Name ___________________ **Chemistry** ___/___/___

Subatomic Particles

In chemistry we study three subatomic particles. These particles are the proton, neutron & electron. The discovery of these subatomic particles proved part of Dalton's atomic theory incorrect. Dalton stated that all matter is made of indivisible atoms. The fact that atoms can be further divided into protons, neutrons and electrons proves atoms can be broken down into more fundamental particles. The chart below summarizes their symbol, location, charge & mass.

Subatomic Particle	Symbol	Location	Charge	Mass	Mass
proton	p^+	nucleus	+1	1.673×10^{-27} kg	1.00728 amu
neutron	n^0	nucleus	0	1.675×10^{-27} kg	1.00866 amu
electron	e^-	outside nucleus	-1	9.11×10^{-31} kg	5.4880×10^{-4} amu

* 1 amu = 1.66×10^{-24} g

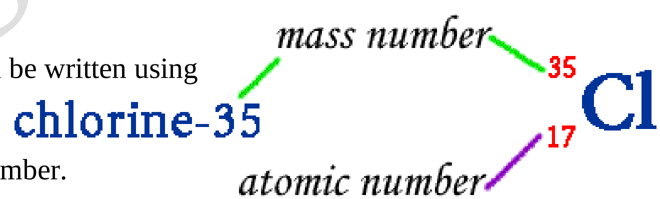
Atomic Number

The number of protons in an atom is called its **atomic number**. For example, an atom of phosphorus has 15 protons in its nucleus. Phosphorus has an atomic number of 15.
The number of electrons and protons in an atom determine its charge. Since protons have a +1 charge and electrons have a -1 charge, in a neutral atom the number of protons is equal to the number of electrons. Thus, in a neutral atom, the atomic number also indicates the number of electrons in an atom. (For now, assume all atoms are neutral. We will discuss charged atoms later this year.)
Summary: In a neutral atom: Atomic Number = # protons = # electrons

Isotopes

Isotopes are two or more atoms of the same element with the same number of protons but a different number of neutrons. The existence of isotopes proves that another part of Dalton's atomic theory is incorrect. Dalton wrote that atoms of the same element have the same physical and chemical properties. Although isotopes have the same chemical properties, they do not have the same physical properties.

Isotopes are written in two different ways. They can be written using their symbol with the mass number (to the upper left) and atomic number (to the lower left) or the isotope name is written with a dash and the mass number.



For example: Two naturally occurring isotopes of chlorine are chlorine-35 & chlorine-37. Thirty-five and thirty-seven are the mass numbers for the two isotopes. Both isotopes have the same atomic number, number of protons and electrons.

isotope name	atomic number	# protons	# neutrons	mass number	# electrons
chlorine-35	17	17	18	35	17
chlorine-37	17	17	20	37	17

Mass Number

The mass of an atom is almost entirely due to the mass of its neutrons and protons. The mass of an electron (9.11×10^{-31} kg) is 1/1836th of the mass of both a proton (1.673×10^{-27} kg) and a neutron (1.675×10^{-27} kg). As a result, the mass of the electrons factors little in the total mass of the atom (it would take over 1800 electrons to equal the mass of 1 neutron).
Summary: Mass Number = # protons + # neutrons

Average Atomic Weight

The **atomic weight of an element is the weighted average of the masses of the isotopes of that element**. The weighted average is determined using the abundance and mass of each isotope. Most elements have more than one naturally occurring isotope.

For example, there are two naturally occurring isotopes of copper, ***copper-63*** (62.93 amu) and ***copper-65***. (64.93 amu). The natural abundances of the isotopes are **69.17%** and **30.83%** respectively.

To determine the atomic weight:

Step 1: Multiply the mass number and the relative abundance (as a decimal). The mass of the electron is insignificant in this calculation and is not used.

isotope name	atomic mass	x	abundance (as a decimal)	=	result
copper-63	62.93 amu	x	0.6917	=	43.53
copper-65	64.93 amu	x	0.3083	=	20.02

Step 2: Add up your results. **Atomic Weight = 63.55 amu**

The mass of a proton is approx. 1.008 amu. The mass of a neutron is approximately 1.009 amu. The mass of the electron is insignificant. When elements are formed from the individual subatomic particles a large amount of energy in the form of heat is released. This loss of mass is called the **mass defect** and this conversion of mass into energy is seen in the equation: $E = mc^2$.

Homework:

1. Which part of Dalton's atomic theory was proven to be incorrect with the discovery of subatomic particles?

All matter is made of indivisible atoms. The discovery of subatomic particles proved atoms could be divided.

2. Fill in the chart below

Subatomic Particle	Symbol	Location	Charge	Mass
neutron	**n^0**	**nucleus**	**0**	**1.675×10^{-27} kg**
electron	**e^-**	**outside nucleus**	**-1**	**9.11×10^{-31} kg**
proton	**p^+**	**nucleus**	**+1**	**1.673×10^{-27} kg**

3. What makes an atom neutral?

An atom is neutral when the number of protons equals the number of electrons.

4. What is the relationship between the atomic number of an element and its number of protons?

Atomic number = # protons

5. What is the ratio of the mass of a proton to the mass of an electron?

Mass Proton : Mass Electron

1 : 1836

6. What is the relationship between the number of protons & neutrons and an atom's mass number?

Mass Number = # protons + # neutrons

7. What is an isotope?

Isotopes are two or more atoms of the same element with the same number of protons but a different number of neutrons.

