The Atom & Periodic Table

Unit 2

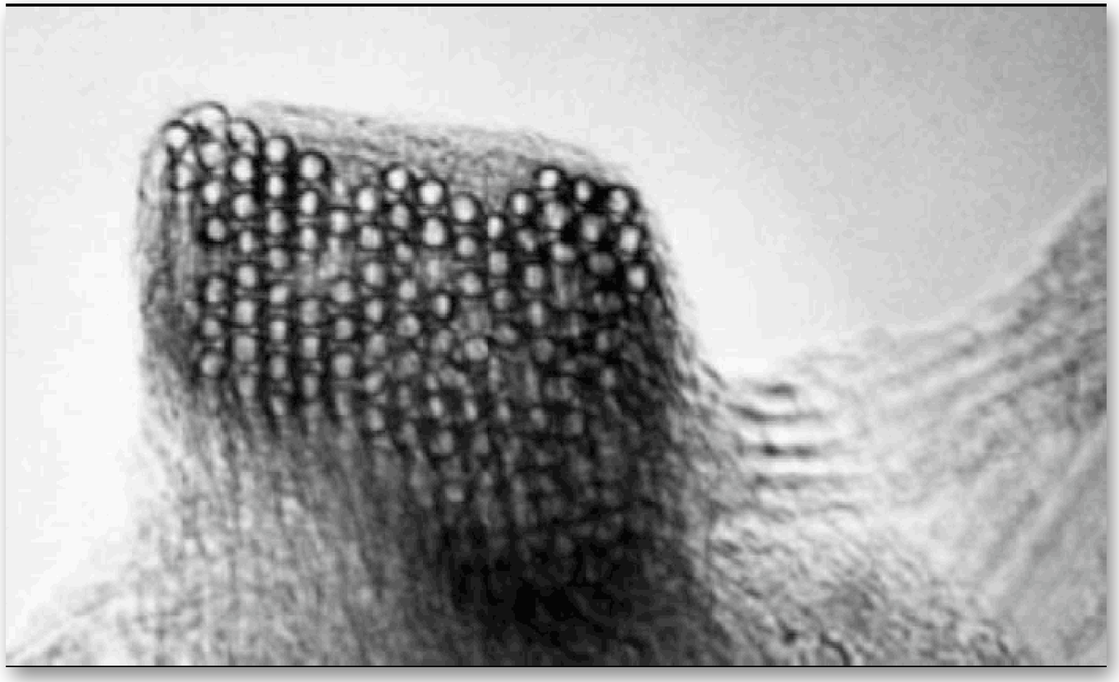
Development of the Atomic Model

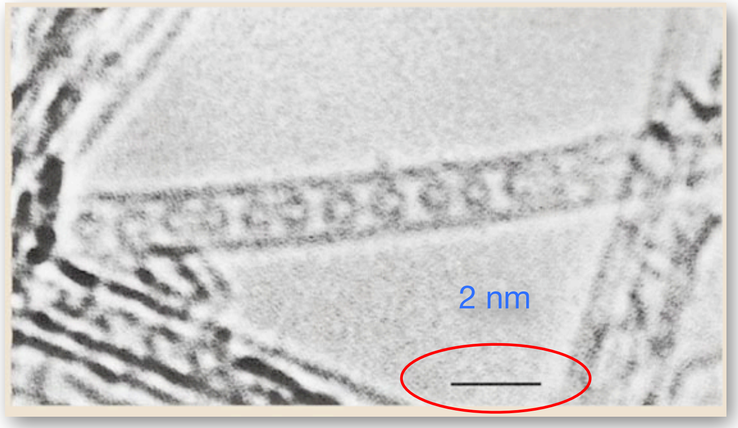
Topic 1

How Small is Small?

How small is an atom?

- Atoms are so small, we have to use special microscopes to see them!

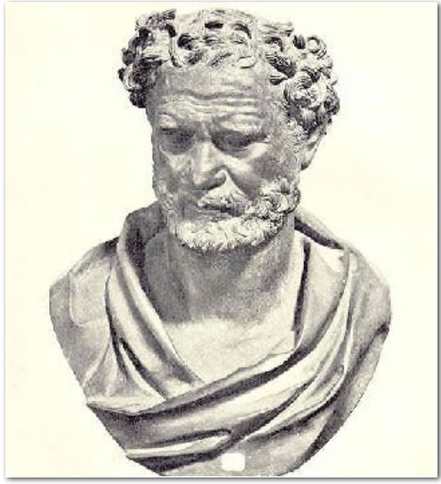




One nanometer equals 1×10^{-9} meters.

Then 62,500,000 of these pictures would fit in one meter!

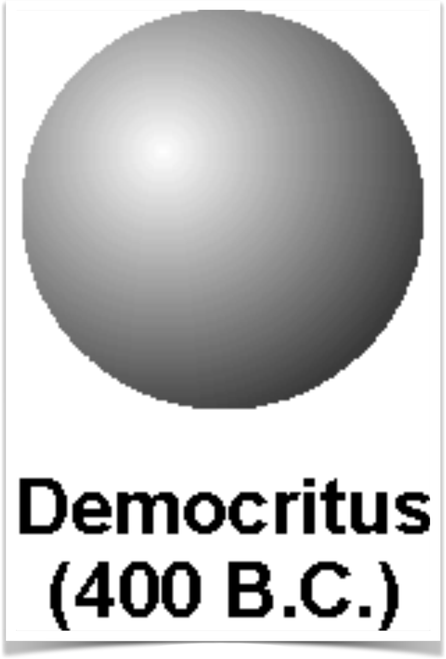
Democritus - First Atomic Theory



Atoms are so small, we have to use special microscopes to see them!

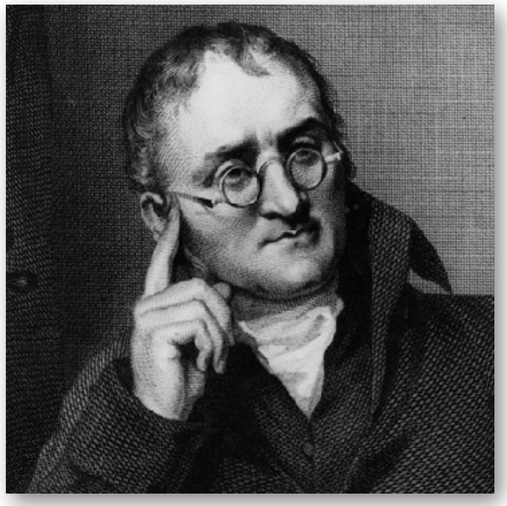
The smallest piece of matter is indivisible (atomos, which means 'not to be cut')

Atoms:
small
hard particles
made of the same material
always moving
capable of joining together



Dalton's Atomic Theory

1808 - Billiard Ball Model



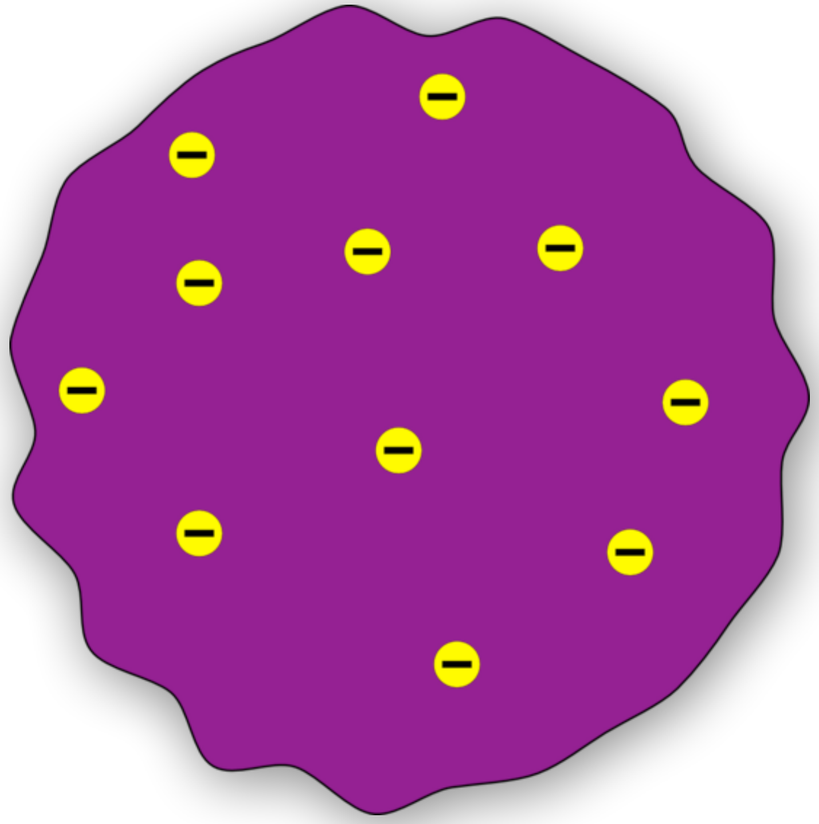
- **John Dalton, an English school teacher, believed that that a few kinds of atoms made up all matter.**

Matter is composed of extremely small particles called atoms, which cannot be subdivided, created, or destroyed.

Thomson's Atomic Theory

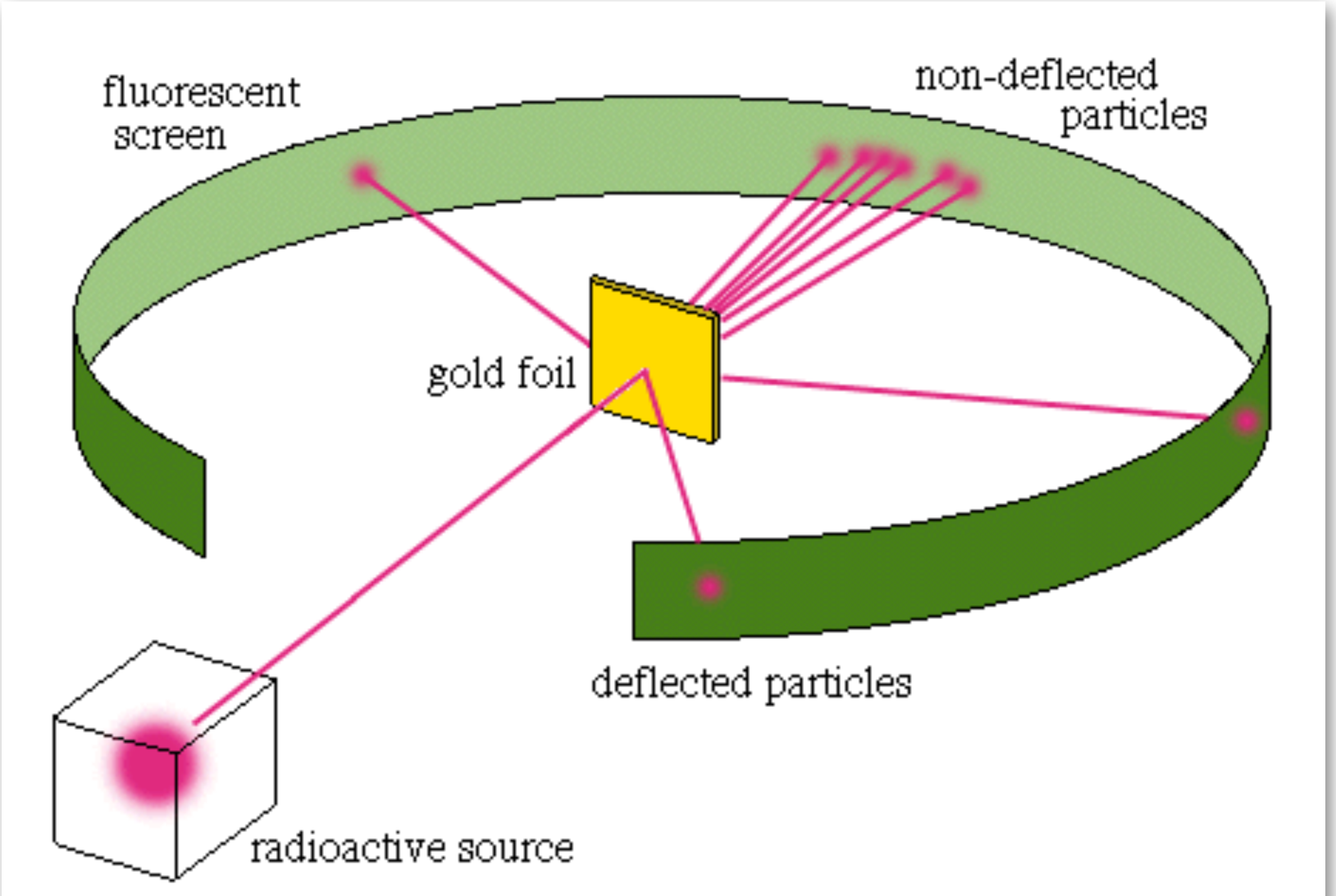
1904 - Plum Pudding Model

- **electrons (plums) evenly distributed throughout a positively charged 'pudding'.**



