CHEM 115
Basic Atomic Structure and How Simple Ions Form

Lecture 3
Prof. Sevian

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Agenda

- A few announcements
  - Clicker questions begin to count as of this Thursday
  - How to use OWL brief intro at lecture on Thursday this week also
  - Test at the beginning of Lab 2 next week (week of February 9)
    - Test will be in a classroom M-1-608 for the first hour of lab, and then return to the laboratory to do the lab
    - Students who are not enrolled in lab…
  - Pre-labs must be done before you get to lab
  - Students' notes (~24 hours after class) will begin to be posted on the course website
- Basic structure of atoms
  - Size and measuring cross section of the nucleus
  - Models
  - Symbols
- Isotopes and atomic mass as an average over them
- How simple ions form
- Kinds of compounds (if time)
  - Ionic vs. molecular

What is an Atom?

B.C.E. – Democritus: an atom is the smallest particle of matter

1800's – Electrons exist and they have some properties (negative charge, very small mass)

Late 1800's-Mid 1900's – Protons and neutrons exist and they have some properties (protons are +, neutrons are neutral, have nearly same mass which is > electron mass)

What do you already know about atoms?

How is the atom organized?

What is the nucleus?

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How small is the nucleus?

Work in pairs. Take one paper as they come around. Each paper contains traces of 10 pennies in a box. The box is 10. cm × 10. cm square.

Goal: Find the area of a single penny (without using a ruler)

- One person closes eyes and makes 50 marks in the box while the other person counts the marks
- If a mark falls outside the box, do over
- Afterward, count how many marks fell inside the pennies
- Use a proportion to figure out what the area of a single penny is

Proportion

$$\frac{\#\ of\ "hits"}{total\ \#\ of\ marks} = \frac{area\ of\ 10\ pennies}{total\ area\ of\ the\ box}$$

$$\frac{\#\ of\ "hits"}{50} = \frac{area\ of\ 10\ pennies}{100\ \mathrm{cm}^2}$$

What is the area of a single penny?

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Discussion questions

*(From en wiki of same name. Schematic cross-section of the first atomic bomb, which was tested at the Trinity site in the framework of the Manhattan Project, and was nicknamed "the gadget" * made from [http://gawain.membrane.com/hew/Nwfaq/Nf)*

Accuracy = how close the measurement is to the true value

Precision = how many significant digits the measurement can give

- Why is this method called a cross-section measurement?
- What could you do in the procedure to get a more precise measurement?
- Why is this method of measurement more precise than using a ruler?
- Why is a cross section measurement used for measuring the area occupied by the nucleus of an atom?
- What conditions limited our accuracy in measuring the penny?
- What conditions would limit the accuracy in measuring the cross-sectional area of the nucleus in an atom?

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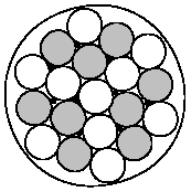
What does an atom look like?

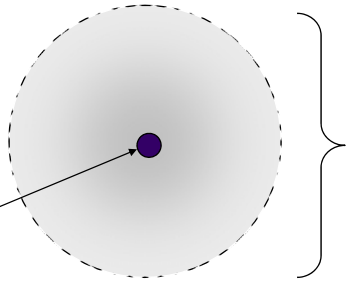
Model 1



Thomson, 1898
has + and - charges

Model 2

Rutherford, 1910
Nucleus (+) is very small,
atom is mostly empty space



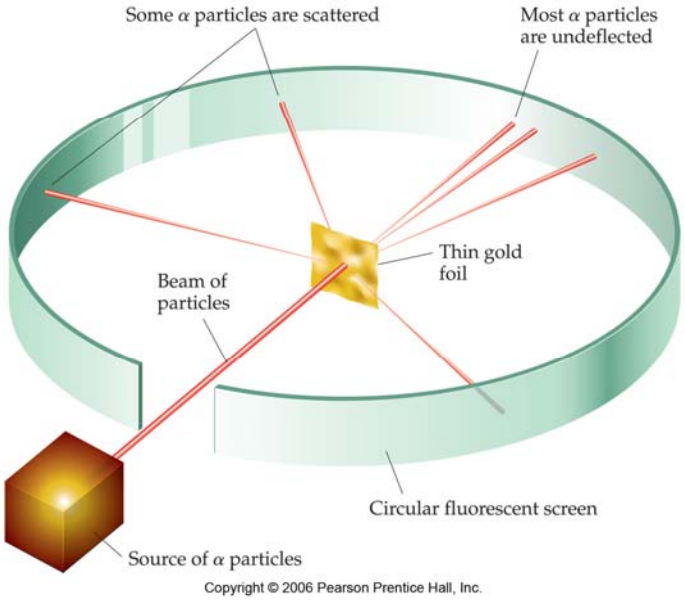
Electrons occupy most of atom's space (though they are tiny) 10^{-8} cm.

