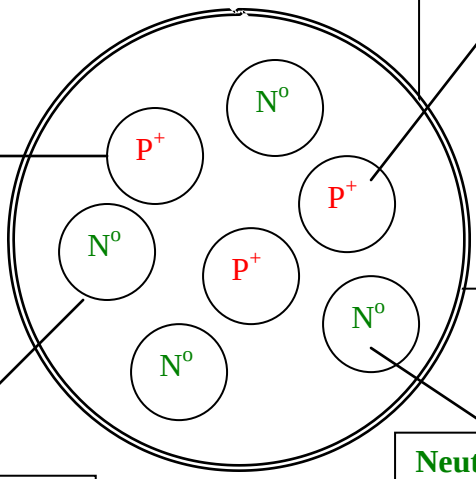
1. A. MODERN MODEL OF THE ATOM: A CLOSER LOOK AT THE NUCLEUS

Since Bohr, the model of the atom has become even more sophisticated. Scientists had to explain why even the thin lines in an emission spectrum could be resolved into more fine lines, and they had to include the discovery of neutrons into their model.

The atom is the smallest unit of an element that still behaves like the entire element, but that's not to say that the smaller parts do not exist. Rutherford showed that every atom's mass is concentrated in its nucleus, and if we zoom into the nucleus, we see a whole new world within it.

The Nucleus of an Atom



Proton:

- each of these particles has a +1 charge.
- The number of protons defines the element. For example only hydrogen has 1 proton. Only helium has two protons etc.
- The number of **protons = atomic number** of the element; the elements are listed in order of atomic number in the periodic table.

A proton is made up of two up quarks (charge of 2/3 each) and one down quark (-1/3 charge), for a sum-charge of +1.

A neutron is made up of two down quarks (charge of -1/3 each) and one up quark (2/3 charge, for a sum-charge of 0.) The mass of the neutron is slightly larger than that of the proton.

Neutron:

- Each of these particles has no charge; neutrons are neutral.

The number of neutrons stabilizes the nucleus. Having too many neutrons or too few in the nucleus cause the atom to breakdown and release radiation. The sum of neutrons and protons make up the **mass number**.

Use the information on the previous page to answer the following:

a) What particle defines an element?

b) What is a mass number?

c) What is the important role of the neutron in the nucleus?

d) Show how the quark recipe for protons in neutrons makes mathematical sense.

More In Class Examples

1. a. What is the atomic number of hydrogen?_____

b. Of phosphorus (P)?_____

c. How many protons are in the nucleus of a hydrogen atom?_____

d. How many protons are in the nucleus of a phosphorus atom?_____

2. Neutral atoms have the same number of electrons as protons. How many electrons are in each sulfur atom(S)._____

3. What is the charge of a neutron?_____

4. What is the mass number of an atom containing 2 neutrons and 1 proton?_____

2. A. MODERN MODEL OF THE ATOM: ISOTOPES AND ISOTOPE NOTATION

Definition: *Isotopes* are different versions of the same element.
Example

- These different versions have the same atomic number but a different mass number.

  What's implied?

- The chemical properties of isotopes are almost identical. The extra weight sometimes slows down the rate at which things react, but it does not affect whether they react.

  Example

- The physical properties of isotopes differ. They also have different nuclear properties. Some have stable nuclei. Others are radioactive and break down, releasing gamma, alpha or beta radiation.

Example

Isotope Notation

$$ {}^{m}_{p}X $$

m = mass number = # of protons + # of neutrons
p = atomic number = number of protons (note that the # of protons go up in order in the periodic table)

In Class Examples (we are assuming that all these isotopes are electrically neutral)

1. Complete the table below:

Name	**Isotope Notation**	**Atomic Number**	**Mass Number**	**Number of Protons**	**Number of Neutrons**	**Number of Electrons**
nitrogen			14			
oxygen					7	
		15	31			18

Example 2 Use isotope notation to represent a...

a. Na atom with 12 neutrons

b. Mg atom with a mass number of 23

c. atom with 7 protons and 8 neutrons.

d. pair of oxygen isotopes, one with mass number 16; the other with #17

2. Give two examples of isotope pairs.

3. Discuss the similarities and differences between ^{12}C and ^{14}C.

2. B. Modern Model of the Atom: Ions

Definition: An *ion* is a charged atom, meaning that it has either too many electrons or too many protons.

