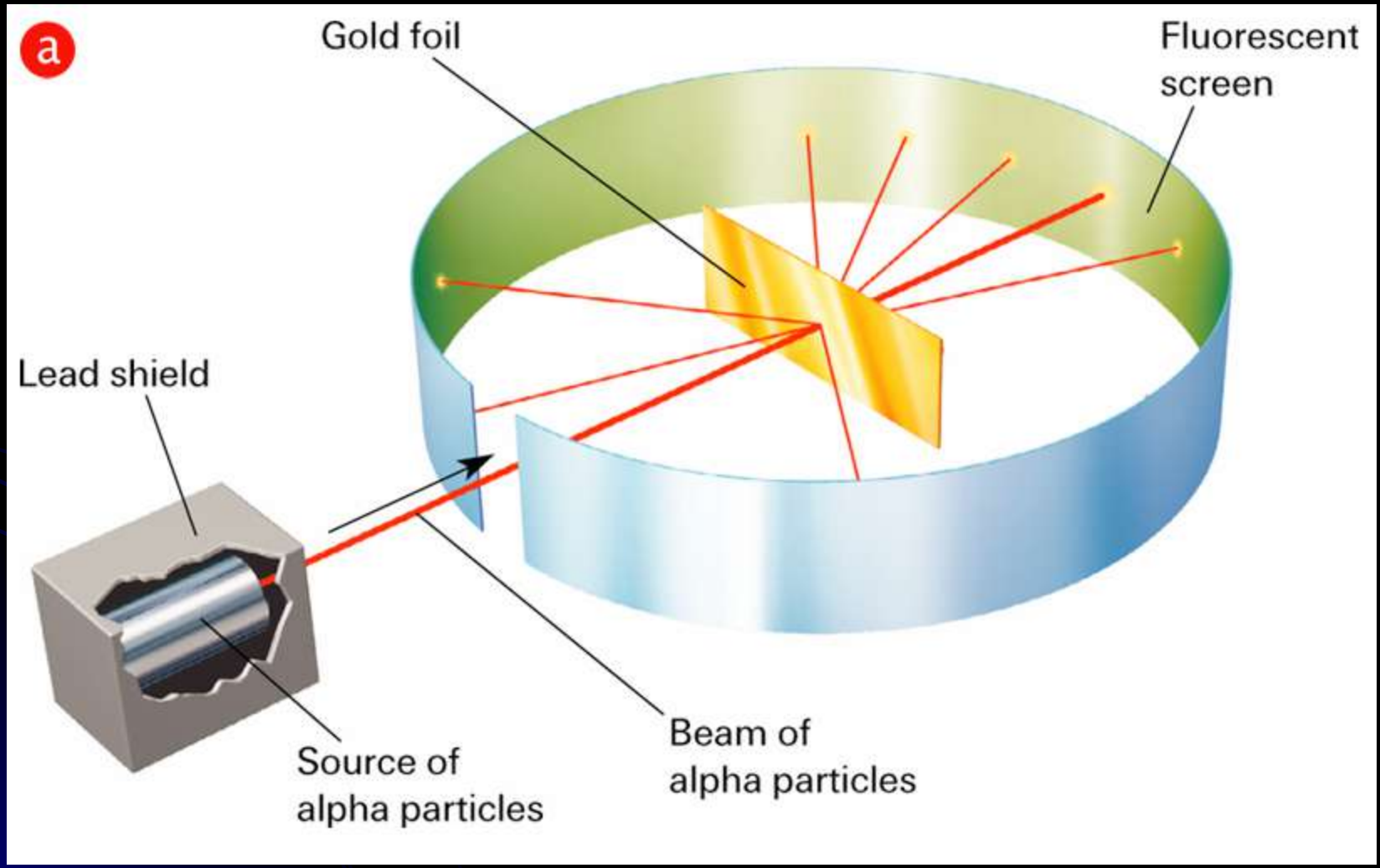
Rutherford's Experiment

- Rutherford decided to test the plum pudding model by shooting alpha particles (helium atoms with no electrons) at a thin sheet of gold foil.
- The particles should pass through the foil with slight deflection.
- HOWEVER, many alpha particles passed straight through, and some particles actually bounced back.