Rutherford's Atomic Theory

1911 - Nuclear Model (Gold Foil Experiment)



Rutherford's Conclusions

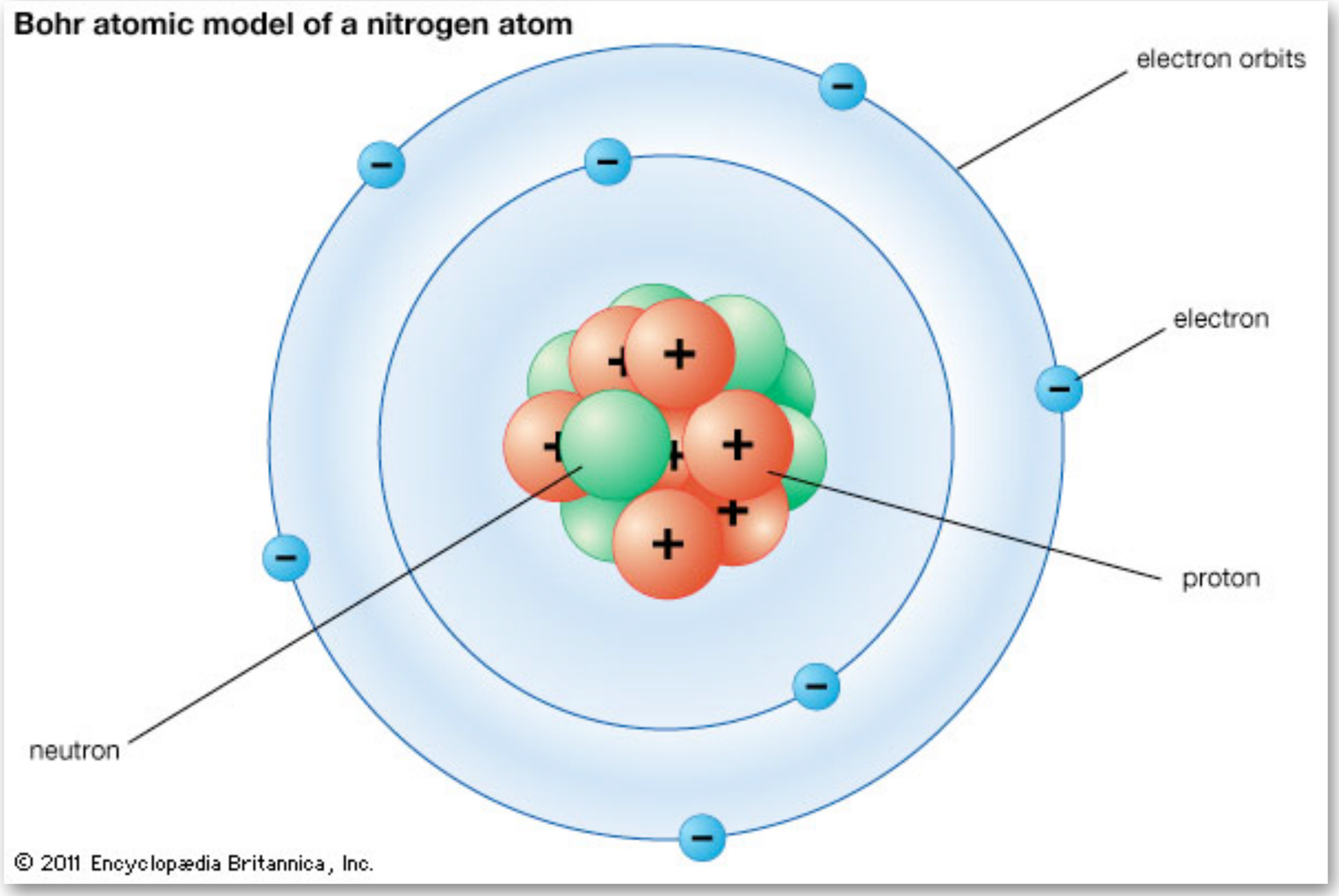
1. Atoms are MOSTLY EMPTY SPACE

2. In the atom is a DENSE, POSITIVELY CHARGED NUCLEUS

Bohr's Atomic Theory

1913 - Planetary Model

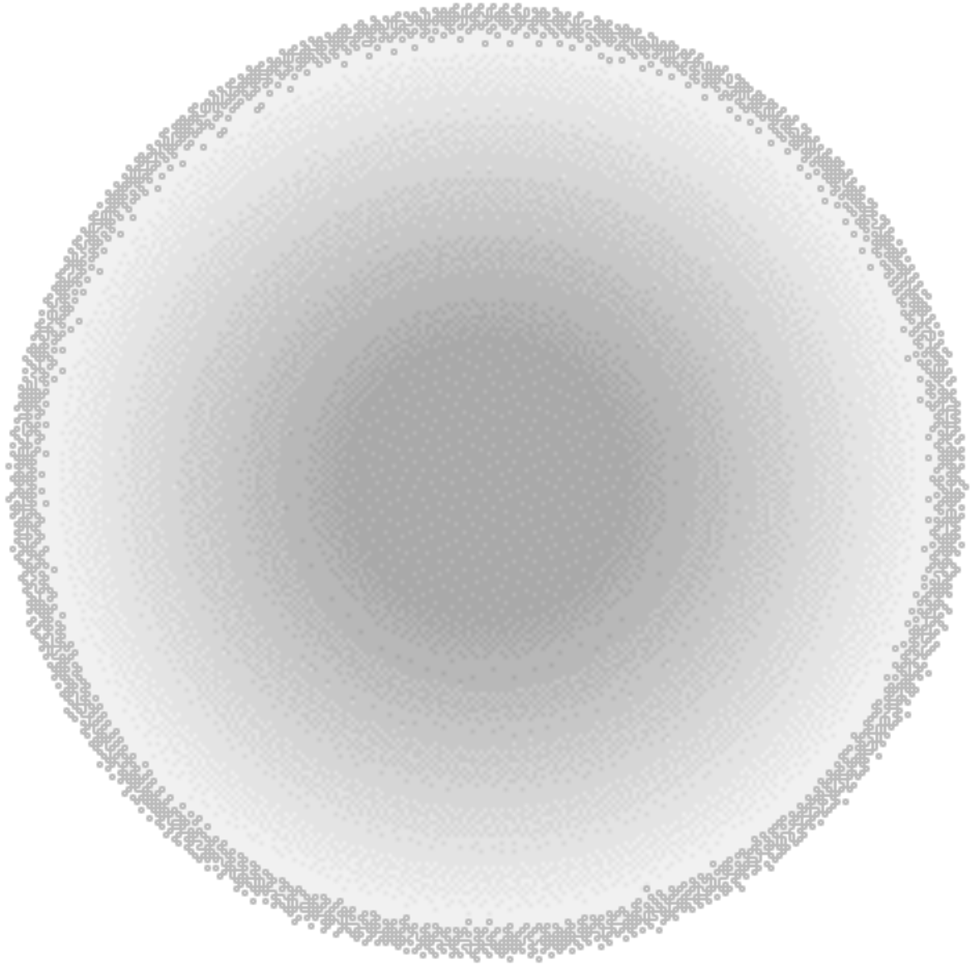
Electrons travel in specific *orbits* around the nucleus.



Quantum Mechanical Model

Modern Model, Cloud Model, Atomic Orbital Model

Electrons travel in diffuse clouds around the nucleus (*orbitals*)



Regents Practice

The modern model of the atom shows that electrons are

1) found in regions called orbitals
2) orbiting the nucleus in fixed paths
3) located in a solid sphere covering the nucleus
4) combined with neutrons in the nucleus

Which conclusion is based on the "gold foil experiment" and the resulting model of the atom?

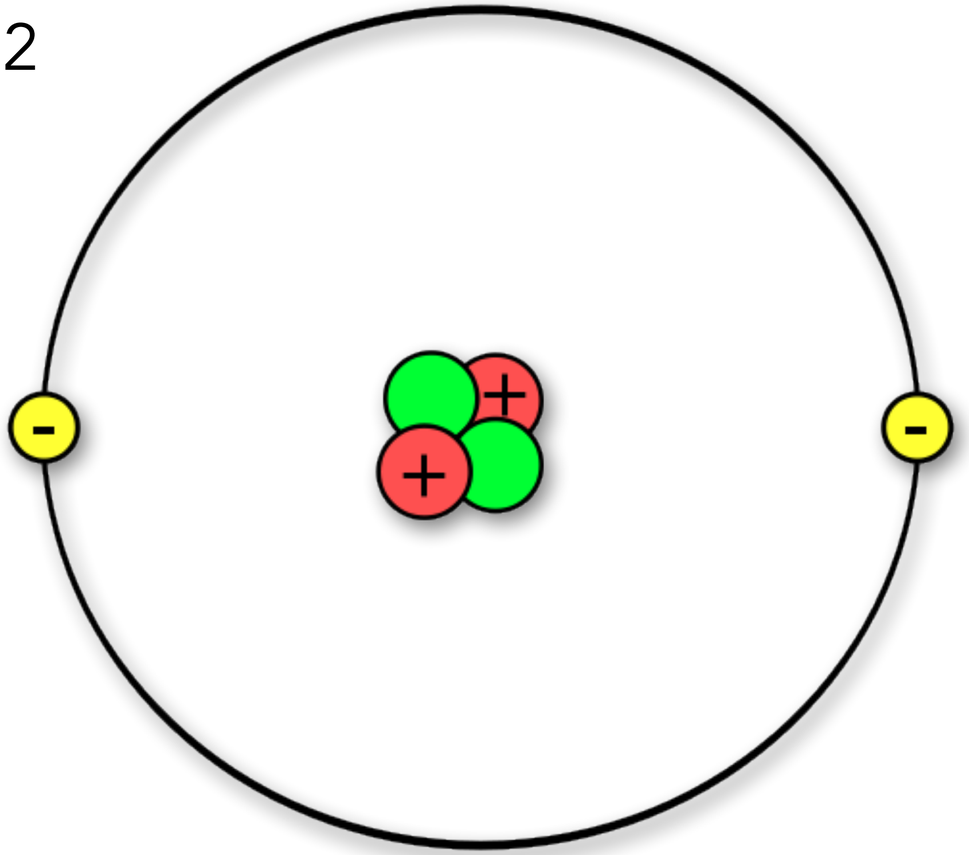
1) An atom has hardly any empty space, and the nucleus has a negative charge.
2) An atom is mainly empty space, and the nucleus has a negative charge.
3) An atom is mainly empty space, and the nucleus has a positive charge.
4) An atom has hardly any empty space, and the nucleus has a positive charge.