Nucleus contains most of mass and all of + charge. Size is 10^{-12} cm.

Note: not drawn to scale!

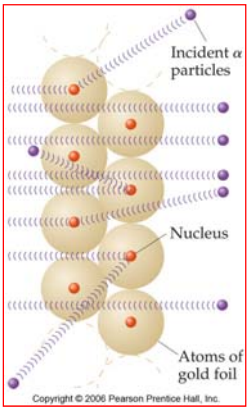
http://micro.magnet.fsu.edu/primer/java/scienceopticsu/powersof10/

More about Rutherford's Experiments



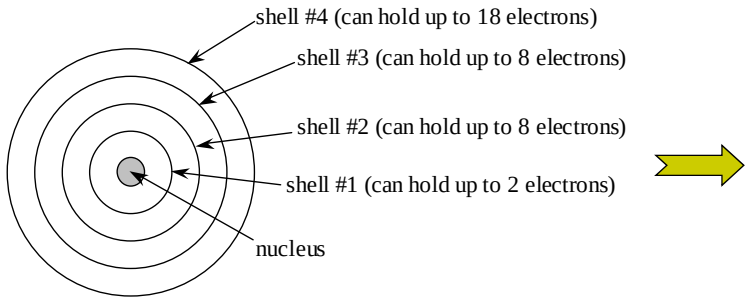
"It was almost as if you fired a 15-inch shell into a piece of tissue paper and it came back and hit you."

– Ernest Rutherford



What does an atom look like?

Model 3



Bohr, 1912

Model explains the hydrogen spectrum (stay tuned until chapter 6…)

Note: not drawn to scale!

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What does an atom look like?

Model 4 Schrodinger, Heisenberg, Bohr, de Broglie and some others, 1912-1924

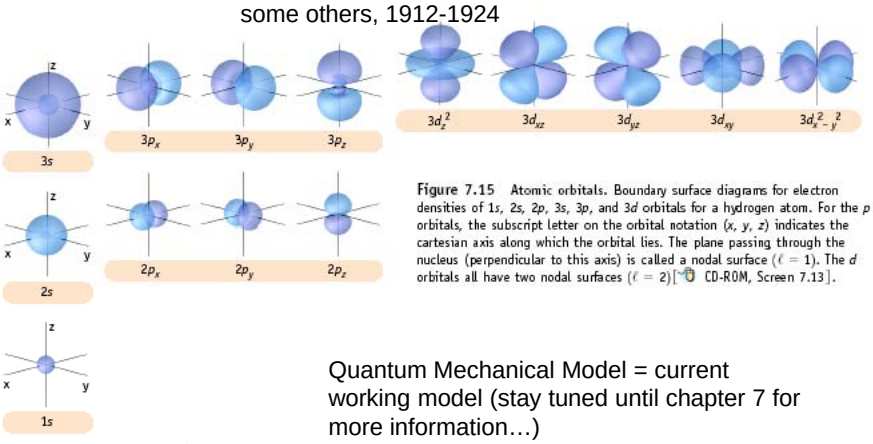

Figure 7.15 Atomic orbitals. Boundary surface diagrams for electron densities of 1*s*, 2*s*, 2*p*, 3*s*, 3*p*, and 3*d* orbitals for a hydrogen atom. For the *p* orbitals, the subscript letter on the orbital notation (*x*, *y*, *z*) indicates the cartesian axis along which the orbital lies. The plane passing through the nucleus (perpendicular to this axis) is called a nodal surface ($\ell = 1$). The *d* orbitals all have two nodal surfaces ($\ell = 2$) [CD-ROM, Screen 7.13].

Quantum Mechanical Model = current working model (stay tuned until chapter 7 for more information…)

What's in an Atom?

	Location	Charge	Mass
Proton	Nucleus	+	~1 a.m.u.
Neutron	Nucleus	0	~1 a.m.u.
Electron	Most of atom's space	-	$1/1836^{th}$ of an a.m.u.

The Actual Numbers

	Charge	Mass
Proton	$+1.602 \times 10^{-19}$ C	1.007276 a.m.u.
Neutron	0	1.008665 a.m.u.
Electron	-1.602×10^{-19} C	0.00054858 a.m.u.

