Section 2.4 (Chemistry-First) and 3.4 (Atoms-First) The Structure of the Elements

An Introduction to Chemistry

By Mark Bishop

Atoms

- The atom is the smallest part of the element that retains the chemical characteristics of the element itself.
- Tiny…about 10^{-10} m
  - If the atoms in your body were 1 in. in diameter, you'd bump your head on the moon.
- Huge number of atoms in even a small sample of an element
  - 1/2 carat diamond has 5×10^{21} atoms…if lined up, would stretch to the sun.

Charge

- Charge is the fundamental characteristic of particles that causes electromagnetic forces.
- Some particles have charge and some do not.
- There are two types of charge, positive and negative.
- Particles with opposite charge attract.
- Particles with like charge repel.

Particles in the Atom

- **Neutron (n)**

  0 charge 1.00867 u* in nucleus

- **Proton (p)**

  +1 charge 1.00728 u in nucleus

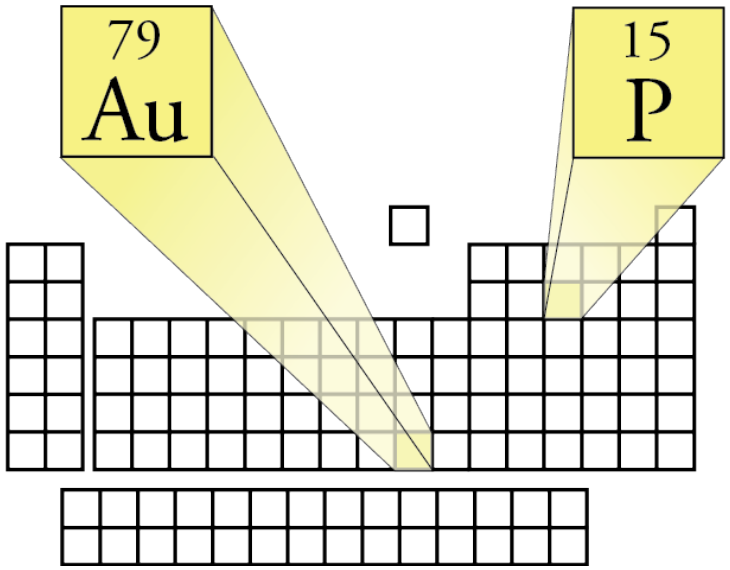
- **Electron (e^-)**

  –1 charge 0.000549 u outside nucleus

*An ***atomic mass*** unit (also called the ***unified mass unit***) is 1/12 the mass of a carbon atom that has 6 protons, 6 neutrons, and 6 electrons. The modern abbreviation for atomic mass unit is u, but amu is commonly used.

Different elements – Different numbers of protons, neutrons, and electrons.

Gold atom	Phosphorus atom
79 protons	15 protons
118 neutrons	16 neutrons
79 electrons	15 electrons

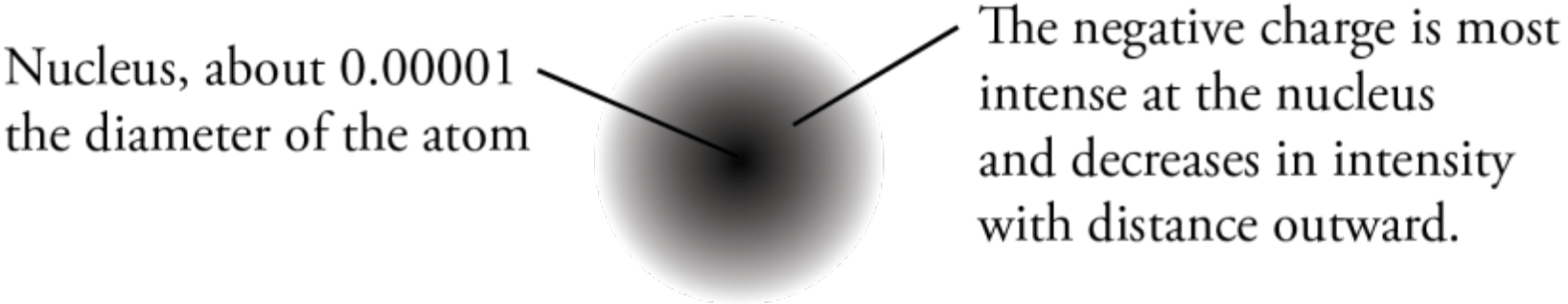


The Nucleus

- The protons and neutrons are in a tiny core of the atom called the ***nucleus***.
- If an atom were the size of the earth, the diameter of the nucleus would be just a little longer than the length of a football field.
- If the nuclei of the atoms in your body were about an inch in diameter, you'd have to stand on the dark side of the earth to avoid burning your hair in the sun.

