Density is a distinguishing property of matter. Another important property useful for identifying matter is solubility. Solubility refers to the *maximum amount of a solute* that will dissolve in a *given amount of solvent* at a *specified temperature*. So solubility depends on amounts of solute and solvent, and the temperature. For example: the solubility of potassium chlorate, $KClO_3$, is listed in a chemical handbook as: 7.1 g per 100 grams of water at 20 deg.C, and 57 g per 100 grams water at 100 deg.C. Represent this information in the form of conversion factors (i.e., ratios):

$$\left[\frac{7.1\ g\ KClO_3}{100\ g\ H_2O}\right] @\ 20^oC \quad \text{and} \quad \left[\frac{57\ g\ KClO_3}{100\ g\ H_2O}\right] @\ 100^oC$$

1. How much water is necessary to completely dissolve 25.0 g of $KClO_3$ at 20 deg.C?
2. A solution is prepared by dissolving 10.5 g of $KClO_3$ in 40.0 mL of water at 100 deg.C. Will all of the solute dissolve?
3. The solution prepared in question 2 is cooled to 20 deg.C.
   a. How much $KClO_3$ will remain in solution?
   b. How much $KClO_3$ will be precipitated? (The precipitate is any $KClO_3$ over the maximum amount that can dissolve, in the amount of solvent present at the specified temperature.)

Chapter 2 - Some fundamental laws of chemistry & elementary aspects about atoms, molecules and ions.

Fundamental Laws. Workers in science have always shared their findings, and early on some common collective findings and observations became apparent. Among these are the following: (1) substances having identical properties must be identical substances. (2) some substances are more fundamental than others and are called elements. Elements could not be decomposed into simpler substances by O.C.M, but they could react/combine to form other substances with different properties called compounds. (3) the composition of compounds having identical properties is always the same. This finding was so universal that it became known as the Law of Constant Composition. For example, multiple independent analyses of the compound potassium chlorate always showed it to be composed of 31.90% potassium, 28.93% chlorine, and 39.17% oxygen, by weight, no matter from whence it came.

Percents and fractions are convenient ways to represent information between related items. The sum of individual percents must add to 100 %, and the sum of individual fractions must add to 1.000. Percent composition of a compound, and weight fractions of elements in compounds, are really conversion factors (i.e., ratios) in disguise.

(4) careful mass measurements of all substances present before and after a chemical reaction shows that the total mass does not change. This was a difficult finding to verify b/c it had to be learned that any gases present had to be confined in order to have their masses included. Nevertheless, this observation was so universal that it became known as the Law of Conservation of Mass. (And there is a corresponding Law of Conservation of Energy.)

These findings were established at the start of the 19^{th} century and they awaited some explanation. In about 1815 it was provided by John Dalton. In order to account for these observations, Dalton constructed the following model for matter:

An atom is the smallest division of an element that can display all properties of the element (color, mass, mp, bp, ...)
Atoms combine to form compounds in definite and fixed amounts by weight. (this means in fixed numbers too)
A molecule is the smallest division of a compound that can display all properties of the compound.

Some features of Dalton's theory have been modified in light of current knowledge about atoms and molecules. Most importantly, atoms of a given element CAN have different masses b/c of isotopic forms, and the concept of an individual molecule is best applied to covalent compounds b/c NO molecules are present in simple crystalline ionic solids.

Show how this model of matter can account for the universal findings noted above. Consider the following quantitative applications of Dalton's model:

1. Calcium (Ca) and Chlorine (Cl) combine to form a compound. In one case 1.593 g of Ca is reacted with 3.128 g of Cl to form 4.421 g of compound, with some Cl left over. In another case 2.391 g of Ca is react with 4.017 g of Cl, and 6.280 g of compound is formed with some Ca left over. Does this information illustrate the Law of Constant Composition?

2. When 2.317 g of Epsom=s salt is strongly heated, water of crystallization is expelled, and 1.130 g of solid anhydrate remains. What per cent of Epsom=s salt is due to water of crystallization. The Law of Constant Composition operates for hydrates as well as for other compounds. Accordingly, how much Epsom salt would be required to obtain 3.50 g or anhydrate. (Hydrated forms contain water of crystallization. Anhydrous forms do not.)

