Atomic Theory – Part 1

Reading: Ch 2 sections 1 – 6, 8	Homework: Chapter 2: 39, 47, 43, 49, 51*, 53, 55, 57, 71, 73, 77, 99, 103 (optional)

* = 'important' homework question

The Atomic Theory (John Dalton, 1803)

Dalton revisited the Ancient Greek Philosophers' (Democritus *et. al.*, 460 BC) ideas pertaining to how *all* matter is constructed from very small indivisible particles ('atomos').

Dalton formulated a set of ideas (postulates), known as "The Atomic Theory of Matter", that would (~100 years) later be shown to be correct

Postulates of Dalton's Atomic Theory of Matter

1. **Matter is composed of extremely small particles called *atoms***

2. **All atoms of a given element are *identical*, the atoms of each element are different and have different chemical and physical properties**

3. **Atoms are not changed into different types of atom(s) via chemical reactions. Atoms can neither be created nor destroyed**

4. **Compounds are formed when atoms of more than one type are combined. A compound always has the same relative number and kind of atoms**

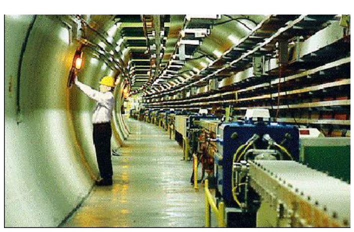
Notes on Dalton's Atomic Theory

Atomic Structure

Discussion: In the introductory lectures we took a brief look at different types of matter (i.e. elements, compounds and mixtures). We know these materials are made from the smallest stable units of matter, atoms.

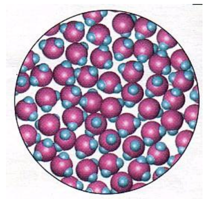
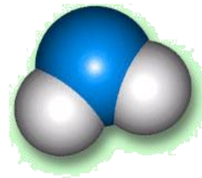
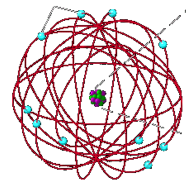
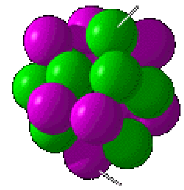
Atoms themselves are in turn made from smaller *unstable* particles – recall as many of these fundamental 'building blocks' of matter as you can:

Question: How are ***all*** of these fundamental 'building blocks' of matter related? Sketch a flow chart:



Fermi Lab, located in West Chicago, IL, is the world's largest 'atom smasher*'. Fermi is where scientists perform experiments in an attempt to understand the origins of the universe

<u>Example</u>: Water

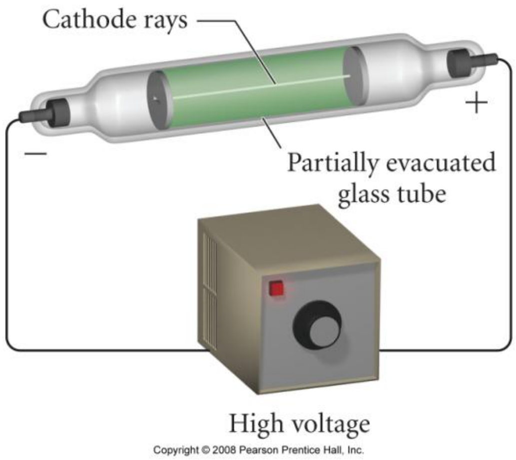
    

In many ways we take atomic theory, as well as its eventual confirmatory experimental results, for granted (i.e. we don't think about where it came from, we just assume and use it).

At the turn of the 19th century and for the next ~ 100 years this work was a the cutting edge of scientific research and was pursued by some of the world's greatest scientific minds

<u>Task (complete outside of class)</u>: Complete the reading assignment for this note packet. Make notes on the following topics and make reference to the included illustrations in your discussions. *This material, as well as other similar assignments, will likely form the basis of any extra credit questions appearing on midterm exams*.