Structure of Atoms

- Electrons are strange. This will be described in more detail in a later chapter.
- For now, we will not attempt to describe the nature of the electron itself.
- We can say that it generates a negative charge that is most intense at the nucleus and diminishes in intensity with increasing distance from the nucleus.



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The Electron

"If I seem unusually clear to you, you must have misunderstood what I said."

Alan Greenspan,

Head of the Federal Reserve Board

"It is probably as meaningless to discuss how much room an electron takes up as to discuss how much room a fear, an anxiety, or an uncertainty takes up."

Sir James Hopwood Jeans,
English mathematician, physicist and astronomer (1877-1946)

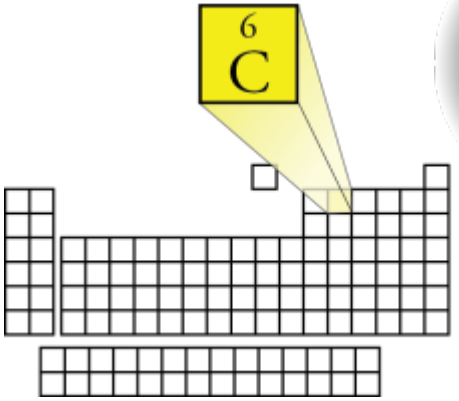
Atomic Number and Mass Number

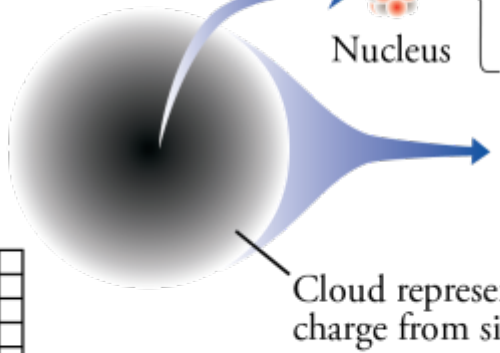
- The number of protons in an atom—which is also the number of electrons in an uncharged atom—is known as the element's ***atomic number***.
  - The atomic number can be found above each of the elements' symbols on the periodic table.
- The sum of the numbers of protons and neutrons in the nucleus of an atom is called the atom's ***mass number***.

Carbon-12 Atom

Carbon atom

6 protons
6 neutrons
(in most carbon atoms)
6 electrons
(in uncharged atom)