Atomic mass units

1 a.m.u. = 1.661×10^{-24} grams

Important Implications

1. For an atom to be neutral, it must have equal quantities of protons (+) and electrons (-).
2. Different quantities of neutrons do not affect the total charge of an atom. It (apparently) doesn't matter how many neutrons are in an atom, although there are models to explain why certain trends are seen.
3. Most of the mass of an atom is in the nucleus (protons and neutrons). Can estimate an atom's mass by counting protons + neutrons.

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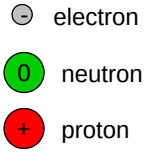
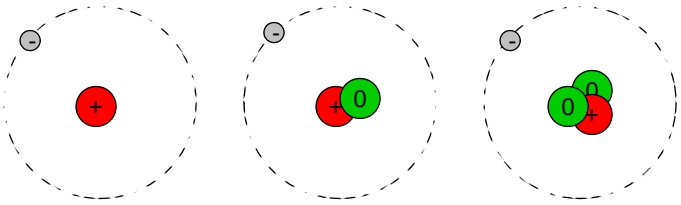


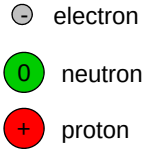
How Can the Nucleus Vary?

Three different isotopes of hydrogen atoms

(Note: Bohr model is incorrect, but very useful)



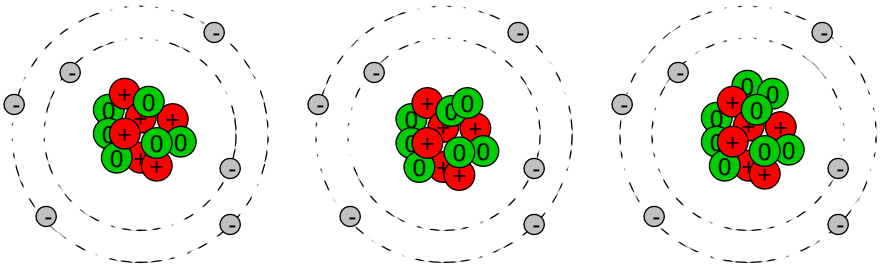
Same	All have 1 electron	All have 1 proton	All neutral
Different	No neutrons	1 neutron	2 neutrons
Symbol	${}_{1}^{1}\mathrm{H}$	${}_{1}^{2}\mathrm{H}$	${}_{1}^{3}\mathrm{H}$



How Can the Nucleus Vary?

Three different isotopes of carbon atoms

(Note: Bohr model is incorrect, but very useful)

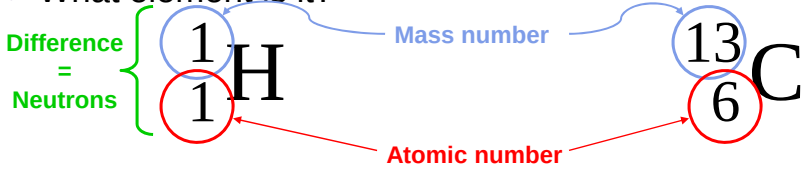


Same	All have 6 electrons	All have 6 protons	All neutral
Different	6 neutrons	7 neutrons	8 neutrons
Symbol	$^{12}_{6}C$	$^{13}_{6}C$	$^{14}_{6}C$

What Information does the Symbol Contain?

Where is each piece of information contained?

- How many protons?
- Why is the quantity of protons called the atomic number?
- How many neutrons?
- How many total particles in the nucleus? Why is this called the mass number?
- What element is it?



Catching up on some vocabulary

How would you define these words now?

- Isotope
- Nucleus
- Neutral
- Mass number
- Atomic number

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Think-Pair-Share

Fill in the missing information				
Symbol	Protons	Neutrons	Mass Number	Electrons (in neutral atom)
$^{11}_{5}B$				
		20	37	
$^{37}_{17}Cl^{-}$				

What we've learned so far

- Over the years, various models of atomic structure have been developed
- All models are incorrect, some models are useful under certain circumstances
- The majority of the space that an atom takes up is the domain of electrons in the atom (the nucleus is very small)
- Nucleus is positive (due to protons), electrons outside/around nucleus are negative
- Symbolic notation for isotopes
  - atomic number bottom left of symbol
  - mass number top left of symbol
  - charge top right of symbol
  - atomic number and symbol are redundant information

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Check your understanding

- How many protons are in an atom of aluminum? _____
  - How did you figure it out?
- How many electrons are in a Br^- ion? _____
  - How did you figure it out?
- Which isotopes are isoelectronic?