Cathode Rays and electrons (J.J. Thompson)



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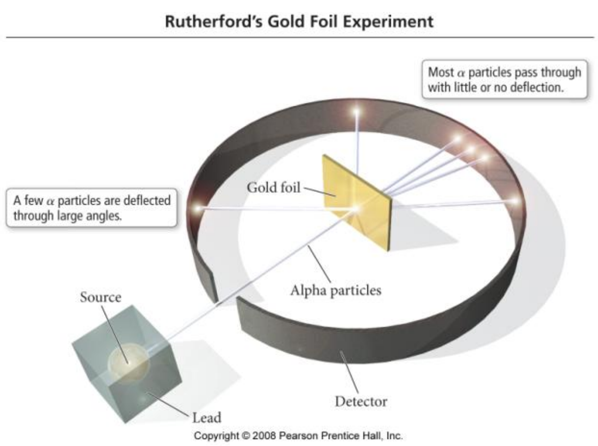
The Nuclear Atom (Rutherford)



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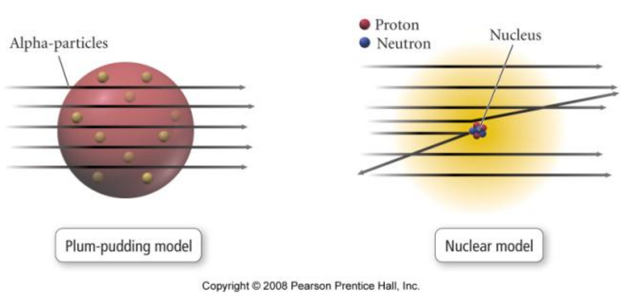
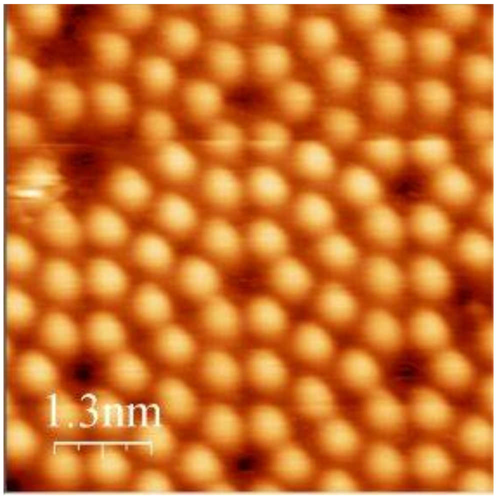


Atoms and Isotopes

Review: Atoms are the smallest type of *stable* matter, they are typically spherical and have diameters of ~ 0.18 – 0.60 nanometers.



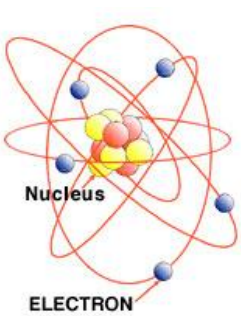
Shown on the left is an STM image of a silicon chip's (Si (s)) surface. Note that it has a repeating 'giant' structure.

Question: Based on the scale, what is the approximate width of a silicon atom in nm?

Answer:

Ask me about the *extra credit* magnification….

The 'Classical' view of atomic structure



Questions:

1. What is found at the center of an atom?

2. What two different types of subatomic particle are found inside the nucleus? (*sub*atomic means '*smaller than'* atomic)

3.  What 'orbits' the nucleus?

4. Sketch a generic diagram of an atom using the slide as a guide. Based on the slide, how many times smaller is the diameter of the nucleus than the atom as a whole?

<u>Comparison of subatomic particles</u> (i.e. the things atoms are made from)

<u>Particle</u>	<u>Symbol</u>	<u>Charge</u>	<u>Relative mass</u>
Electron	***e***	-1	1
Proton	***p***	+1	1836
Neutron*	***n***	0	1839

* ask me to tell you a very poor neutron joke - it starts with ‘a neutron walks into a bar’…..

Electrons are *much lighter* than the neutrons and protons (that, in turn, ‘inhabit’ the nucleus) ⇒ ELECTRONS MOVE MUCH MORE QUICKELY THAN THE NEUCLIUS EVER CAN (this is called the Born – Oppenheimer Approximation).

This is why electrons are said to either ‘orbit’ the nucleus or exist as ‘blurred out’ electron ‘clouds’. This is the *main* difference between the ‘classical’ and ‘modern’ models of atomic structure. We will study the modern ‘electron cloud’ model in depth later in the course.

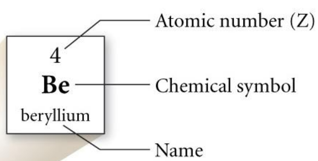
Question: Are ATOMS* electrically charged?   Answer: ______

Question: What then must be true for EVERY atom in terms of the number of electrons and protons it contains?

*Aside: We saw/will see in lab that ***ions*** are made by electrically charging atoms or molecules, we will study this concept in more detail later.