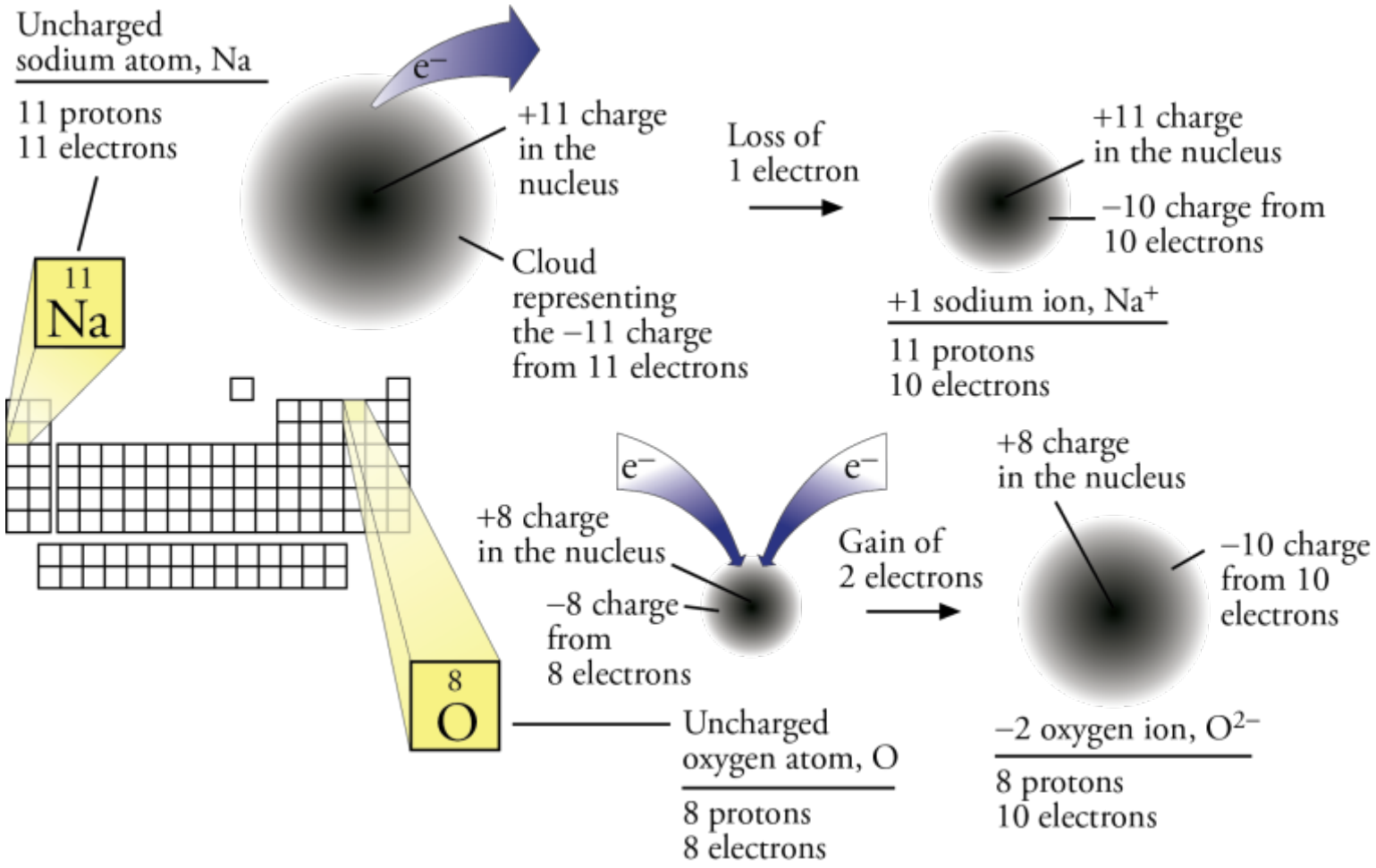


Particle	Charge	Mass
proton	+1	1.00728 u (1.6726×10^{-24} g)
neutron	0	1.00867 u (1.6750×10^{-24} g)
electron	−1	0.000549 u (9.1096×10^{-28} g)

Ions

- ***Ions*** are charged particles due to a loss or gain of electrons.
- When particles lose one or more electrons, leaving them with a positive overall charge, they become ***cations***.
- When particles gain one or more electrons, leaving them with a negative overall charge, they become ***anions***.