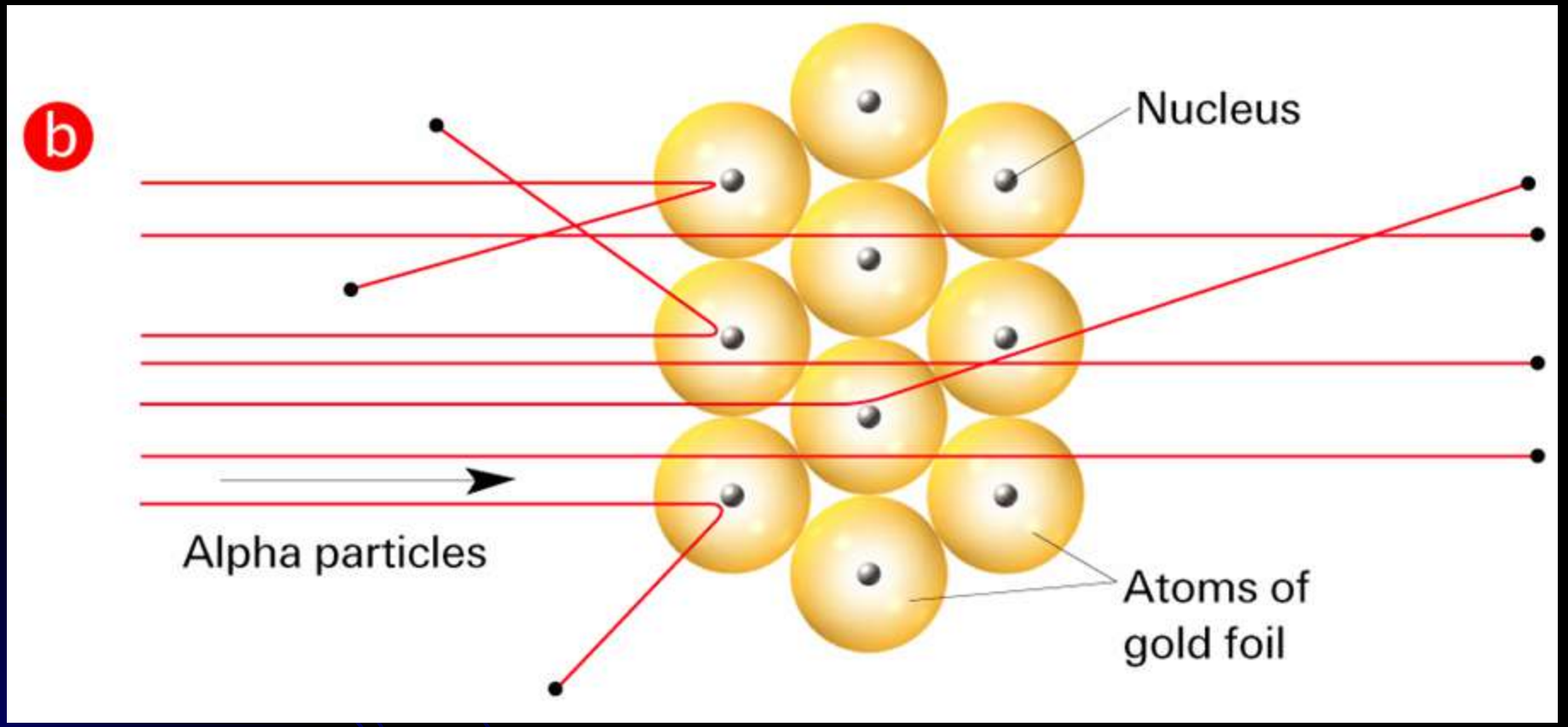
Rutherford's Experiment



Rutherford's Experiment

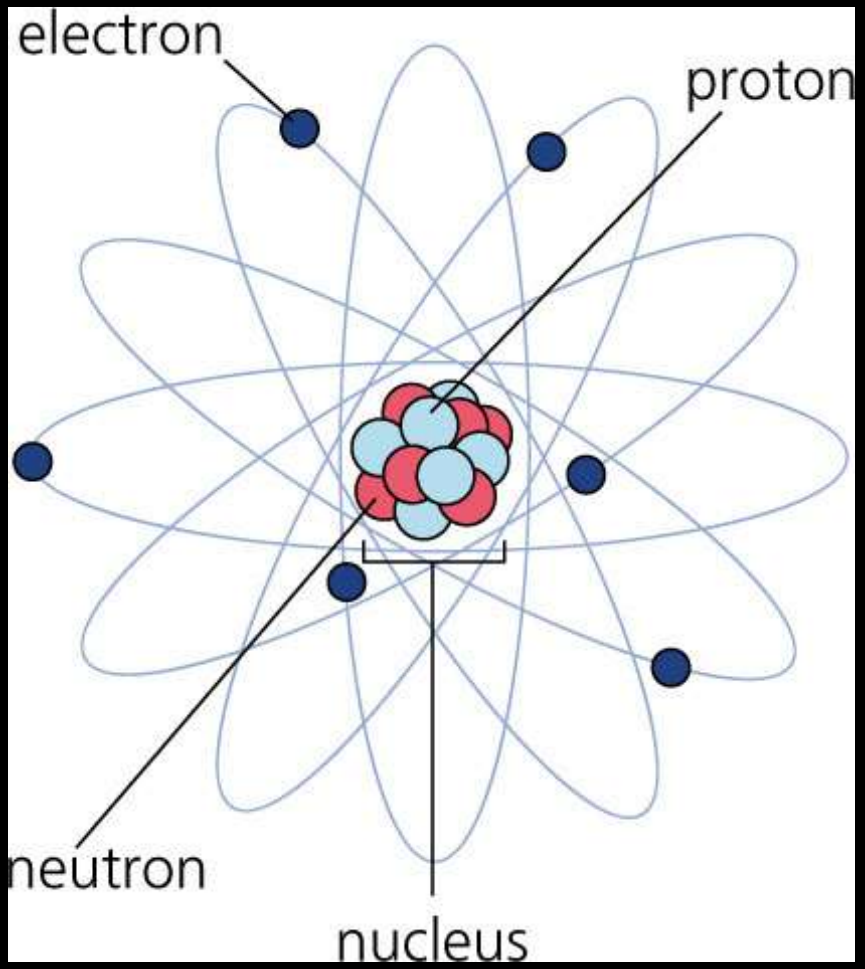
- Rutherford proposed that the atom is mostly empty space, thus explaining the lack of deflection of most of the alpha particles.
- He concluded that all the positive charge and most of the mass are concentrated in a small region and has a positive charge called the nucleus.
- The nucleus is the tiny central core of an atom and is composed of protons and neutrons.

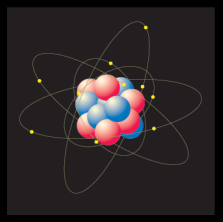
Rutherford's Experiment



Atomic Structure

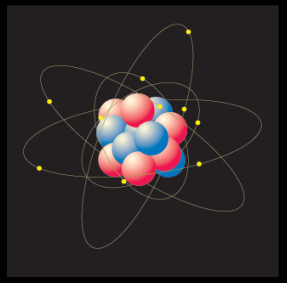
- In the nuclear atom, the protons and neutrons are located in the nucleus.
- The electrons are distributed around the nucleus and occupy almost all of the volume.





4.2 Section Assessment

1. What are the three types of subatomic particles?
2. How does the Rutherford model describe the structure of atoms?
3. What are the charges and relative masses of the three main subatomic particles?
4. Compare Rutherford's expected outcome of the gold-foil experiment with the actual outcome.



4.2 Section Assessment

5. What experimental evidence led Rutherford to conclude that an atom is mostly empty space?
6. How did Rutherford's model of the atom differ from Thomson's plum pudding model?

Warm-Up Sept. 16

1. Who discovered the proton? Neutron? Electron?
2. Draw the plum pudding model? Who created it?
3. What did Rutherford shoot at the gold foil?

Section 4.3 – Distinguishing Among Atoms

- Elements are different because they contain different numbers of protons.
- The atomic number of an element is the number of protons in the nucleus of an atom of that element.
- The atomic number identifies an element.
- Atoms are electrically neutral, so the number of protons equals the number of electrons.

Atomic Mass

CONCEPTUAL PROBLEM 4.1

Understanding Atomic Number

The element nitrogen (N), shown here in liquid form, has an atomic number of 7. How many protons and electrons are in a neutral nitrogen atom?