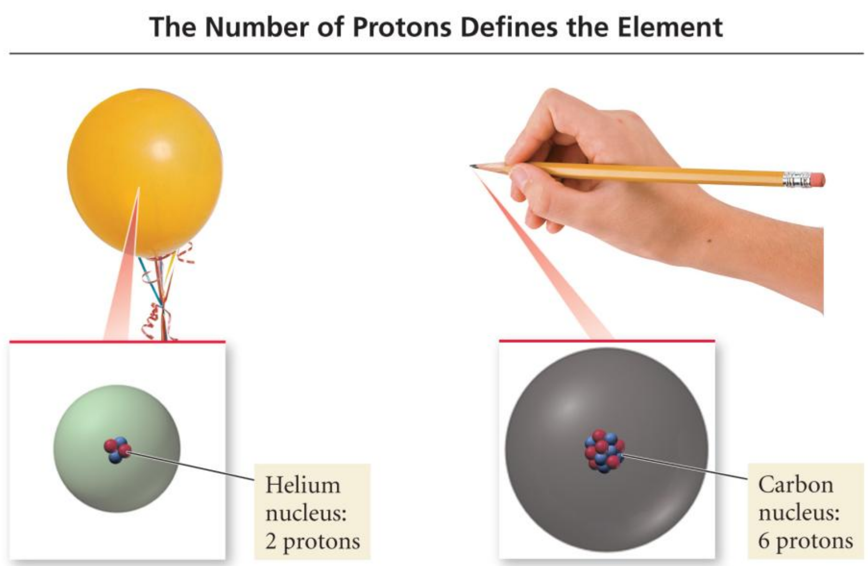
Question: Where can we find out the number of protons, Z, (and therefore also the number of electrons) an atom has?

The Periodic Table



1 H hydrogen																	2 He helium
3 Li lithium	4 Be beryllium											5 B boron	6 C carbon	7 N nitrogen	8 O oxygen	9 F fluorine	10 Ne neon
11 Na sodium	12 Mg magnesium											13 Al aluminum	14 Si silicon	15 P phosphorus	16 S sulfur	17 Cl chlorine	18 Ar argon
19 K potassium	20 Ca calcium	21 Sc scandium	22 Ti titanium	23 V vanadium	24 Cr chromium	25 Mn manganese	26 Fe iron	27 Co cobalt	28 Ni nickel	29 Cu copper	30 Zn zinc	31 Ga gallium	32 Ge germanium	33 As arsenic	34 Se selenium	35 Br bromine	36 Kr krypton
37 Rb rubidium	38 Sr strontium	39 Y yttrium	40 Zr zirconium	41 Nb niobium	42 Mo molybdenum	43 Tc technetium	44 Ru ruthenium	45 Rh rhodium	46 Pd palladium	47 Ag silver	48 Cd cadmium	49 In indium	50 Sn tin	51 Sb antimony	52 Te tellurium	53 I iodine	54 Xe xenon
55 Cs cesium	56 Ba barium	57 La lathanum	72 Hf hafnium	73 Ta tantalum	74 W tungsten	75 Re rhenium	76 Os osmium	77 Ir iridium	78 Pt platinum	79 Au gold	80 Hg mercury	81 Tl thallium	82 Pb lead	83 Bi bismuth	84 Po polonium	85 At astatine	86 Rn radon
87 Fr francium	88 Ra radium	89 Ac actinium	104 Rf rutherfordium	105 Db dubnium	106 Sg seaborgium	107 Bh bohrium	108 Hs hassium	109 Mt meitnerium	110 Ds darmstadtium	111 Rg roentgenium	112 **		114 **		116 **		
			58 Ce cerium	59 Pr praseodymium	60 Nd neodymium	61 Pm promethium	62 Sm samarium	63 Eu europium	64 Gd gadolinium	65 Tb terbium	66 Dy dysprosium	67 Ho holmium	68 Er erbium	69 Tm thulium	70 Yb ytterbium	71 Lu lutetium	
			90 Th thorium	91 Pa protactinium	92 U uranium	93 Np neptunium	94 Pu plutonium	95 Am americium	96 Cm curium	97 Bk berkelium	98 Cf californium	99 Es einsteinium	100 Fm fermium	101 Md mendelevium	102 No nobelium	103 Lr lawrencium	

Note how the P. Table is *fundamentally* arranged in terms of *increasing* atomic number (Z)