In the modern wave-mechanical model of the atom, the orbitals are regions of the most probable location of

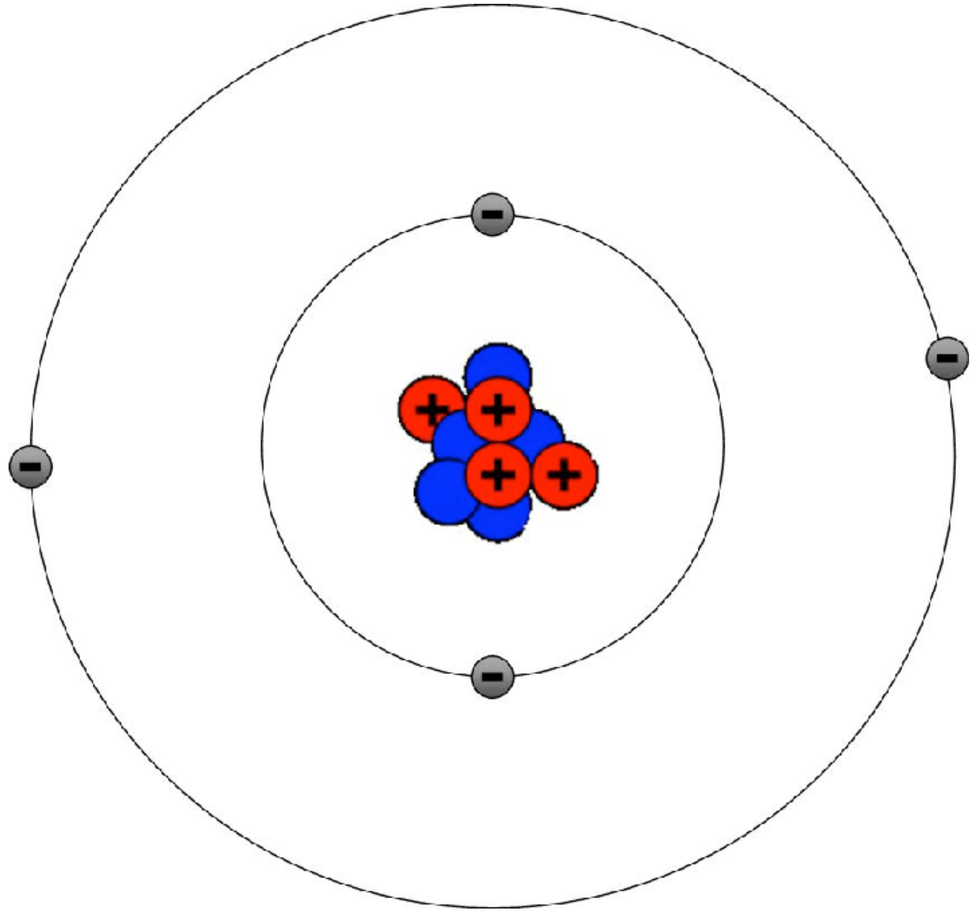
1) electrons 2) protons 3) positrons 4) neutrons

Subatomic Particles & Symbols

Topic 2

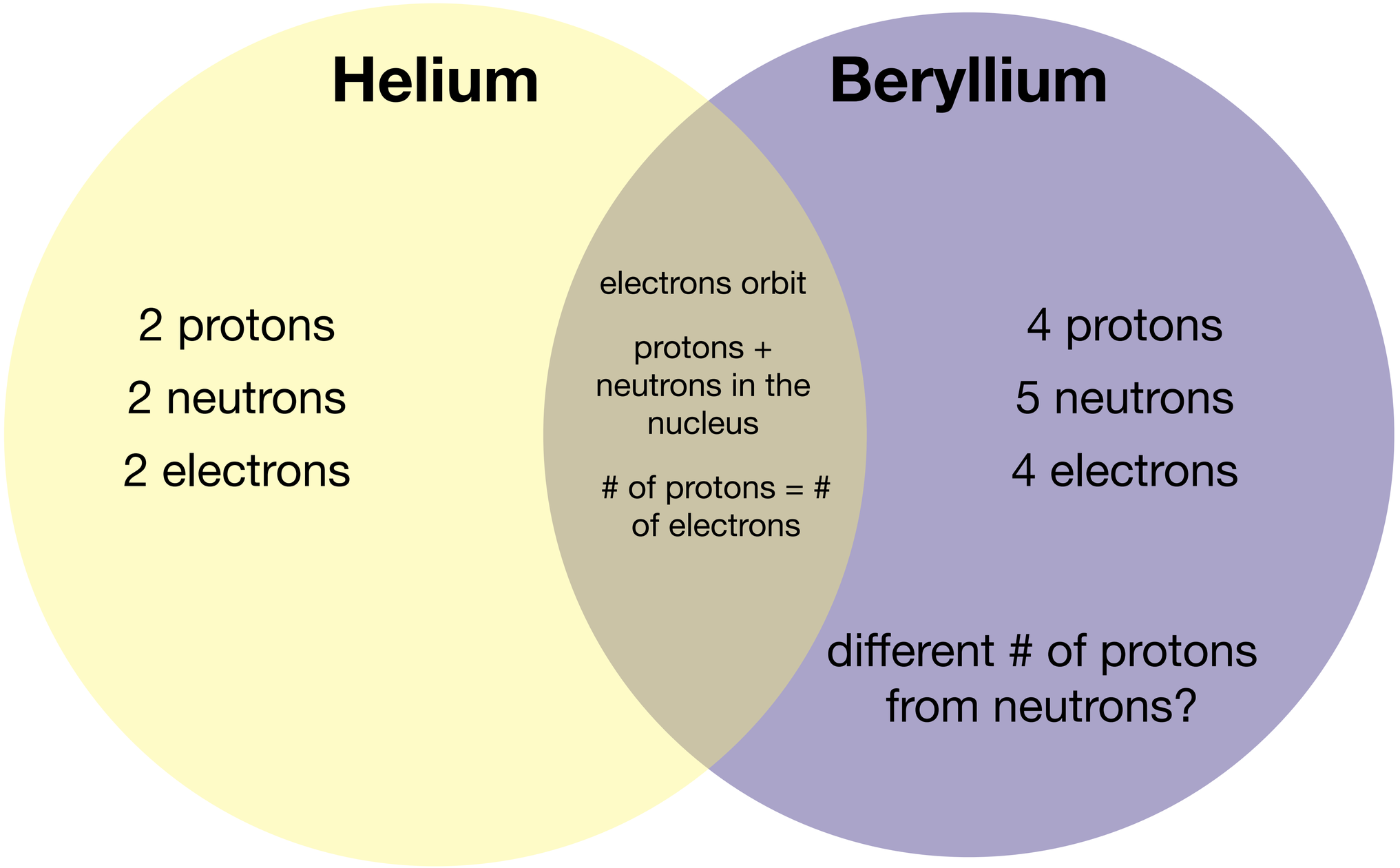


He



Be

1. Compare the two models. List three similarities and three differences.
2. Based on the models, why do you think helium is number 2 (the second element) and beryllium number 4 (the fourth element) on the periodic table?


Helium
Beryllium
2 protons
2 neutrons
2 electrons
electrons orbit
protons + neutrons in the nucleus
# of protons = # of electrons
4 protons
5 neutrons
4 electrons
different # of protons from neutrons?

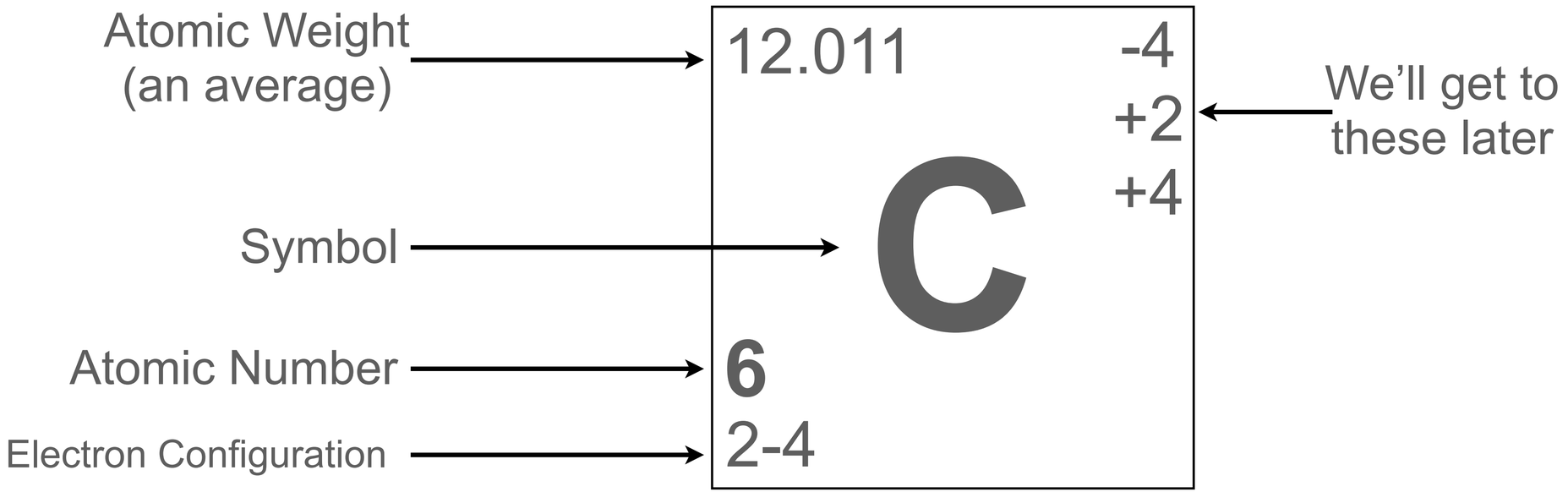
Subatomic Particles & Properties

Particle	Symbol	Location	Electrical Charge	Approximate Relative Mass (u)
Electron	e^-	Outside nucleus	1-	1/1840 (essentially 0)
Proton	p^+	Inside nucleus	1+	1
Neutron	n^0	Inside nucleus	0	1

- **What does the unit ‘u’ mean?**
  atomic mass unit (1/12 of the mass of a carbon-12 atom)

- **ATOMS are electrically** neutral **. This means that the number of** electrons **must equal the number of** protons **.**

Get out your Reference Tables!!



Atomic Number: # of protons in the nucleus

Mass Number: # of protons + neutrons in the nucleus

Regents Practice

Which notation represents an atom of sodium with an atomic number of 11 and a mass number of 24?

1) $^{24}_{11}\mathrm{Na}$ 2) $^{11}_{24}\mathrm{Na}$ 3) $^{35}_{11}\mathrm{Na}$ 4) $^{13}_{11}\mathrm{Na}$

What is the mass number of the nuclear symbol $^{19}_{9}\mathrm{F}$?

1) 28 2) 10 3) 19 4) 9

Which statement is true about a proton and an electron?

1) They have different masses and different charges.
2) They have different masses and the same charges.
3) They have the same masses and different charges.
4) They have the same masses and the same charges.

Regents Practice

The atomic number of an atom is *always* equal to the number of its

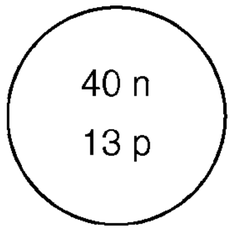
1) protons plus electrons
2) protons plus neutrons
3) neutrons, only
4) protons, only

What is the total number of electrons found in an atom of sulfur?