One part of Dalton=s model states that atoms of a given element are all alike (have the same mass). Another part states that atoms combine in fixed proportions by *weight (or mass)*. But this also means that atoms combine in fixed proportions by *numbers* as well, b/c a fixed mass of element A will always contain the same number of atoms of A. This interpretation finds direct expression as the Law of Multiple Proportions. Examples: CO and CO_2, N_2O and N_3O_4

3. An element forms several different compounds with oxygen. In one of these compounds, 11.983 g of the element reacts with oxygen to form 24.39 g of compound. In another compound, 10.117 g of oxygen reacts with the element to form 17.95 g of compound. Show whether these compounds illustrate the Law of Constant Composition or the Law of Multiple Proportions.

4. Several different compounds contain the elements of nitrogen (N) and oxygen (O). One compound analyzes for 30.4% nitrogen. Another compound is composed of 63.2% oxygen. Are the compound the same? If not the same, then find the simplest ratio of atoms of one element, for the same amount of other element, present in both compounds.

Relative weights (masses) of atoms. Some ideas about relative weights of atoms started to appear by combining analytical information with assumed formulas. It is known (by experiment) that chlorine and sulfur combine to form (several) compounds. However, suppose that the relative weights of sulfur and chlorine atoms are not known. One of the compounds containing both sulfur and chlorine is analyzed (by experiment) and found to contain 18.44 % sulfur, by weight. *If the formula of this compound is S Cl*, then the molecule contains one atom of sulfur for each atom of chlorine, so one chlorine atom is heavier than one sulfur atom. In fact it will be 81.56/18.44 = 4.42 times as heavy as one sulfur atom. *If the formula is* $S\,Cl_2$, then two Cl atoms are 4.42 times as heavy as one sulfur atom, or one chlorine atom is 2.21 times as heavy as one sulfur atom. *If the formula is* $S\,Cl_3$ *...* The system of atomic weights depends on knowing the formula.

Elementary structure of atoms. Some very clever investigations into atoms showed the presence of three fundamental particles. Atoms have a very small and dense central region called a nucleus. The nucleus contains two of these particles, the *proton* and *neutron*. The proton is positively charged (+) and has total responsibility for the identity of the atom. Potassium atoms have 19 protons in their nuclei, no more, no less. At atom with 20 protons in the nucleus is not a potassium atom, it is a calcium atom. The number of protons in the nucleus of an atom is called its ATOMIC NUMBER and is the integer number listed on the periodic table. The neutron does not carry a charge. The third particle is much lighter than the first two and is much farther away from the nucleus. It is called the *electron*. Electrons are negatively charged (-). Atoms are electrically neutral so the number of protons present in the nucleus will be the same as the number of electrons moving about the nucleus. But this situation can be changed.

Electrons can be added to a neutral atom to form a negative specie called an *anion.* In general, non-metal elements form anions. $Cl + e^{1-} = Cl^{1-}$ (chlorine atom plus an electron forms a chloride anion)

Electrons can be removed from neutral atoms to form positive species called *cations*. in general, metal elements form cations. $K = K^{1+} + e^{1-}$ (potassium atom loses an electron to form a potassium cation)

Note that only electrons are removed from, and added to, atoms in chemical reactions; the numbers of protons and neutrons present never changes. (The science of chemistry is very much the study of electrons.)

A system of notation is used to represent atoms, cations, and anions. Atoms are indicated by their symbols, just as they appear in the periodic table. A left superscript above the symbol shows the mass number (integer atomic weight = # protons + # neutrons). A left subscript below the symbol shows the atomic number (# protons). The charge present on a cation or anion is represented by a right superscript above the symbol. The absence of charge indicates a neutral atom (# electrons = # protons). This scheme permits determining numbers of protons, neutrons and electrons present in an atom or ion.