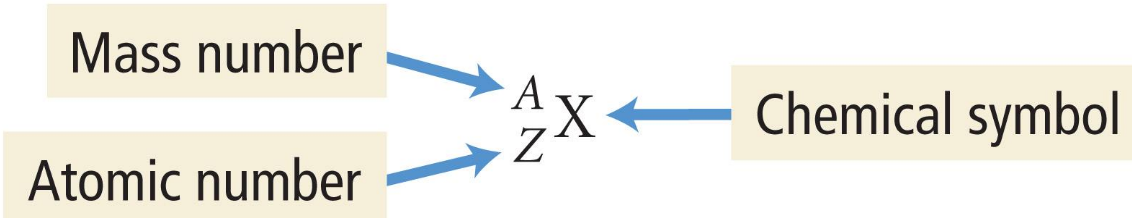


Task: Use the P. Table to determine how many protons and electrons the following types of atoms (elements) have:

Atom	#p	#e	Atom	#p	#e	Atom	#p	#e
Carbon (C):			Silicon (Si):			Lead (Pb):		

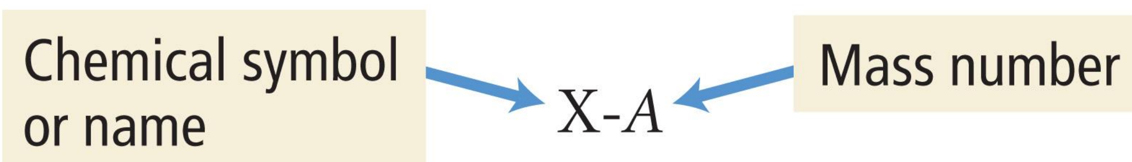
Discussion: The atomic number (Z) indicates the number of protons an individual atom has. What other type of subatomic particle is also found within an atom's nucleus? How is the number of these particles within any nucleus represented and/or determined?

COMPLETE ATOMIC SYMBOL:



Example: Write the complete atomic symbol for an atom of Carbon that contains 6 protons and 6 neutrons.

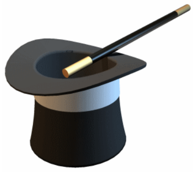
'Shorthand' version of the complete atomic symbol:



Task: Carbon–14 has a mass number of 14. Use this information to write its complete atomic symbol. Do the same for U-235 and Cl-35.

* remind me to tell a story about U-235 and U-234

Understanding Isotopes

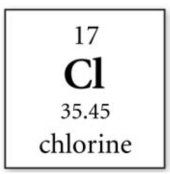


An element has a FIXED number of protons in its nucleus.

(This information is contained within the element's Atomic Number. E.g. All hydrogen (H) atoms have 1 *proton* in their nuclei, while all carbon (C) atoms have 6 protons in their nuclei).

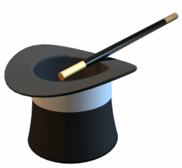
HOWEVER, an element can have a VARIABLE number of *neutrons* in its nuclei.

(This does NOT alter the identity of the element (#p same), but DOES make the element heavier or lighter (# n changed))



The AVERAGE atomic mass value for ALL an element's isotopes is displayed in the periodic table.

E.g. Chlorine has a mass number of 35.45 amu* – there are *NO single* chlorine atoms in existence with a mass of 35.45 amu (i.e. no such thing as 0.45 of a neutron!), but there are Cl isotopes with mass numbers of 35 and 37 – their *weighted average* is 35.45 amu



The complete atomic symbol's mass number' (A) and the respective Element's 'box weight' in the periodic table do NOT convey the same information.

The complete atomic symbol denotes the mass of ONE isotope of the element in amu, while the p. table gives is the average mass of ALL isotopes of the element in amu.

*Note: an amu is an **a**tomic **m**ass **u**nit – the mass of a ***single*** proton or neutron. This is $\approx 1.66053873 \times 10^{-24}$ g.

It is *much* simpler to count atomic masses in amu – "an atom of carbon -12 (which contains 6 p and 6 n, so has a mass number of 12) weighs 12 amu" is better than saying "an atom of carbon -12 weigh 1.992648×10^{-23} grams"!

Task: Complete the following table for the isotopes of Carbon. (Tip: what are the values of #p and #e ALWAYS for carbon? Where would you find this information?)

Complete atomic Symbol	#p	#e	#n
			5
			6
			7
			**8**

I have a *very* poor ^{14}C joke; ask at your own peril….