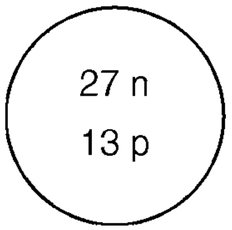
1) 16
2) 6
3) 32
4) 8

Which diagram represents the nucleus of an atom of $^{27}_{13}\mathrm{Al}$?

1)



2)



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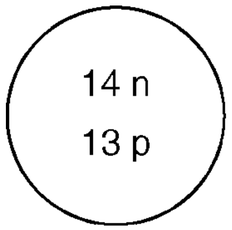

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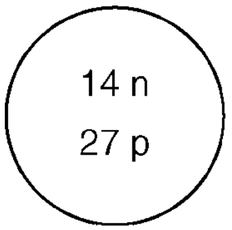
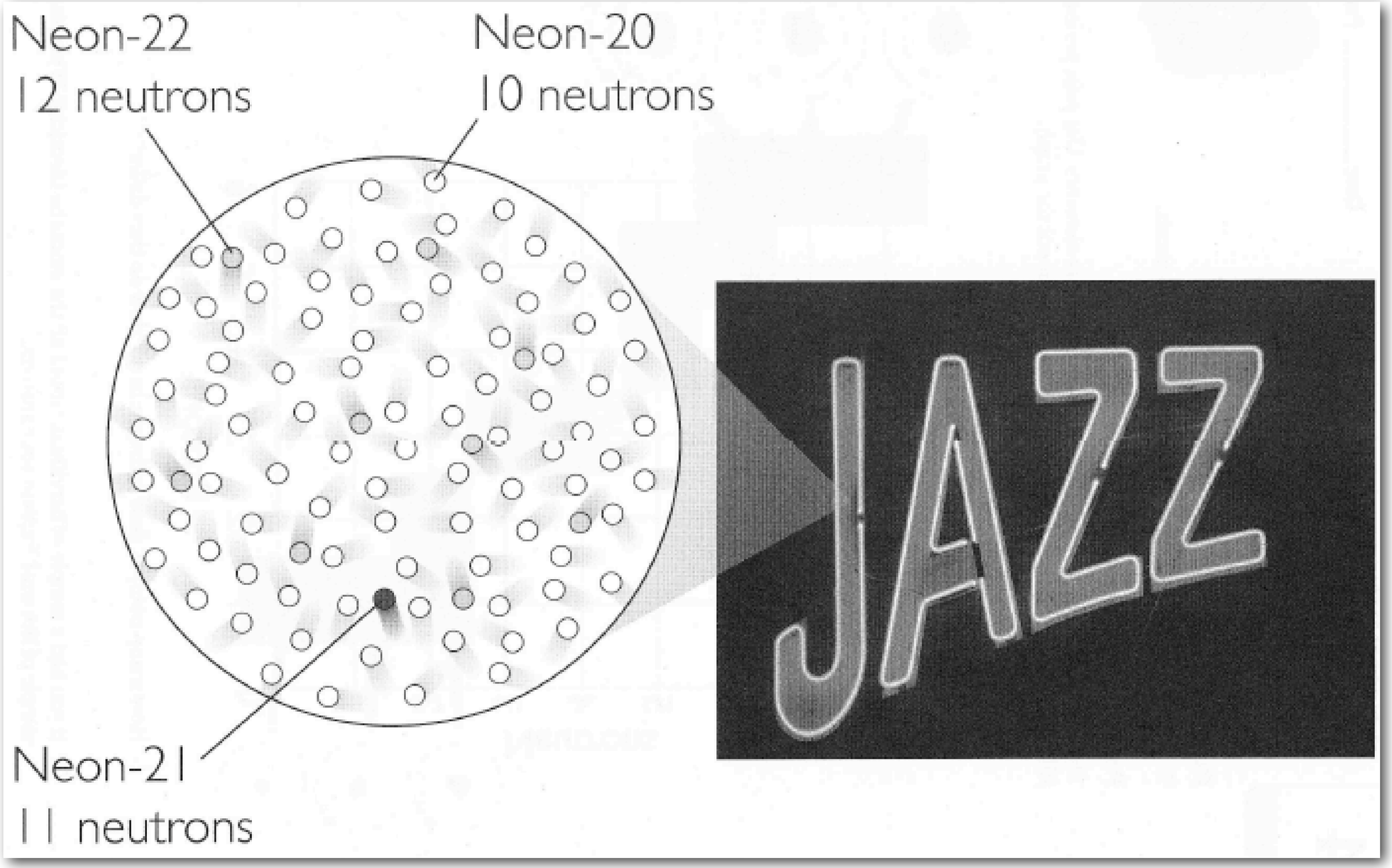


Isotopes

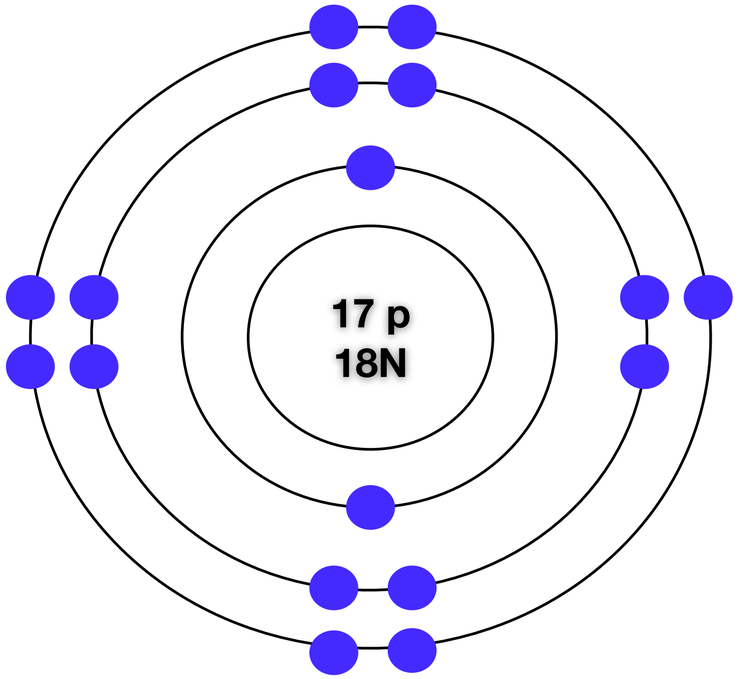
Topic 3



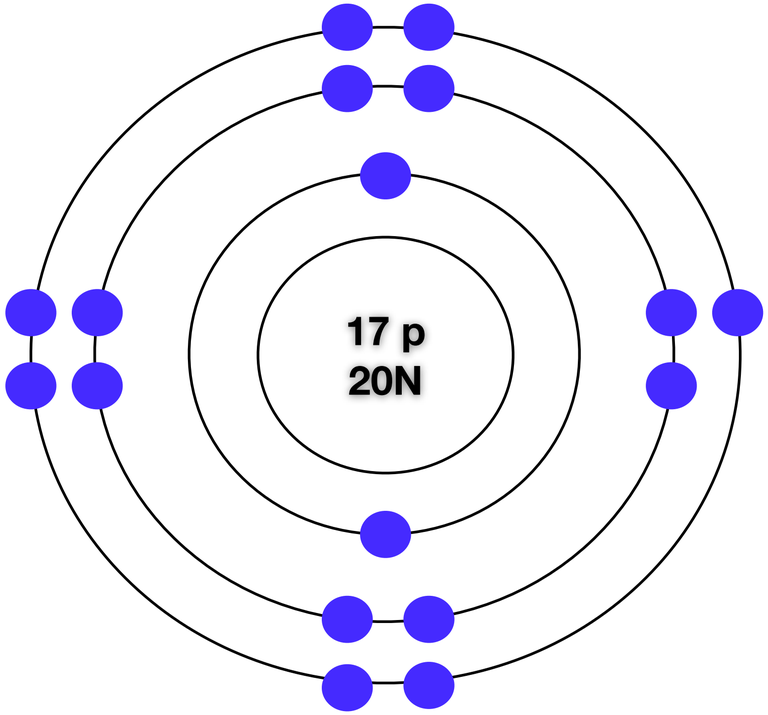
Notation of Atoms

^{35}Cl	Cl-35	Chlorine-35

Chlorine - 35



Chlorine - 37



Isotopes (Iso-, meaning same)

Atoms with same # of protons, different # of neutrons

- What are three things that are the *same* between atoms that are isotopes?
  1. **Same chemical properties**
  2. **Same atomic number**
  3. **Same number of electrons**

- What are two things that are *different*?
  1. **Different number of neutrons**
  2. **Different mass numbers**

Remember!

- **Number of protons defines the element.**

- **Number of neutrons determines the isotope**

Vocabulary

***Atomic Mass*:** given to a number of decimal places. This is because, in most cases, there are a number of naturally occurring isotopes.

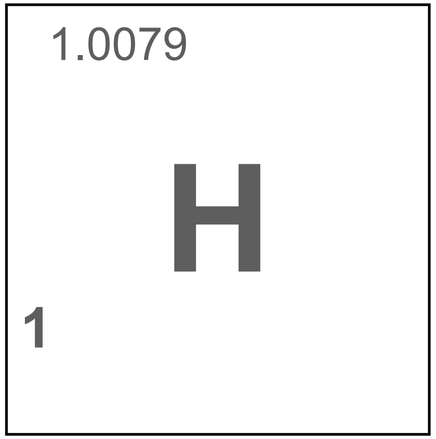
***Mass Number*:** the number of protons and neutrons in the isotope.

Atomic Mass vs. Mass Number

Isotope	Atomic Number	Number of Protons	Number of Neutrons	Number of Electrons	Mass Number (amu)
Hydrogen-1	1	1	0	1	1
Hydrogen-2 (deuterium)	1	1	1	1	2
Hydrogen-3 (tritium)	1	1	2	1	3

Hydrogen has three isotopes. (Atomic mass = 1.0079 amu)

Based on this information, which isotope must be the most abundant?



Example

For example:
A natural sample of C (atomic mass = 12.011 amu) is a mixture of C-12 (98.89%) and C-14 (1.11%).

Carbon's atomic number is 6, has an average atomic mass of 12.011 amu, and carbon's most common isotope has a mass number of 12 amu.

Therefore, the most common type of carbon atom has 6 protons, 6 neutrons and 6 electrons. Another naturally-occurring isotope of carbon is C-14, but it is rare in comparison to the amount of C-12 in nature.

Regents Practice

What is the total number of neutrons in the nucleus of a neutral atom that has 19 electrons and a mass number of 39?

1) 19 2) 20 3) 58 4) 39

What is the mass number of an atom that has six protons, six electrons, and eight neutrons?