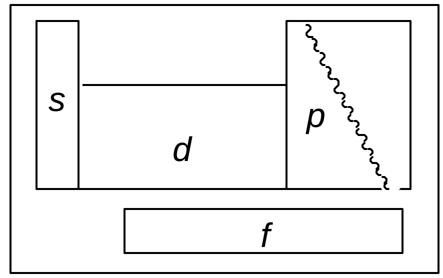
5. Determine the number of sub-atomic particles (i.e., p^+, n, and e^-) present in each of the following:

^{208}Pb H ^{2}H K^+ Cl^- ^{238}U Sb^{3+} Se^{2-} Pb-207

6. Complete the following table:

symbol	at.#	mass #	# electrons	# protons	#neutrons	charge	at.wt.
F^{1-}							
		14	7			0	
			10		14	+3	26.98
	16					-2	

Periodic Table of the Elements … is a left-to-right arrangement of elements, sequential in terms of increasing *atomic number*. Whenever a noble gas is encountered then a new line is started under the previous line, sort of like the page-return / line-feed made by a typewriter. Vertical columns of elements are called *groups*. Groups of elements have similar chemical properties due to presence of similar numbers and types of outermost electrons. Outermost electrons are called valence shell electrons (vse) and are of paramount importance in chemistry. Several named P.T. sections based on the underlined criteria are identified below:



A. Types of vse's - *s, p, d* and *f* sections as shown to the right

s section -	two elements across in width
p	six
d	ten
f	fourteen

MAIN GROUP ELEMENTS - all elements in *s* AND *p* sections.
TRANSITION ELEMENTS *d*
INNER-TRANSITION ELEMENTS *f*

B. Vertical Columns - Families of elements

Alkali Metals	Main Group I	Li, Na, K, Rb, Cs	have 1 *s* vse
Alkaline Earths	Main Group II	Be, Mg, Ca, Sr, Ba, Ra	2 *s*
Halogens	Main Group VII	F, Cl, Br, I	2 *s* + 5 *p*
Noble Gases	Main Group VIII	He, Ne, Ar, Kr, Xe	2 *s* + 6 *p*

C. lose or gain vse's? - metals or non-metals
Metal elements tend to lose negative electrons forming positive ions (cations).
Metal elements are located left of the diagonal line in the *p* section
Non-metal elements tend to gain negative electrons forming negative ions (anions).
Non-metal elements are located right of the diagonal line.
The further an element is from the diagonal line the greater its metal or non-metal character. Elements that border the line are often called semi-metals.

Applications of Periodic Table Information

A. Determining **CHARGES** of common ions: (depends on location of element in P.T.)
1. *MAIN GROUP* elements: number of electrons lost (by metals) or gained (by non-metals) is predicted by number of "steps" to nearest noble gas.
2. TRANSITION elements: All share a common +2 charge, with other charges.
3. INNER-TRANSITION elements: All share a common +3 charge " " " "
Determine expected ion charges for the following elements: Na, Cl, Ba, O, Ga, P

B. Determining **FORMULAS** for simple *BINARY* compounds of MAIN GROUP elements
1. Cation of a metal element combined with an anion of a non-metal element forms an IONIC compound. The formula is the simplest ratio of ions that leads to charge neutralization. Determine expected formulas of binary compounds from ions of the following pairs of elements: Na & Cl, Mg & Br, K & P, Ba & As

2. Two or more non-metal elements form MOLECULAR compounds (or ions) Formulas for molecular compounds are not as easily predicted as for ionic compounds because no charges are present. In addition, the same set of elements often form more than one molecular compound (Law of Multiple Proportions) . Suggest reasonable formulas for molecular compounds containing the pairs of elements shown: C & O, N & O, S & Cl, N & Cl

C. Naming of BINARY Compounds:

1. BINARY IONIC compounds: name the metal first (as the element) and then name the non-metal - but change its ending to -IDE.
Determine the names of the ionic compounds met above.

2. BINARY MOLECULAR compounds: name more electropositive non-metal element first (it has lesser non-metal character) and then name the more electronegative non-metal element (it has greater non-metal character) - but change its ending to - IDE. Determine the names of the molecular compounds met above.