Practice Problems

1. Complete the table.

Element	Atomic number	Protons	Electrons
K	19	(a)	19
(b)	(c)	(d)	5
S	16	(e)	(f)
V	(g)	23	(h)

2. How many protons and electrons are in each atom?

a. fluorine

b. calcium

c. aluminum

Mass Number

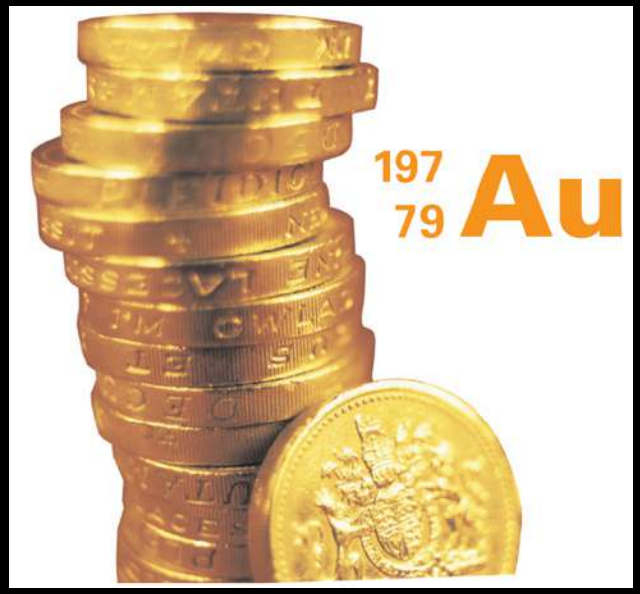
- Most of the mass of an atom is concentrated in the nucleus made of protons and neutrons.
- The total number of protons and neutrons is the mass number.
- The number of neutrons in an atom is the difference between the mass number and the atomic number.

$$\text{Number of neutrons} = \text{mass number} - \text{atomic number}$$

Shorthand

- Atomic information can be written in two forms of shorthand.
- The first form has the symbol of the element with the mass number as a superscript and the atomic number as a subscript. Ex: $^{197}_{79}Au$
- The second form is the element name followed by the mass number.

Ex. gold-197



Periodic Table

- On the periodic table the element symbol is in the middle with the atomic number above and the atomic mass below.

ATOMIC NUMBER →

ELEMENT SYMBOL →

ATOMIC MASS →

Number of Subatomic Particles

Determining the Composition of an Atom

How many protons, electrons, and neutrons are in each atom?

	Atomic number	Mass number
a. Beryllium (Be)	4	9
b. Neon (Ne)	10	20
c. Sodium (Na)	11	23

Practice Problems

1. How many neutrons are in each atom?

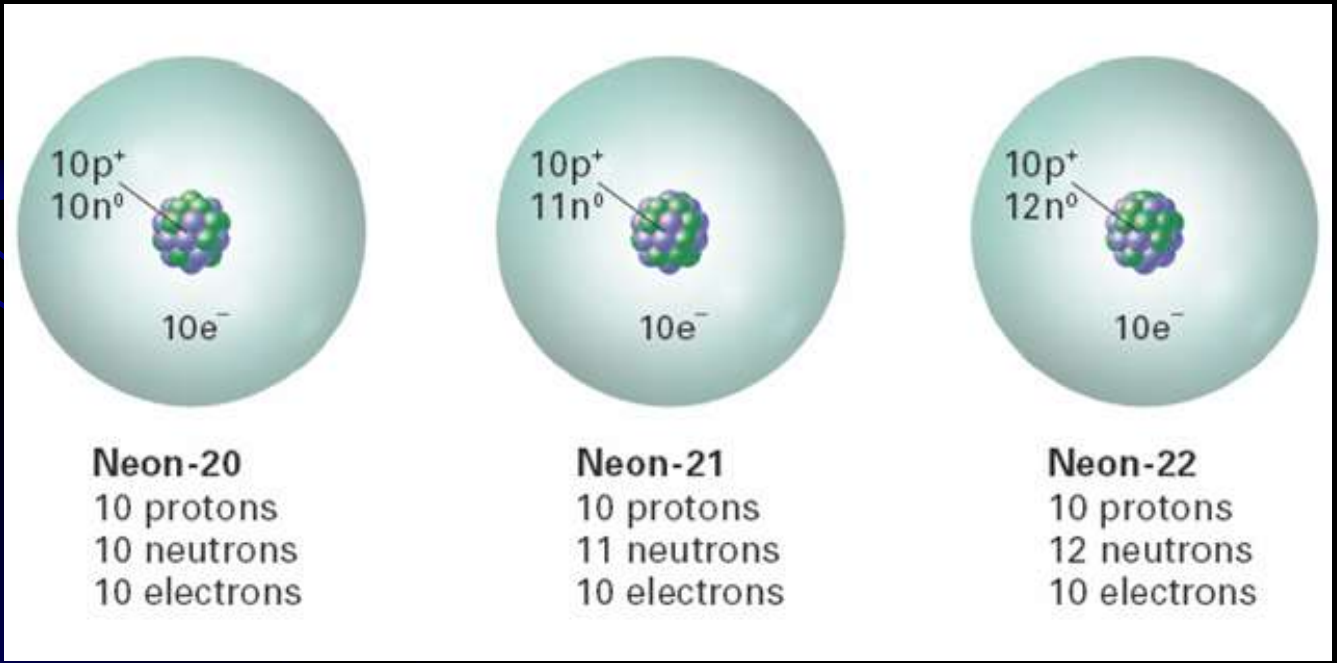
a. $^{16}_{8}O$ **b.** $^{32}_{16}S$ **c.** $^{108}_{47}Ag$