1) 6 2) 20 3) 14 4) 12

What is the total number of neutrons in an atom of aluminum-27? **14**

The atomic mass of an element is the weighted average of the masses of

1) all of its radioactive isotopes
2) its two least abundant isotopes
3) all of its naturally occurring isotopes
4) its two most abundant isotopes

Review of Topic 3

- **Isotopes: Same protons, different neutrons**
- **Mass Number: # of protons and neutrons in an isotope**
- **Atomic Mass: Given in decimal form, showing that more than one isotope can be present**

- ***Bohr & Lewis Dot Structures for Electrons in Atoms***

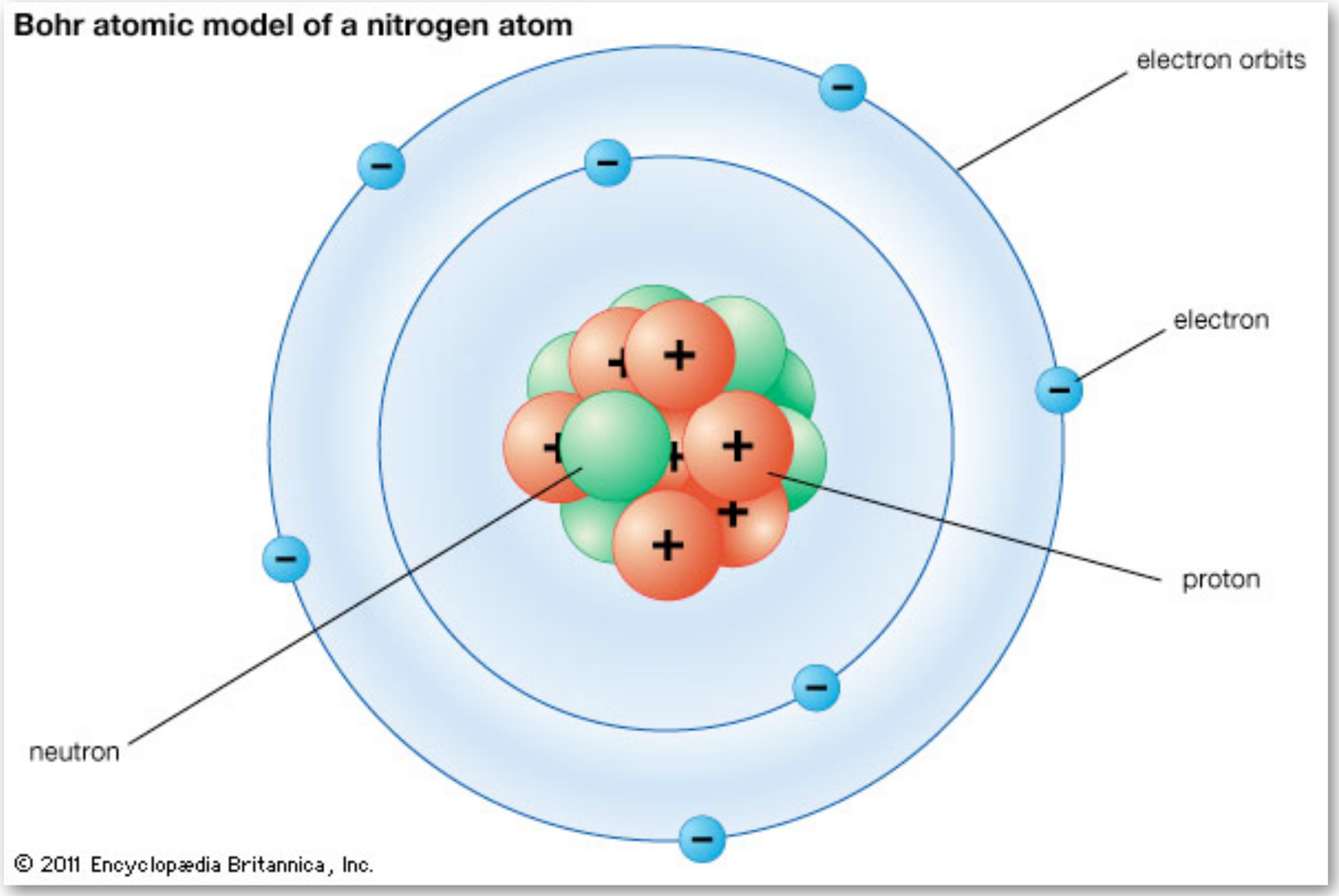
Electrons in Atoms

Topic 4

Describe Bohr's model of the atom. Sketch it!

Bohr - A review

electrons exist in orbits around the nucleus.



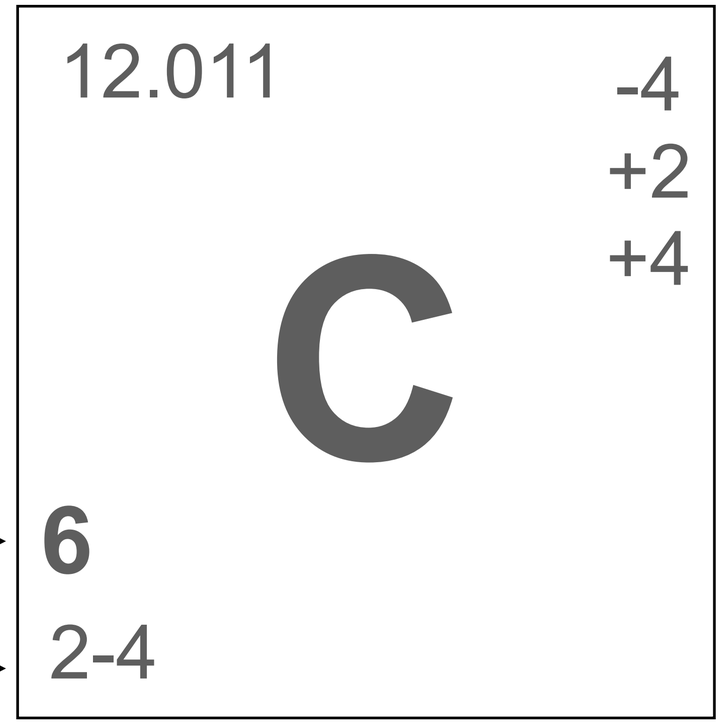
Bohr - Higher Level Information

- Electrons can be only certain distances from the nucleus.
- Each distance corresponds to a certain quantity of energy.
- An electron that is close to the nucleus has less energy than one further away from the nucleus.
- Difference in energy between two levels is a ***quantum of energy***.

Electrons in Atoms

- In an atom, the number of protons (p^+) always equals the number of electrons (e^-)
- ATOMS ARE ELECTRICALLY NEUTRAL (no charge)

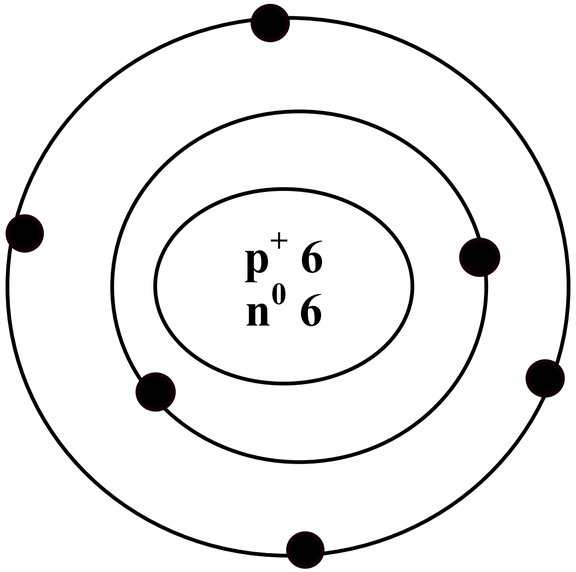
- The closer the orbit is to the nucleus, the *lower* the amount of energy.



Bohr Diagrams

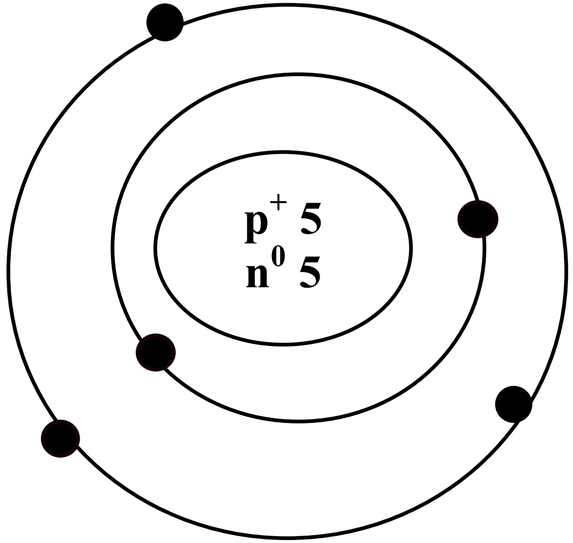
Carbon-12

Electron configuration 2–4
2 e^- in the first orbit
4 e^- in the second orbit



Boron-10

Electron configuration 2–3
2 e^- in the first orbit
3 e^- in the second orbit



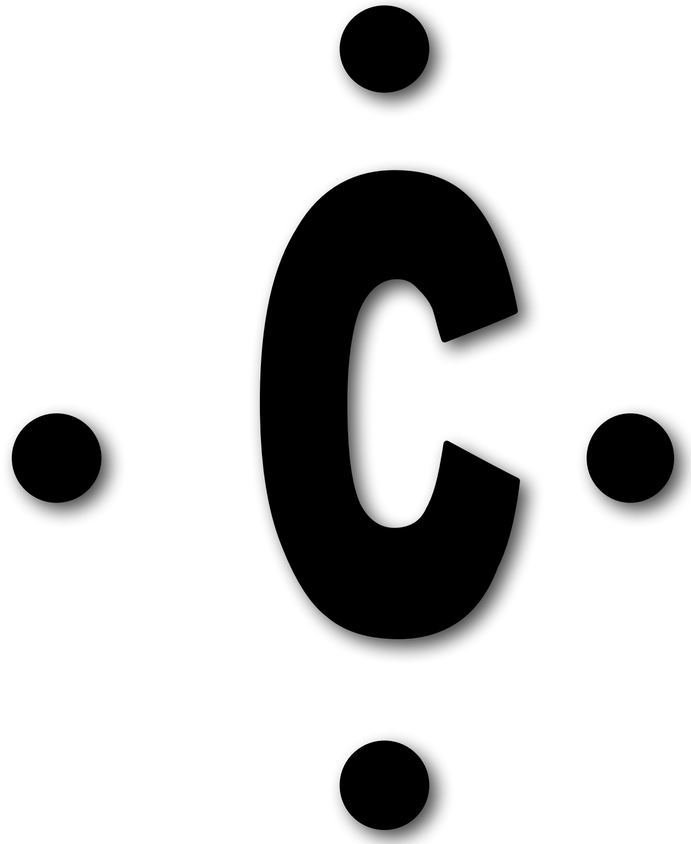
Lewis Dot (electron dot diagrams)

- Represent electrons in the outer most energy level or *valence electrons*.

Example # 1 **Carbon**

Electron configuration 2-4

# of valence electrons 4



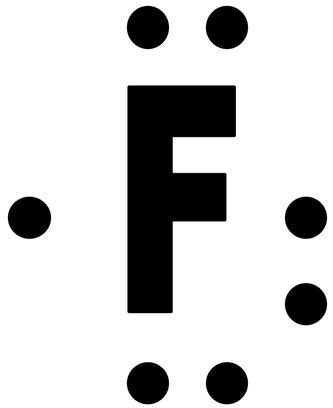
Examples

When more than 4 valence electrons, they are put in pairs

Example # 2 **Fluorine**

Electron configuration 2-7

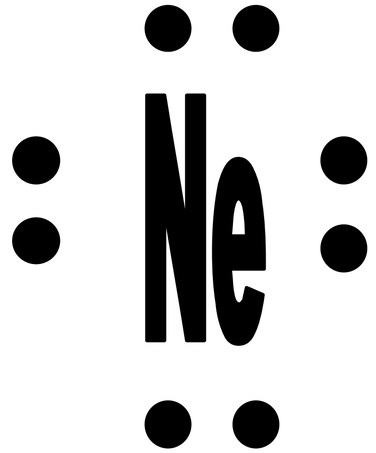
# of valence electrons 7



Example # 3 **Neon**

Electron configuration 2-8

# of valence electrons 8



Further Practice

$$^{25}_{12}Mg$$

$$^{37}_{17}Cl$$

Regents Practice

What is the total number of electrons in the valence shell of an atom of aluminum in the ground state?

1) 8 2) 2 3) 3 4) 10

Compared to an electron in the first electron shell of an atom, an electron in the third shell of the same atom has

1) less energy 2) more mass 3) less mass 4) more energy

Which Lewis electron-dot structure is drawn correctly for the atom it represents?