8. The existence of isotopes, proved which part of Dalton's atomic theory incorrect?

Atoms of the same element have the same physical and chemical properties. Isotopes are not the same physically.

9. What are two ways that you can represent an isotope of bismuth that has 126 neutrons?

Bismuth-209 & $^{209}Bi_{83}$

10. Write the mass number, atomic number, number of electrons, protons and neutrons for the following isotopes.

a. $^{207}_{82}\mathrm{Pb}$

mass # - **207** # neutrons - **125**

atomic # - **82** # electrons - **82**

name - **lead-207** # protons - **82**

b. $^{109}_{47}\mathrm{Ag}$

mass # - **109** # neutrons - **62**

atomic # - **47** # electrons - **47**

name - **silver-109** # protons - **47**

c. $^{226}_{88}\mathrm{Ra}$

mass # - **226** # neutrons - **138**

atomic # - **88** # electrons - **88**

name - **radium-226** # protons - **88**

d. $^{257}_{99}\mathrm{Es}$

mass # - **257** # neutrons - **158**

atomic # - **99** # electrons - **99**

name - **einsteinium-257** # protons - **99**

11. Fill in all of the missing information.

isotope name	#p	#n	#e-	mass #	atomic #	Isotope symbol
Sodium-23	11	12	**11**	**23**	**11**	**23 Na 11**
Hydrogen-1	**1**	**0**	**1**	1	1	**1 H 1**
Iodine-127	**53**	**74**	**53**	**127**	**53**	**127 I 53**
Californium-251	**98**	**153**	**98**	**251**	**98**	251 Cf 98
Astatine-210	**85**	**125**	85	210	**85**	**210 At 85**
Gold-197	**79**	118	**79**	**197**	79	**197 Au 79**
Potassium-41	19	**22**	**19**	41	**19**	**41 K 19**
ytterbium-171	**70**	**101**	**70**	**171**	**70**	**171 Yb 70**
Osmium-190	**76**	**114**	**76**	**190**	**76**	190 Os 76
Fluorine-19	9	10	**9**	**19**	**9**	**19 F 9**

13. **Given the following information, calculate the atomic mass.**

a. $^{28}\mathrm{Si}$ (92.21%) 28 x 0.9221 = 25.8188
$^{29}\mathrm{Si}$ (4.70%) 29 x 0.0470 = 1.363
$^{30}\mathrm{Si}$ (3.09%) 30 x 0.0309 = 0.927
28.1088 amu

b. $^{32}\mathrm{S}$ (95.0%) 32 x 0.950 = 30.4
$^{33}\mathrm{S}$ (0.8%) 33 x 0.008 = 0.264
$^{34}\mathrm{S}$ (4.2%) 34 x 0.042 = 1.428
32.092 amu

c. ^{64}Zn	(48.89%)	64 x 0.4889 = 31.2896		d. ^{70}Ge	(21.2%)	70 x 0.212 = 14.84
^{66}Zn	(27.81%)	66 x 0.2781 = 18.3546		^{72}Ge	(27.7%)	72 x 0.277 = 19.944
^{67}Zn	(4.11%)	67 x 0.0411 = 2.7537		^{73}Ge	(7.7%)	73 x 0.077 = 5.621
^{68}Zn	(18.57%)	68 x 0.1857 = 12.6726		^{74}Ge	(34.9%)	74 x 0.349 = 25.826
^{70}Zn	(0.62%)	70 x 0.0062 = 0.434		^{78}Ge	(7.4%)	78 x 0.074 = 5.772
		65.4595				**72.003**

13. A certain element has two stable isotopes. The mass of one of the isotopes is 62.93 amu and the mass of the other isotope is 64.93 amu. Determine the percent abundance of each isotope.

Copper-63: 69.2%
Copper-65: 30.8%

14. Indium (In) has two isotopes, Indium-113(amu= 112.904) & Indium-115 (amu=114.904). The average atomic weight of indium is 114.818 amu. Determine the percent abundance of each isotope. Answer should be given to the hundredths place.

Indium-113: 4.3%
Indium-115: 95.7%

15. Chlorine (Cl) has two isotopes, chlorine-35(amu= 34.969) & chlorine-37(amu=36.966). The average atomic weight of chlorine is 35.4527 amu. Determine the percent abundance of each isotope. Answer should be given to the hundredths place.

Chlorine-35: 75.8%
Chlorine-37: 24.2%

16. Element X is found in two forms: 90% is an isotope that has a mass of 20.0 and 10% is an isotope that has a mass of 22.0. What is the atomic mass of element X?

20.2 amu

17. What is the average atomic mass of a hypothetical sample of element X if it is found that 20% of the sample contains an isotope with mass of 100; 50% of the sample contains an isotope of the element with mass of 102; and 30% of the sample contains an isotope of the element with a mass of 105?

102.5 amu

At the completion of this assignment you will be prepared to take the following Chapter 2 on-line quizzes:

• atomic number quiz	• name that isotope quiz
• atomic weight quiz	• number of neutrons quiz
• isotope chart quiz 1	• number of protons quiz
• isotope chart quiz 2	• proton, neutron and electron facts quiz 1
• mass number quiz	• proton, neutron and electron facts quiz 2