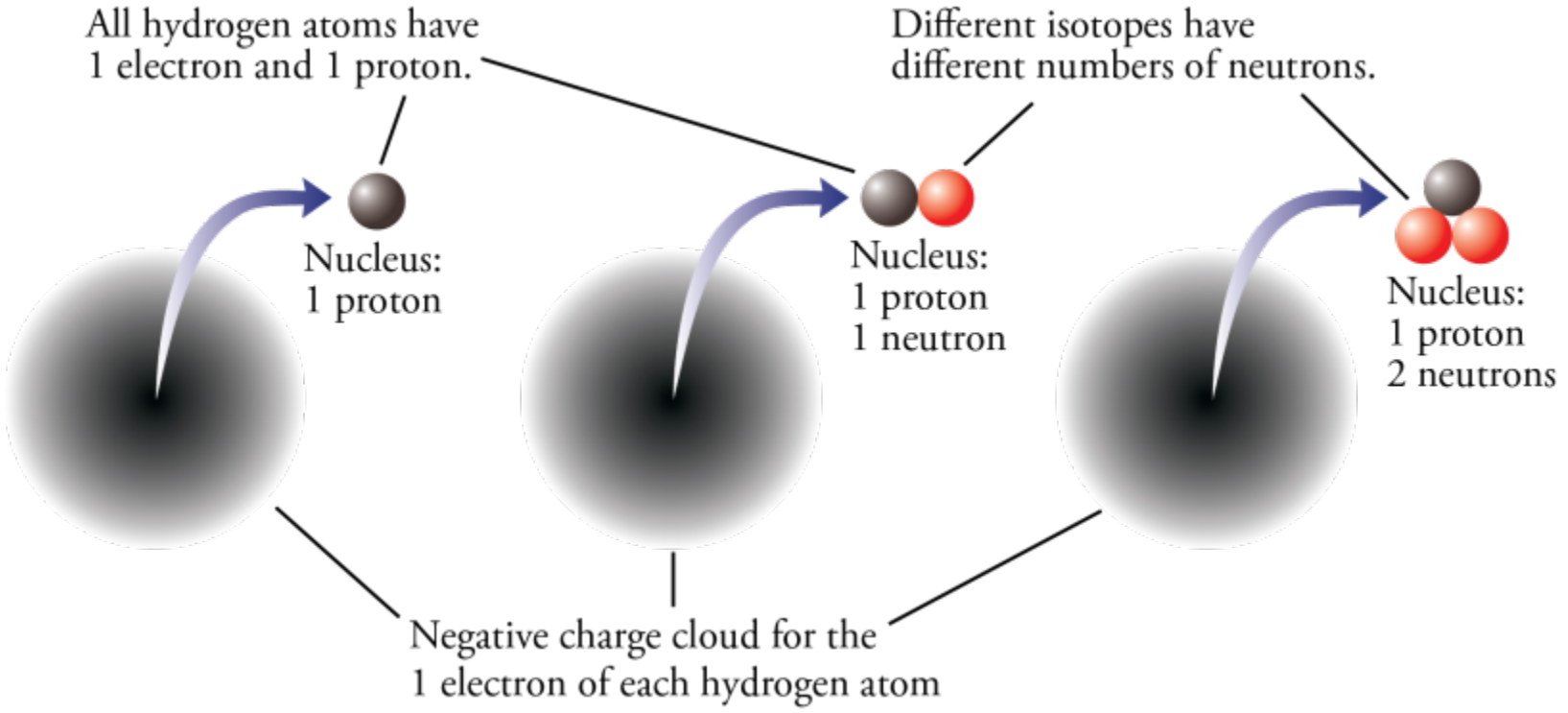
Example Ions



Effect on Chemical Changes

- Electrons
  - Can be gained, lost, or shared…actively participate in chemical changes
  - Affect other atoms through their -1 charge
- Protons
  - Affect other atoms through their +1 charge
  - Determine the number of electrons in uncharged atoms
- Neutrons
  - No charge…no effect outside the atom and no direct effect on the number of electrons.

Isotopes of Hydrogen



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Isotopes

- ***Isotopes*** are atoms with the same atomic number but different mass numbers.
- ***Isotopes*** are atoms with the same number of protons and electrons in the uncharged atom but different numbers of neutrons.
- ***Isotopes*** are atoms of the same element with different masses.

Possible Discovery of Elements 113 and 115

- Dubna, Russia
- Dubna's Joint Institute for Nuclear Research and Lawrence Livermore National Laboratory
- Bombarded a target enriched in americium, ^{243}Am, with calcium atoms, ^{48}Ca.
- From analysis of decay products, they concluded that four atoms of element 115 were created.

Elements 113 and 115

- Created $^{288}115$, which lasted about 100 milliseconds…a very long time for this large an isotope.
- $^{288}115$ emitted an α-particle, ^{4}He, to form $^{284}113$.

Why try to make elements that last such a short time?

- To support theories of the nature of matter.
  - The standard model of the nature of matter predicts that elements with roughly 184 neutrons and 114 protons would be fairly stable. (See next slide.)
  - $^{288}115$, which lasted a relatively long time, has 115 protons and 173 neutrons.

Why try to make elements that last such a short time? (cont.)

- The technology developed to make new elements is also being used for medical purposes.
  - Heavy-ion therapy as a treatment for inoperable cancers
    - Beams of carbon atoms shot at tumor.
    - Heavier particle beam is less likely to scatter.
    - Releases most of energy at end of path so easier to focus.

Tin has ten natural isotopes.