1) 

2) 

3) 

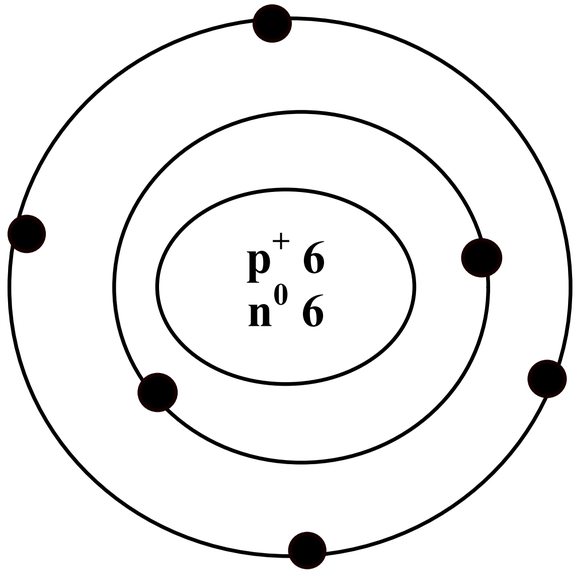
4) 

What is the total number of electrons in the outermost shell of a phosphorus atom in the ground state?

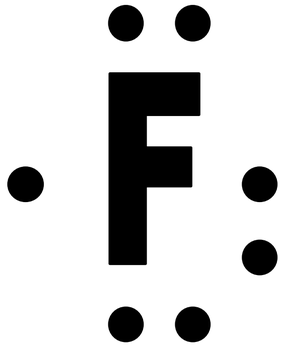
1) 1 2) 2 3) 3 4) 5

Topic 4 Review

Bohr Diagrams

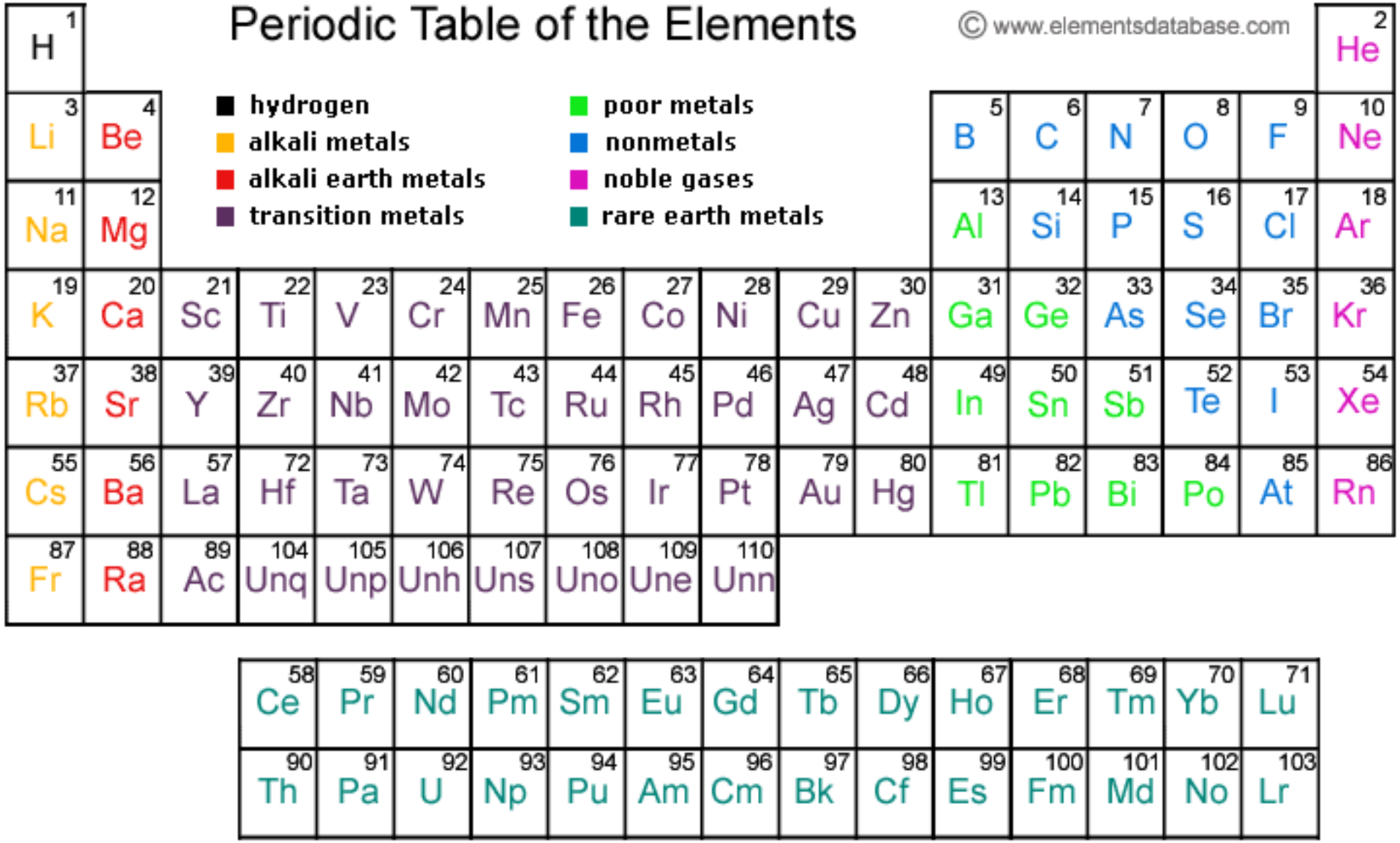


Lewis-dot Structures



Introduction to the Periodic Table

Topic 5

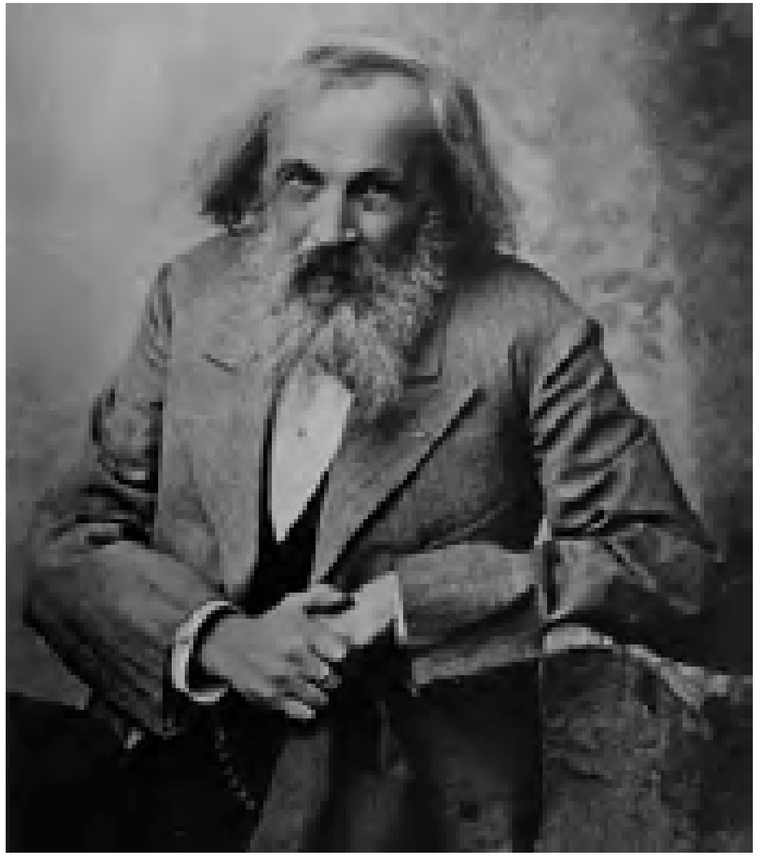


A Truly Great Discovery

In 1869, Dmitri Mendeleev presented to his peers at the Russian Chemical Society, his thoughts on the elements.

*Mendeleev noticed a regular or **periodic** recurrence of physical and chemical properties.*

REIHEN	GRUPPE I. — R^2O	GRUPPE II. — RO	GRUPPE III. — R^2O^3	GRUPPE IV. RH^4 RO^2	GRUPPE V. RH^3 R^2O^5	GRUPPE VI. RH^2 RO^3	GRUPPE VII. RH R^2O^7	GRUPPE VIII. — RO^4
1	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59, Ni=59, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —



Mosely

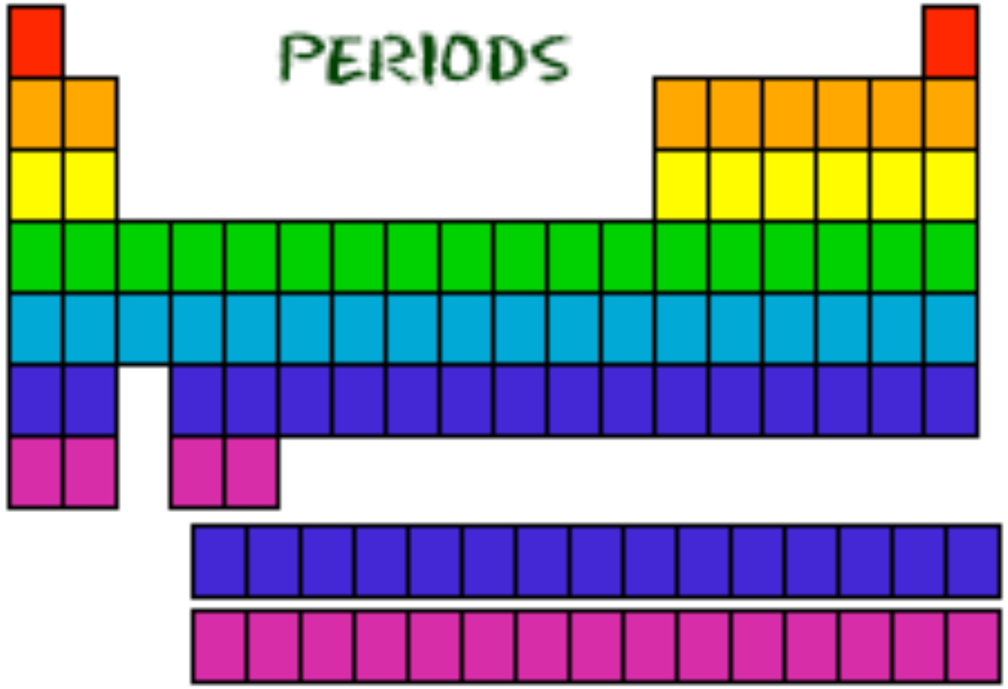
Periodic Table Organized by Atomic Number

Modern periodic tables have vertical columns with atoms of similar properties one under the other.
(British scientist **Mosley** in 1912)