  $^{56}_{26}Fe^{2+}$ $^{55}_{26}Fe^{3+}$ $^{51}_{23}V$ $^{55}_{25}Mn^{2+}$

  - How did you figure it out?

What does % mean in chemistry?

$$\% = \frac{\text{part}}{\text{whole}} \times 100$$

Example: How would you figure out what % of students in the room are between the ages of 20-29?

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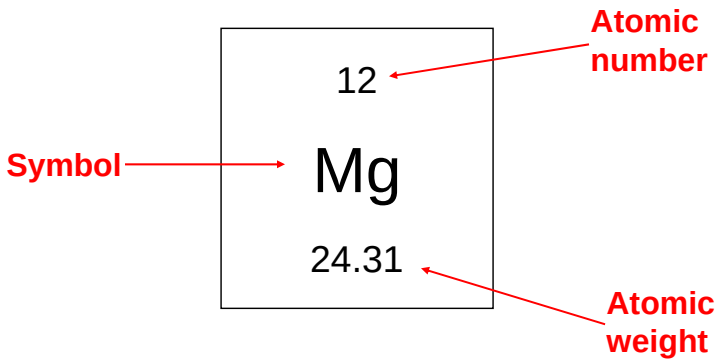
Isotopes and Natural Abundances

The mass of a typical sample of an element is a weighted average of the masses of the isotopes

Isotopes of magnesium	$12\ p^+$ $12\ n^o$	$12\ p^+$ $13\ n^o$	$12\ p^+$ $14\ n^o$	This is the atomic weight on the periodic table
Natural Abundance	78.99%	10.00%	11.01%	
	×	×	×	
Mass of Isotope (amu)	23.9850	24.9858	25.9826	
	18.95 +	2.499 +	2.861	= 24.31

Reading the Periodic Table



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Organization of the Periodic Table

Terminology we will use all year

- Period = row across
- Group = column down
  Several common groups
  - Group 1A: Alkali metals
  - Group 2A: Alkaline earth metals
  - Group 7A: Halogens
  - Group 8A: Noble gases
  - Groups B: Transition metals

- Early chemists (Mendeleev, Moseley) organized the Periodic Table according to properties of elements
- There are reasons why the Periodic Table is organized the way it is (stay tuned until chapters 6 and 7)

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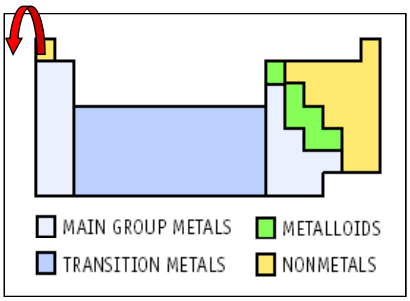
What is an Ion?

1. Hydrogen loses an electron to form H^+



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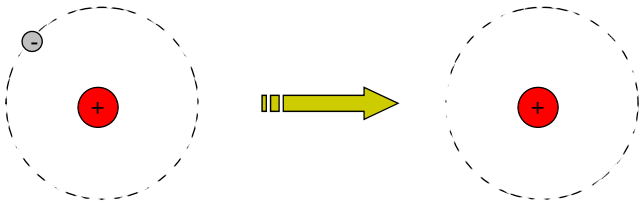

Neutral H atom **H^+ ion**

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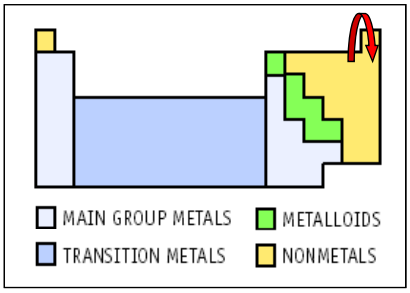
What is an Ion?

2. Nonmetals (except H) gain electrons to form negatively charged ions



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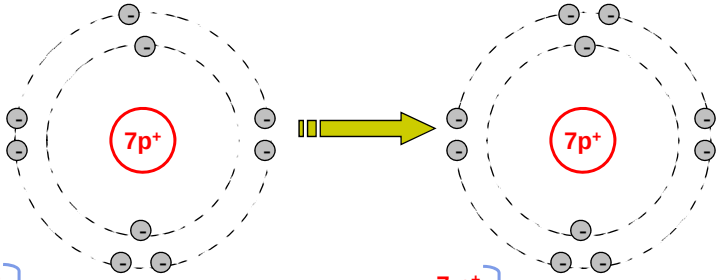