d. $^{80}_{35}Br$ **e.** $^{207}_{82}Pb$

2. Express the composition of each atom in the other type of shorthand form.
   a. carbon-12
   b. fluorine-19
   c. beryllium-9

Isotopes

- Isotopes are atoms that have the same number of protons but different number of neutrons.
- Because isotopes of an element have different numbers of neutrons, they also have different mass numbers.



Practice Problems

1. Three isotopes of oxygen are oxygen-16, oxygen-17, and oxygen-18. Write the symbol for each, including the atomic number and mass number.

2. Three isotopes of chromium are chromium-50, chromium-52, and chromium-53. How many neutrons are in each isotope?

Atomic Mass

- An atomic mass unit (amu) is defined as one twelfth of a carbon-12 atom.
- Atomic mass is measured in amus.
- In nature, most elements occur as a mixture of two or more isotopes.
- The atomic mass of an element is the weighted average mass of the atoms in a naturally occurring sample of the element.

Atomic Mass

CONCEPTUAL PROBLEM 4.3

Using Atomic Mass to Determine the Relative Abundance of Isotopes

The atomic mass of copper is 63.546 amu. Which of copper's two isotopes is more abundant: copper-63 or copper-65?

Practice Problems

1. Boron has two isotopes: boron-10 and boron-11. Which is more abundant, given that the atomic mass of boron is 10.81 amu?
2. There are three isotopes or silicon; they have mass numbers of 28, 29, and 30. The atomic mass of silicon is 28.086 amu. Comment on the relative abundance of these three isotopes.

Atomic Mass

- To calculate the atomic mass of an element, multiply the mass of each isotope by its natural abundance, expressed as a decimal, and then add the products.

For example, carbon has two stable isotopes:

- Carbon-12 with a mass of 12.000 amu, which has a natural abundance of 98.89%, and
- Carbon-13 with a mass of 13.003 amu, which has a natural abundance of 1.11%.

$$\begin{aligned}\text{Atomic mass of carbon} &= (12.000\ \text{amu} \times 0.9889) + (13.003\ \text{amu} \times 0.0111) \\ &= 12.011\ \text{amu}\end{aligned}$$

Atomic Mass

Calculating Atomic Mass

Element X has two natural isotopes. The isotope with a mass of 10.012 amu (^{10}X) has a relative abundance of 19.91%. The isotope with a mass of 11.009 amu (^{11}X) has a relative abundance of 80.09%. Calculate the atomic mass of this element.