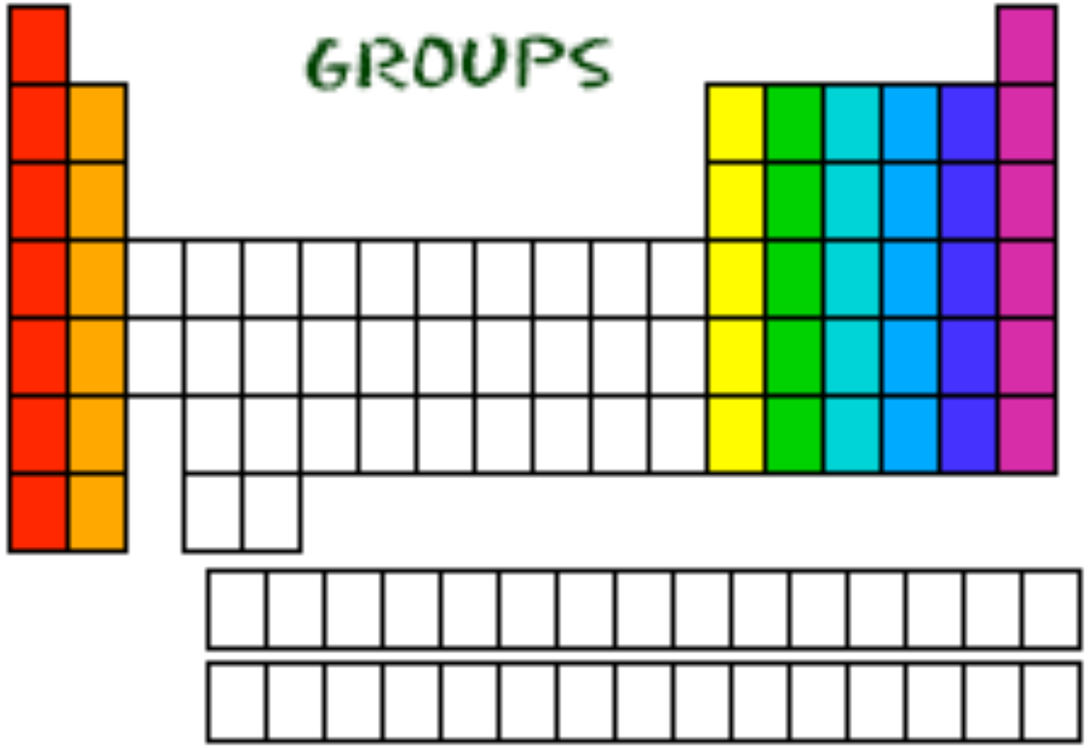
Both scientists predicted the existence of several elements before they were discovered. The periodic table is still used today to predict the existence of elements that have not been discovered yet.

Organization

Horizontal rows are called **periods**.



Vertical columns are **groups** or **families**.



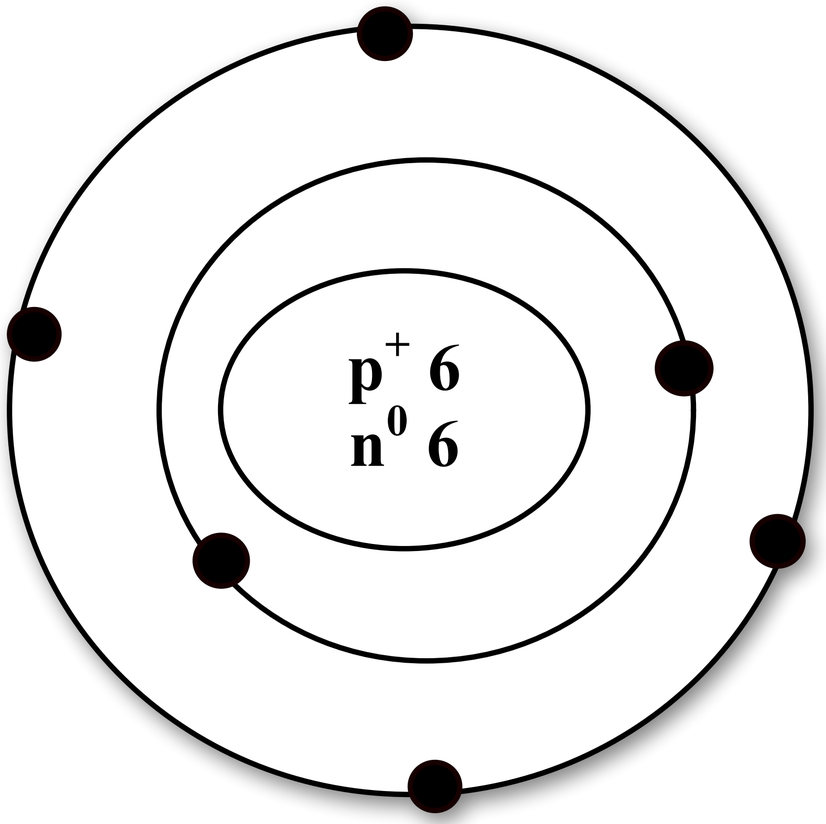
Groups have similar properties; a period contains the full range of properties.

Valence Electrons

These are the numbers of electrons in the outer shell.

What do you notice about valence electrons going across a period?

What do you notice about valence electrons going down a group?



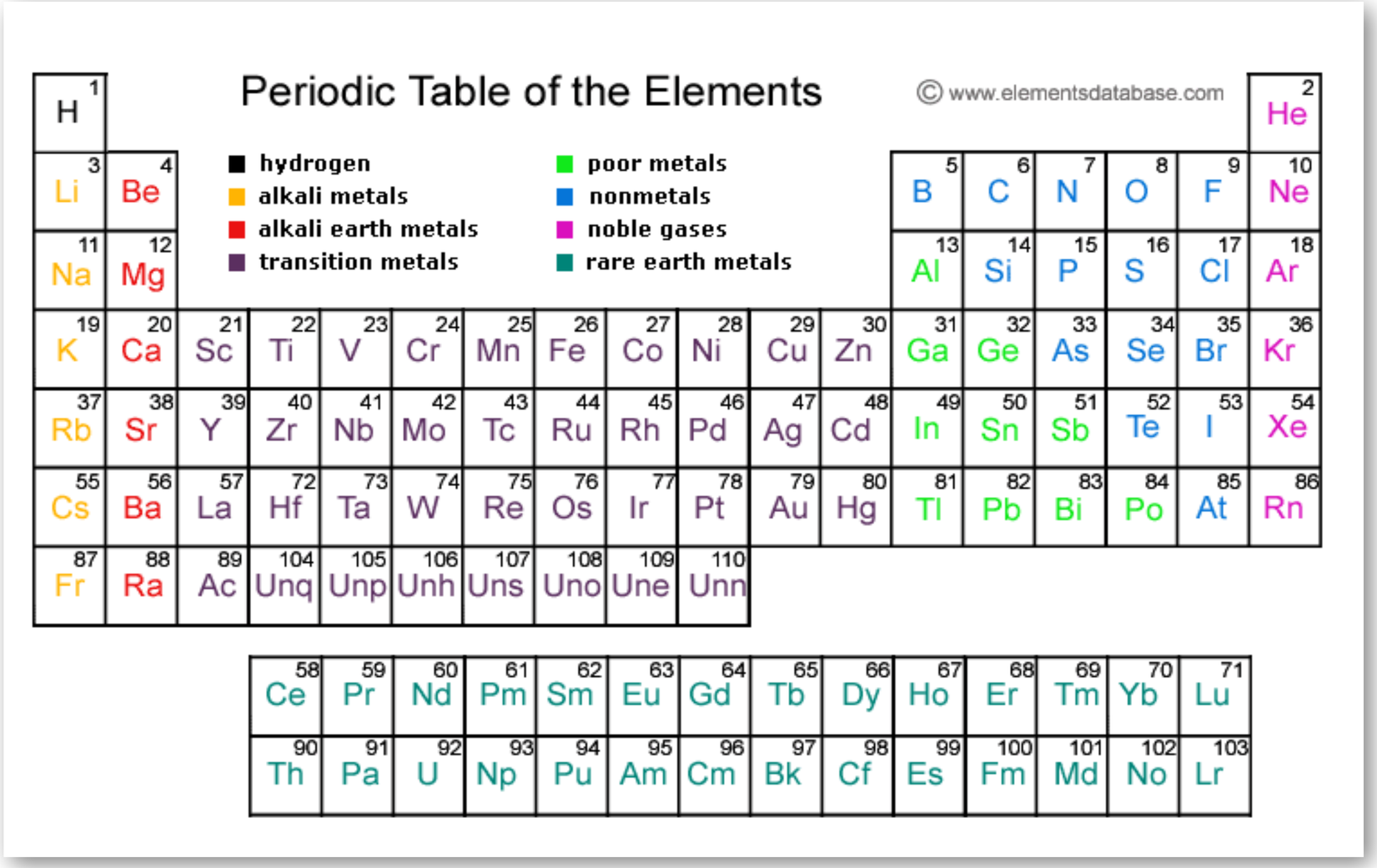
Chemical changes are all caused as elements COMPETE for each other's valence electrons!!!

The Periodic Law:

When elements are arranged in order of increasing atomic number, there is a *periodic pattern* in their physical and chemical properties.

Topic 5 Review

- The Periodic table was organized by Mendeleev
- Elements organized into periods and groups by their properties.



Element Properties & The Periodic Table

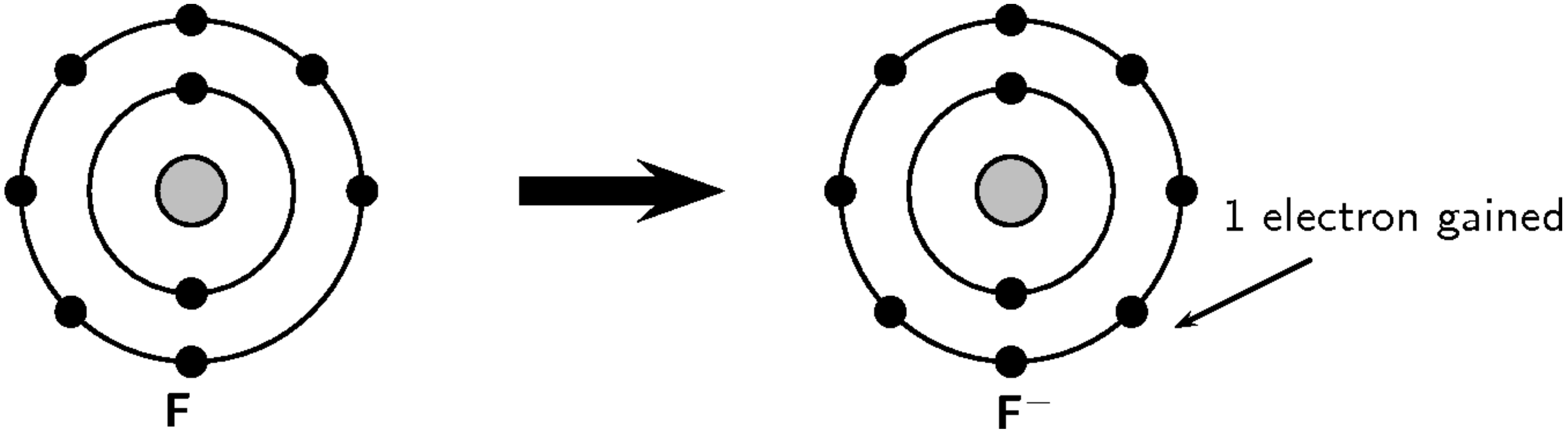
Topic 6 (Lab: Properties of Elements)

1. What does the word “inert” mean?
2. Do you know which group on the periodic table is sometimes called the “inert gases”?
3. What do you notice about the electron configuration of elements in this group?
4. Can you make a connection between the electron configurations and the fact that this group is chemically inert? What do you think that connection is?