Determining Relative isotopic abundance

Typical Question: Naturally occurring magnesium has the following isotopic abundances:

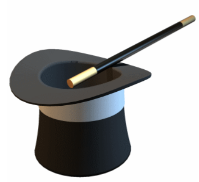
Isotope	Abundance	Mass (amu)
^{24}Mg	78.99	23.98504
^{25}Mg	10.00	24.98584
^{26}Mg	11.01	25.98259

What is the average atomic mass of Mg?

The isotopic abundances of any series of isotopes *always* add up to 100%

The sum of the *weighted abundances* is equal to the average atomic mass (as found in the P. Table).

Determine each isotope's *weighted abundance* by multiplying its FRACTIONAL ABUNDANCE by its isotopic mass



Edit the table supplied to make two new columns - *fractional abundance* and *weighted abundance.*

Determine the weighted abundances and then combine them to find the element's average atomic mass.

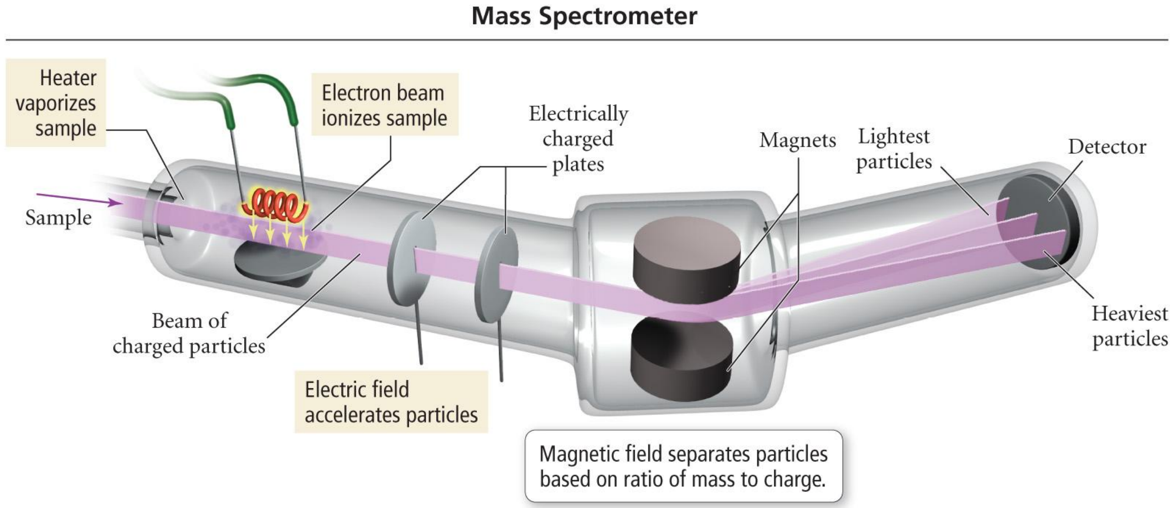
Answer:

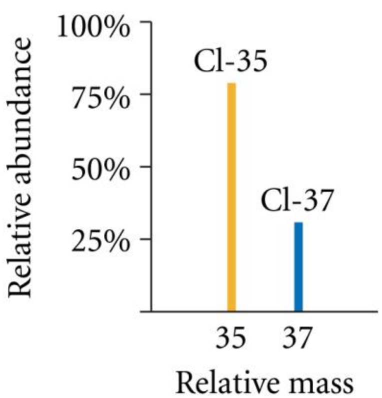
Isotope	Abundance	Fractional Abundance		Mass (amu)		Weighted Abundance (amu)
^{24}Mg	78.99	**0.7899**	**x**	**23.98504**	**=**	
^{25}Mg	10.00	**0.1000**	**x**	**24.98584**	**=**	
^{26}Mg	11.01	**0.1101**	**x**	**25.98259**	**=**	

Sum of weighted abundances = ___________________

Check: Is the sum of weighted abundances equal to the average atomic mass for Mg from the P. Table?

Task (complete outside of class): As the above table illustrates, the amu masses of individual atoms (isotopes), or even molecules, can be measured with a high degree of precision. This is made possible through the technique of mass spectroscopy. Make notes on the design and function of a mass spectrometer, as well as how the mass spectrum of Chlorine may be used to determine its average atomic mass (p 68, 69).





"Symbol"

The following question were taken from your 1st practice midterm:

Write the **complete atomic symbol** for the isotope that contains 29 protons and 34 neutrons.

Complete atomic symbol:

Answer: $^{63}_{29}\text{Cu}$