7 p^+
7 e^-
Neutral F atom

7 p^+
8 e^-
F^- ion

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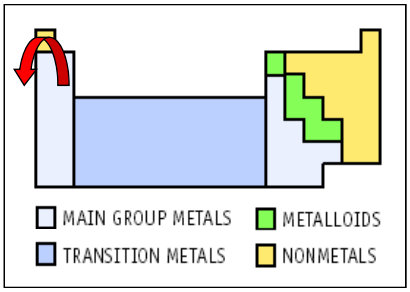
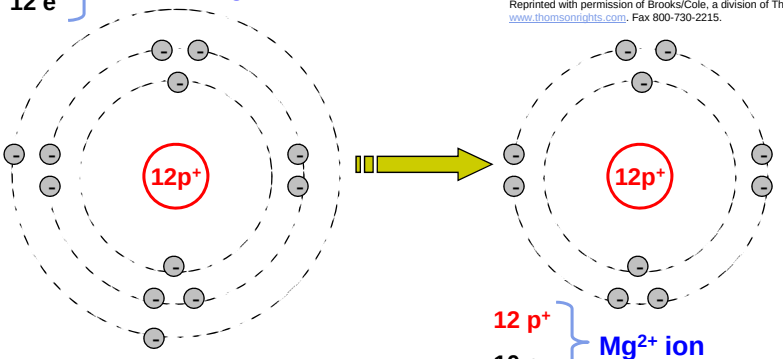
What is an Ion?

3. Metals lose electrons to form positively charged ions



12 p^+
12 e^- } Neutral Mg atom



12 p^+
10 e^- } Mg^{2+} ion

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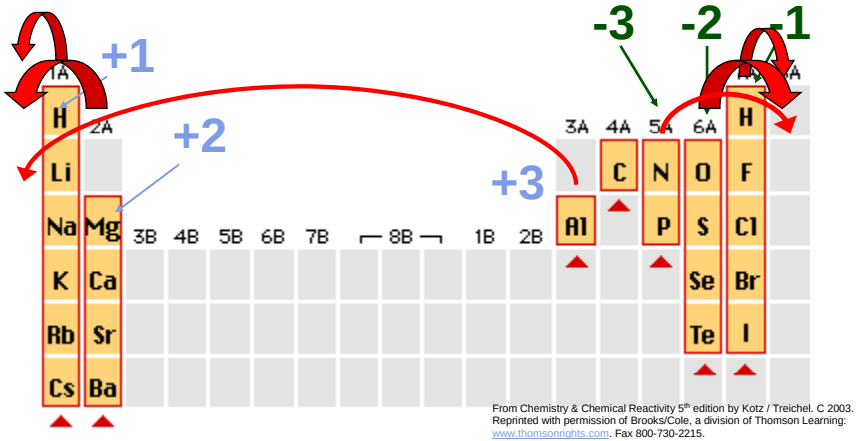
Summary of ion formation: Noble gas envy



Atoms lose or gain electrons to have same number of electrons as nearest Group 8A element

What are the arrows representing in this picture?

What is a "noble gas electron configuration"?

Check your understanding

- When fluorine atoms become ions, what charge are they? What is the symbol of a fluoride ion?

- What is the charge on an aluminum ion? What is its symbol?

Ions and Their Names

When Protons ≠ Electrons

Neutral atom starts with balance of protons & electrons

"noble gas envy" it happens!

Positive Ions

- Metal atoms that lose electrons
- More protons than electrons
- Group A elements always lose electrons to resemble nearest noble gas
- Group B elements can have different quantities of electrons lost
- No name change (but some Group B elements must indicate charge to distinguish)

Negative Ions

- Nonmetal atoms that gain electrons
- Fewer protons than electrons
- Group A elements always gain electrons to resemble nearest noble gas
- Suffix of element name changes to "-ide"

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What we have learned so far

- Atoms are very small
- The nucleus takes up about one-10,000th of the cross-sectional area of an atom, and the electrons occupy the rest of the space
- The nucleus contains the protons and neutrons, which comprise most of the mass of an atom (the mass of an electron is approximately one-2000th the mass of a proton or a neutron
- The identity of an atom (which element it is) is determined by how many protons it has
- The mass number is the quantity of particle in the nucleus
- Because how many neutrons there are does not matter for an atom's identity, different isotopes of elements exist which have different amounts of neutrons - these isotopes have different masses
- An element's "atomic mass" is the average of all naturally existing isotopes
- Atoms gain or lose electrons to form ions - they often do so by the rule of "noble gas envy"
- Non-metals gain electrons (become negative ions), metals lose electrons (become positive ions)

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