Its charge can be calculated from the following:

Charge = # of protons - # of electrons or *Implied*: Electrons = protons - charge

Examples

- ***Ions are chemically different from their neutral counterparts.***

  Example: If someone replaced the calcium ions in your bones with *neutral* calcium, you would be killed!

  Other Examples of How Ions Differ From Neutral Atoms

- To *name* positive ions**,** keep the same name as the one used for the neutral atom.
  Examples Na^{+1} = sodium

- To *name* negative monoatomic ions**,** change the suffix of the neutral name to *ide*
  Examples Cl^{-1} = chlor***ide***, not chlorine
  O^{-2} = ox***ide***, not oxygen

In class examples

Name	Isotope Notation	Atomic Number	Mass Number	Number of Protons	Number of Neutrons	Number of Electrons
Neutral neon			20			
oxide (-2)					7	
		15	31			18
	$^{200}Hg^{+1}$					
	$^{127}I^{-1}$					

Exercises

1. Complete the following table.

Name	Isotope Notation	Atomic Number	Mass Number	Number of Protons	Number of Neutrons	Number of Electrons
Neutral carbon			14			
oxide			15			10
		15	31			18
	$^{9}B^{+3}$					
	$^{79}Se^{-2}$					
	$^{251}Cf^{+2}$					
	$^{19}F^{-1}$					
		19	49			18
		12	25			10
		36	77			36
		1	3			2
			2		1	2
			127		74	54
			40		21	18
			140		81	60
		11			12	10
				12	12	10
		13			14	10
				5	6	2
		17			18	18
fluoride			19			
Calcium ion (+2)			40			

2. Answer the following "who am I?" questions with one of the following terms: *proton, neutron, electron,* or *ion.*

a. I am a positively charged particle found within the nucleus_____
b. I am the least heavy of the subatomic particles_____
c. If magnesium loses electrons, it turns into one of these_____
d. Compared to carbon 13, carbon 14 has one more of these _____
e. If an atom loses one of these, it becomes positively charged_____

3. If it was possible to add 2 protons to a neutral neon atom (mass number: 20), what would you end up with? Show the full isotope notation of the newly created atom and all work needed to arrive at your answer.

4. Show through example how the chemical properties of an ion differ from those of its neutral counterpart.

5. What are isotopes? Give an example of a pair of oxygen isotopes in which only one of the members is radioactive. Use Google or a chemistry textbook or encyclopedia. Can you find five radioactive oxygen isotopes and three that are not?

2. C. Modern Model of the Atom: Shell Diagrams (Bohr-Rutherford Diagrams)

The purpose of these diagrams is to show the nucleus with its correct number of protons and neutrons, but also, more importantly, to give a more detailed view of electrons, one that will help explain the chemical properties of elements.

Rules for the *First Twenty* Elements.

1. When placing electrons in shells, you have to fill, if possible, the innermost shell before beginning to fill the next shell.

2. The maximum number of electrons in the first shell is 2, which is the number of elements in the first horizontal row of the periodic table.

3. The maximum number of electrons in the second shell is 8, which is the number of elements in the second horizontal row of the periodic table.

4. The maximum number of electrons in the third shell is 8, which is the number of elements in the third horizontal row of the periodic table.

Examples

1. Draw a shell diagram for ^{7}Li.

   ANSWER: *Lithium 7* has 3 protons and 4 neutrons, and because it's neutral, it has 3 electrons. We first fill the first shell with 2 electrons (abbreviated 2e): rule #1. The remaining electron has to go into the second shell.

   SHOW BELOW!!!