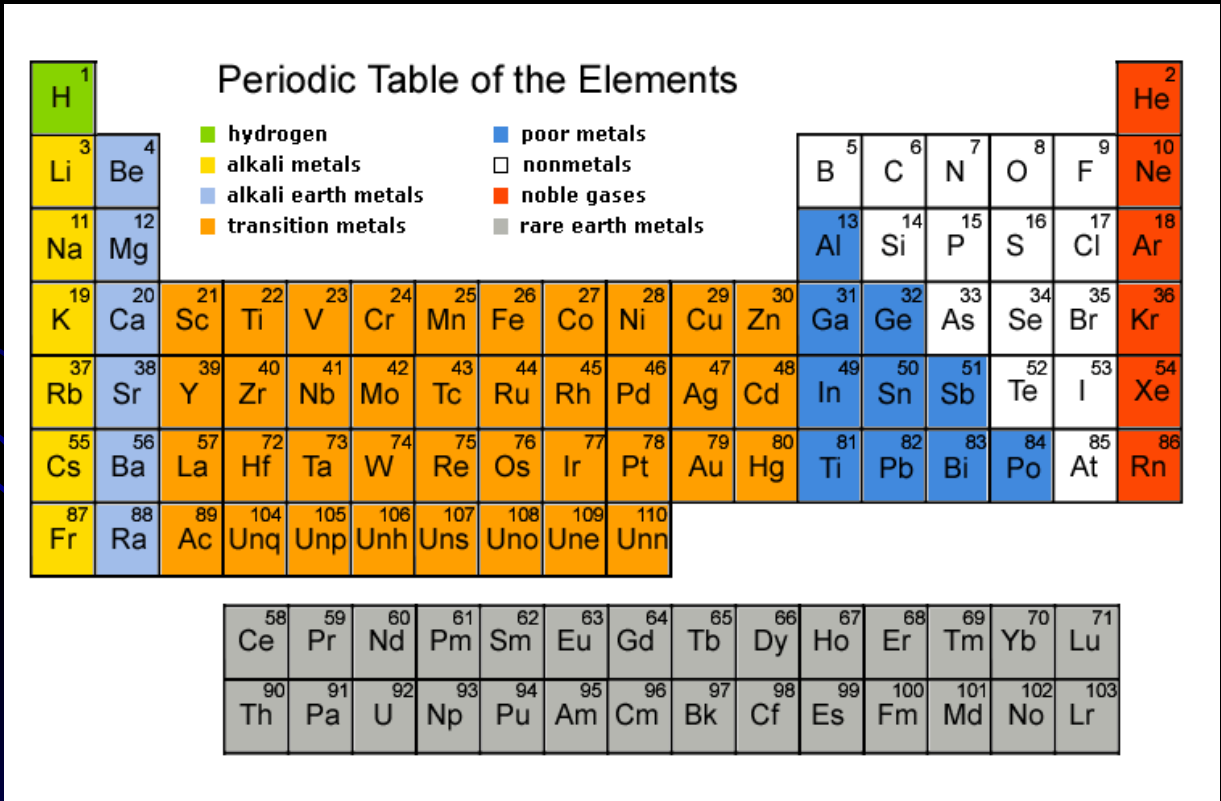
10.012 amu x 0.1991 = 1.993 amu
11.009 amu x 0.8009 = + 8.817 amu
10.810 amu

Practice Problems

1. The element copper has naturally occurring isotopes with mass numbers of 63 and 65. The relative abundance and atomic masses are 69.2% for mass = 62.93 amu, and 30.8% for mass = 64.93 amu. Calculate the average atomic mass of copper.
2. Calculate the atomic mass of bromine. The two isotopes of bromine have atomic masses and relative abundance of 78.92 amu (50.69%) and 80.92 amu (49.31%).

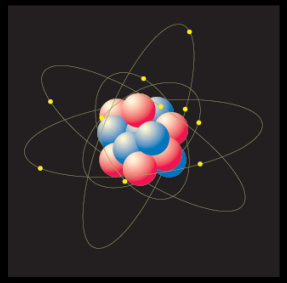
The Periodic Table

- The periodic table is an arrangement of elements in which the elements are separated based on a set of repeating properties.



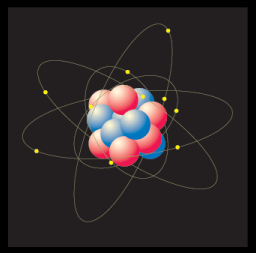
The Periodic Table

- Notice that the elements are listed in order of increasing atomic number.
- Each horizontal row of the periodic table is called a period.
- Each vertical column of the periodic table is called a group.
- Elements within a group have similar physical and chemical properties.



4.3 Section Assessment

1. What distinguishes the atoms of one element from the atoms of another?
2. What equation tells you how to calculate the number of neutrons in an atom?
3. How do the isotopes of a given element differ from one another?
4. What does the number represent in the isotope platinum-194? Write the symbol for this atom using the other shorthand.



4.3 Section Assessment

5. The atomic masses of elements are generally not whole numbers. Explain why.
6. List the number of protons, neutrons, and electrons in each pair of isotopes.
   a. $^{6}_{3}Li$, $^{7}_{3}Li$
   b. $^{42}_{20}Ca$, $^{44}_{20}Ca$
   c. $^{78}_{34}Se$, $^{80}_{34}Se$
7. Name two elements that have properties similar to those of the element calcium.

THE END