D. Naming of other compounds / ions:

1. Polyatomic Molecular ions: (refer to text Table 2.2 on page 43)
Molecular ions often involve oxyanions and corresponding oxyacids.
Be familiar with the following:

nitric acid and nitrate salts — nitrous acid and nitrite salts
sulfuric acid and sulfates — phosphoric acid and phosphates
acetic acid and acetates — carbonic acid and carbonates

Determine the names of the following examples:

$Ca(C_3H_5O_2)_2$, KSCN, MgC_2O_4

2. TRANSITION metal cations: (can have variable positive charges)
The positive charge is written as a Roman numeral and spoken as a number.
For example, Ti(III) and "titanium three cation"

The charge on a transition metal cation can be assigned when the charge of the remaining component in the compound is known. Consider the compound TiO_2 Determine the charge (i.e., oxidation state) of the titanium and then name the compound. This is a binary compound so oxygen has it lowest oxidation state of minus 2. There are TWO oxygen (with a net minus FOUR charge) for each titanium. In order to neutralize the charge titanium must have a plus four charge. The compound name is written as ti*tanium(IV) oxide* and spoken as "titanium four oxide". Determine the names of the following examples:

$FeCl_2$, $CrBr_3$, $Ni(C_2H_3O_2)_2$, $TiCl_4$, VPO_4, $Co_2(SO_4)_3$

<u>Isotopes and atomic weights - as they appear in the periodic table.</u> ISOTOPE = atoms of SAME element with different numbers of neutrons. Mass numbers (i.e., the sum of protons and neutrons) are integers, but atomic masses as found in the periodic table are not. This is because the atomic mass of an element takes into account the masses of all of its isotopes - according to their abundances, whereas mass numbers are for single isotopes only. Abundances of isotopes for a given element does not change, although it is unique for each element. This uniqueness is reflected in different atomic masses of the elements. Atomic masses are weighted-average masses, weighted according to isotopic abundances...

$$\text{Atomic Mass} = \sum \text{(abundances)*(isotope mass)}, \quad \text{for all isotopes.}$$

Consider the following examples:

a. Chlorine has isotopes of mass numbers 35 and 37 with abundances of about 75% and 25% respectively. What is the atomic weight of chlorine?

b. Boron has two major isotopes of mass numbers 10 and 11. The atomic mass of B is 10.811. What are the abundances of the two isotopes? Repeat for copper with mass numbers of 63 and 65.

c. Silicon has three major isotopes of mass 27.977, 28.977 and 29.974 amu. The abundance of ^{28}Si is 92.21% and the atomic mass of silicon is 28.086 amu. What are the abundances of the other two isotopes?

SOLUTIONS

Solubility

1. The specified temperature (20 deg.C) requires selection of the $\left[\frac{7.1\ g\ KClO_3}{100\ g\ H_2O}\right]$ conversion factor.

? grams water = 25.0 g K Cl O$_3$ $\left[\frac{100\ g\ H_2O}{7.1\ g\ KClO_3}\right]$ = 352 grams = 352 mL water

2. The specified temperature (100 deg.C) requires selection of the $\left[\frac{57\ g\ KClO_3}{100\ g\ H_2O}\right]$ conversion factor.

The problem is of a "What if?" testing type. Using either given mass of solute (10.5 g) or solvent (40.0 mL), to calculate the quantity of the other component – and then compare to its amount actually present.

?How many grams KClO$_3$ = 40.0 mL water $\left[\frac{57\ g\ KClO_3}{100\ g\ H_2O}\right]$ = 22.8 g KClO$_3$ can be dissolved

Compare this to the 10.5 g KClO$_3$ actually present, shows that all of the 10.5 g will dissolve.

3. The specified temperature (20 deg.C) requires selection of the $\left[\frac{7.1\ g\ KClO_3}{100\ g\ H_2O}\right]$ conversion factor.