Ions (Charged Atoms - ANIONS & CATIONS)

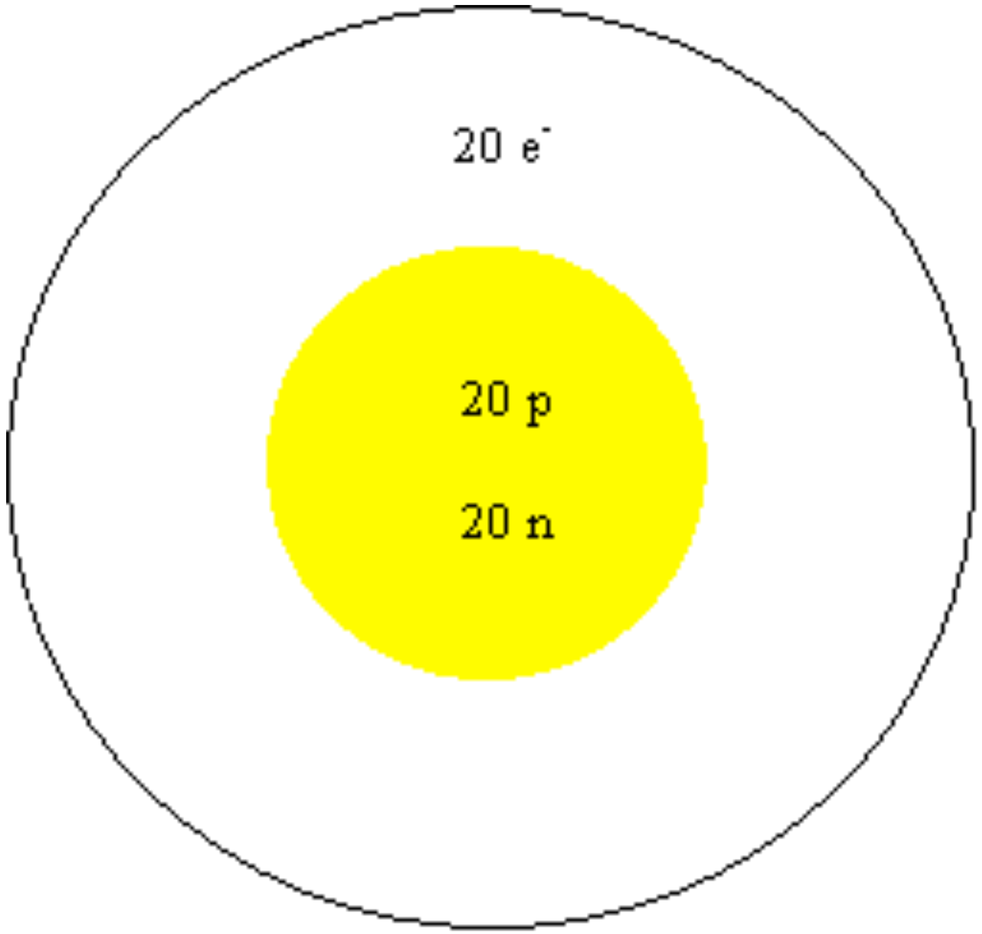
When neutral atoms **lose or gain electrons** they become **ions**.

More electrons than protons = **ANION** (and they are BIGGER) [Non-metals]

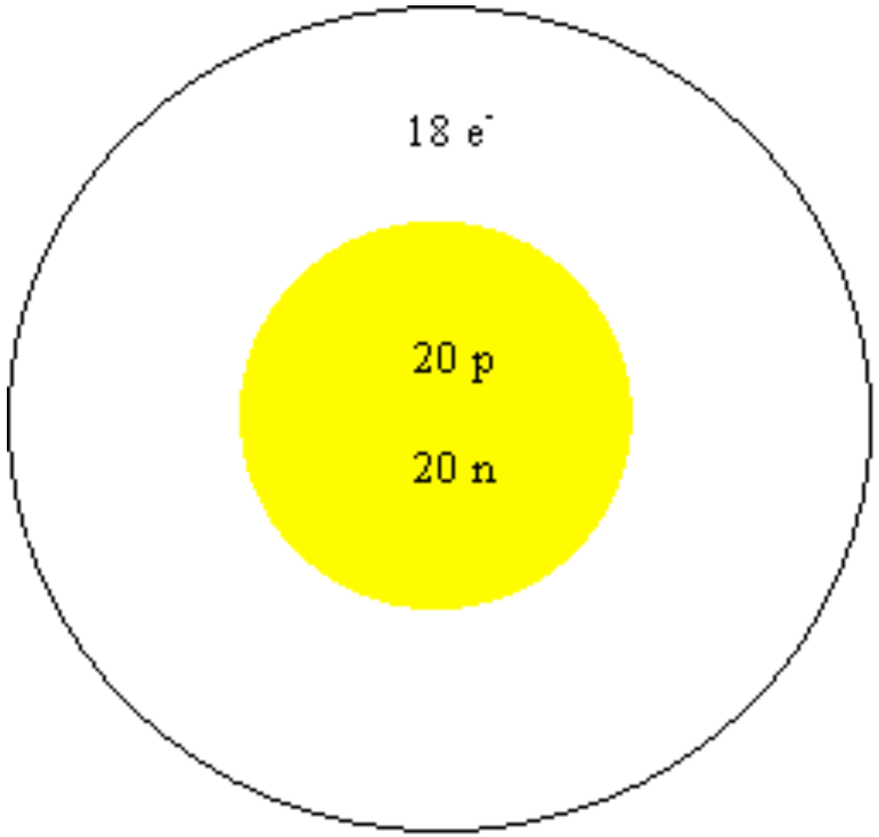


Cations

Less electrons than protons = **CATION** (and they are SMALLER) [Metals]



Ca



Ca^{2+}

Why do ions form?

Ions are formed when:

metals lose electrons (Cations)

non-metals gain electrons (Anions)

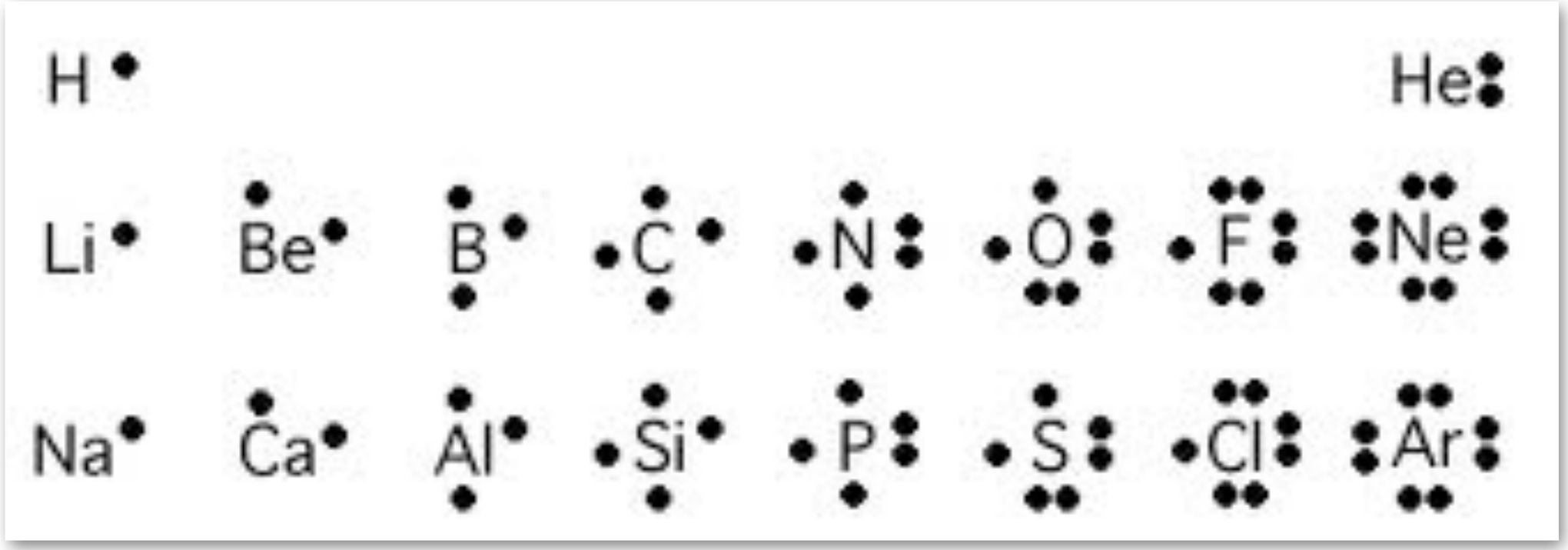
to have a full valence shell of electrons just like the **NOBLE GASES**.

Ion Formation

Which group is the *noble gases*?

Which atoms do you think will ***gain*** electrons to become like a noble gas?

Which atoms do you think will ***lose*** electrons to become like a noble gas?



Remember the Following

Metals lose electrons.
Non-metals gain electrons.
Semi-metals do either.
Noble gases do neither.

Isoelectronic: Same # of electrons

Practice

Is the given atom more likely to lose or gain electrons?

What would the *ionic* Lewis structure look like?

Bromine –> bromide ion

Magnesium –> magnesium ion

Lithium –> lithium ion

Sulfur –> sulfide ion

Regents Practice

How many electrons are contained in an Au^{3+} ion?

1) 82 2) 197 3) 76 4) 79

What is the total charge of the nucleus of a carbon atom?

1) +6 2) -6 3) +12 4) 0

Which particle has the same electron configuration as a potassium ion?

1) sodium ion 2) fluoride ion 3) neon atom 4) argon atom

Which symbol represents a particle with a total of 10 electrons?

1) Al 2) N^{3+} 3) N 4) Al^{3+}

Unit Essentials

Topic 1 - Development of the Atomic Model

ESSENTIALS: Know, Understand, and Be Able To…

- ❑ Define an atom as the smallest piece of matter retaining elemental properties.
- ❑ Summarize Dalton's Atomic Theory and relate this theory to models of atoms and compounds learned in Unit 1.
- ❑ Describe the atomic theories of Thomson, Rutherford, and Bohr and relate experimental evidence to the model of the atom.
- ❑ Describe the Modern Model/Wave Mechanical Model/Electron Cloud Model/Quantum Model and most probable positions of electrons in *orbitals*.
- ❑ Discuss the structure of an atom including location of the protons, electrons, and neutrons in relation to the nucleus.

Topic 2 - Subatomic Particles & Symbols

ESSENTIALS: Know, Understand, and Be Able To…

- ❑ Discuss the structure of an atom including location of the protons, electrons, and neutrons in relation to the nucleus.
- ❑ Describe the three basic subatomic particles (protons, electrons, and neutrons) in terms of relative masses and electrical charges.
- ❑ Use atomic number and mass number of an element to find the number of protons, electrons, and neutrons in a particular atom.

Topic 3 - Isotopes

ESSENTIALS: Know, Understand, and Be Able To…

- ❑ Use atomic number and mass number of an element to find the number of protons, electrons, and neutrons in a particular atom.
- ❑ State how isotopes of an atom differ.
- ❑ Interpret and write isotopic notation.

Topic 4 - Electrons in Atoms

ESSENTIALS: Know, Understand, and Be Able To…

- ❑ Define valence electrons and be able to draw a Lewis dot structure of an atom.
- ❑ Draw Bohr diagrams for any of the first 20 elements.

Topic 5 - Periodic Table Introduction

ESSENTIALS: Know, Understand, and Be Able To…

- ❑ State the periodic law.
- ❑ Distinguish between a period and a group on the Periodic Table.
- ❑ Use the Periodic Table to find the number of valence electrons in atoms.
- ❑ Classify selected elements as metals, nonmetals, or metalloids based on observations of their chemical properties, physical properties, and/or according to their electron configuration.
- ❑ Classify an element as an alkali metal, alkaline earth metal, metalloid, halogen, or noble gas based on the Periodic Table and their chemical properties.

ESSENTIALS: Know, Understand, and Be Able To…

- ❑ Define valence electrons. Draw a Lewis dot structure of an atom.
- ❑ Explain that atoms of elements will lose or gain electrons to form ions which contain a stable filled orbit of 2 (H) or 8 (all other elements).
- ❑ Identify ions with a positive charge as having lost electrons. These are called cations.
- ❑ Identify ions with a negative charge as having gained electrons. These are called anions.