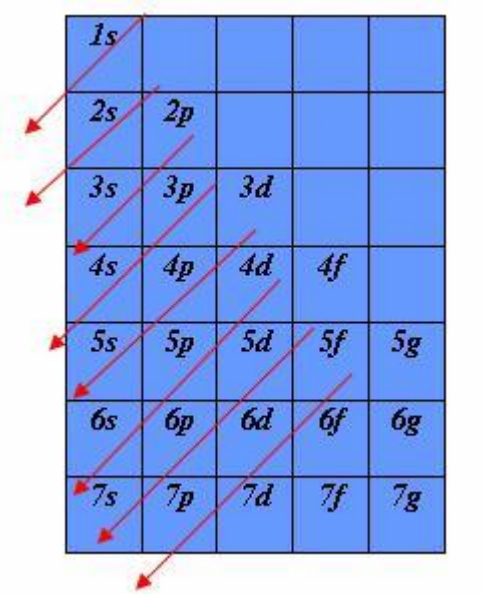
2. Draw a shell diagram for ^{40}Ca.

   ANSWER: *Calcium 40* has 20 protons and 20 neutrons, and because it's neutral, it has 20 electrons.
   We first fill the first shell with 2 electrons (rule #1) The second shell can hold 8 more, so a total of 10 electrons have been placed, so far. (rule #2) The third shell can hold 8 more (for the first 20 elements; rule # 3), so the last two electrons end up in the fourth shell.

   SHOW BELOW!!!

A More Sophisticated Way of Doing Shell Diagrams

In reality not all electrons in a given shell are identical. They have different spin properties and more importantly, past the first shell, they can actually belong to different subshells.The options in the second shell are only ***s*** and ***p***. In the third shell, they can be of the ***s***, ***p*** or ***d*** variety, and in the fourth shell, ***f*** becomes a fourth option.

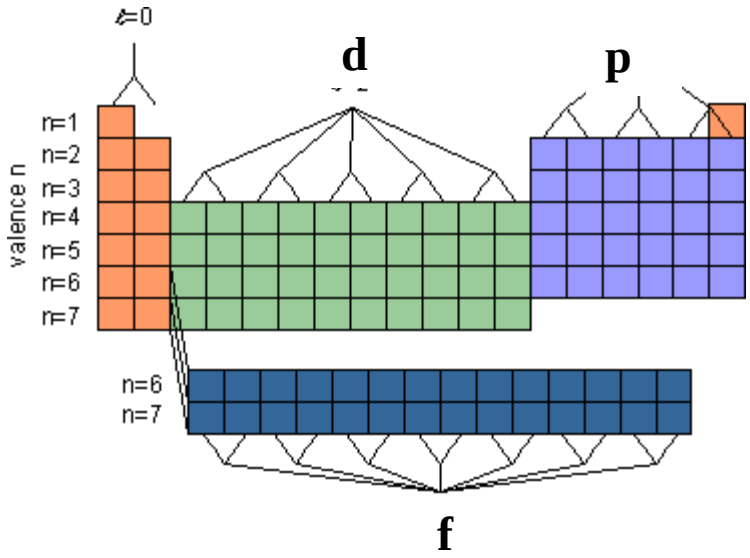


The chart to the left gives the order in which the subshells are filled.

How many electrons do you place in each subshell?

Orbital type	Number of orbitals	Maximum number of electrons
s	**1**	**2**
p	**3**	**6**
d	**5**	**10**
f	**7**	**14**

S



Examples: Write electron configurations for the following

1. **P**

2. **Ca**

3. **Cd**

Exercises

1. Draw a shell diagram for each of the following:

a. ^{23}Na

b. ^{14}N

c. ^{38}Ar

d. ^{35}Cl

e. $^{36}Cl^{-1}$

f. ^{56}Fe

g. $^{16}O^{-2}$

h. ^{3}H

i. $^{2}H^{+1}$

j. ^{1}H

k. $^{9}Be^{+2}$

l. $^{40}Ca^{+2}$

m. $^{39}K^{+1}$

n. ^{20}Ne

Extra

1. Give the electron configuration for the following:
   a. Na
   b. Zn
   c. Ca
   d. Kr
   e. Xe
   f. Lu