Although all of the 10.5 g solute are dissolved at 100 deg.C, this is not necessarily true at 20 deg.C. However, the quantity of solvent (40.0 mL) does not change. Once again, another "What if? test type. Use the unchanging volume of solvent to find how much solute can remain in solution at 20 deg.C…

? g KClO$_3$ = 40.0 g water $\left[\frac{7.1\ g\ KClO_3}{100\ g\ H_2O}\right]$ = 2.84 g solute will remain dissolved

Any amount of solute in excess of 2.84 grams must "precipitate" out of solution, i.e., it will be present as undissolved solid.

total qty solute	10.5 g
solute dissolved	–2.84 g
solute precipitated	**7.7 g**

Quantitative applications of Dalton=s model

1. This problem illustrates the Law of Constant Composition: two substances are the same if they have the same composition. Compositions are compared according to the weight ratios of substances present. So find weight ratio of any two components in the compounds. The ratios Ca / Cl, or Ca / cmpd, or Cl / cmpd (or any of the inverses) could be used. Let's find the Ca / Cl ratio of both compounds.

First preparation:

cmpd = (Ca+Cl)	4.421
Ca in cmpd	–1.593
Cl in cmpd	**2.828**

Ratio Ca / Cl in cmpd = $\left(\frac{1.593\ g\ Ca}{2.828\ g\ Cl}\right)$ = **0.5633**

Second preparation:

cmpd = (Ca+Cl)	6.280
Cl in cmpd	–4.017
Ca in cmpd	**2.263**

Ratio Ca / Cl in cmpd = $\left(\frac{2.263\ g\ Ca}{4.017\ g\ Cl}\right)$ = **0.5634**

Conclusion: Ca / Cl weight ratios are identical to 4 sig.fig. (via the data furnished), so the two preparations are for the SAME compound.

2. This problem employs the weight ratio of a specific compound (Epsom Salt) and (a) coverts it to a percentage, and (b) shows how it may be applied to different quantities of the same compound. A hydrated substance in the solid state contains specific quantities of water embodied in the crystalline solid. The water may be removed upon heating and an anhydrated substance remains.

(a)

Hydrate =(anhydrate + water)	2.317
anhydrate	–1.130
water of crystallization	**1.187**

percent = 100 x part / whole

% water cryst. = $\left(\frac{1.187\ g\ H_2O}{2.317\ g\ Hydrate}\right)$ = 51.23 %

(b) ? g hydrate = 3.50 g anhydrate $\left[\frac{2.317\ g\ hydrate}{1.130\ g\ anhydrate}\right]$ = 7.176 g anhydrate

3. Two (or more) elements can be present in more than one compound (NO, N_2O, NO_2, N_2O_3,…for example). Compare the first two examples: relative to one oxygen atom in both compounds - there are two nitrogen atoms in the second compound as compared to one in the first. Because twice the number quantity of atoms must have twice the mass, then there are twice the mass of nitrogen atoms in the second compound as compared to the first – relative to the same mass of oxygen in both compounds. The small whole number ratio of masses of one element present in two compounds, relative to a fixed mass of another element, illustrates the Law of Multiple Proportions.

To begin with, determine same mass ratios of elements in both comounds			
CMPD I		CMPD II	
cmpd	24.39g	cmpd	17.950
element	–11.983	oxygen	–10.117
oxygen	12.407	element	7.833
ratio element / oxygen = **0.9658**		ratio element / oxygen = **0.7742**	

Firstly, recognize the different element / oxygen weight ratios of the two compounds means the Law of Constant Composition is not obeyed here; the two compounds are clearly different substances.

Secondly, recognize that an appearing non-fraction such as 0.9658 or 0.7742 becomes a fraction if ONE is considered the denominator in both cases, i.e., 0.9658 = $\frac{0.9658}{1}$, and 0.7742 = $\frac{0.7742}{1}$.

Thirdly, recognize both ratios (as fractions) have the same denominator, i.e., ONE, and since the ratio is element / oxygen, the ONE refers to oxygen in both compounds, and therefore is based on the same quantity of oxygen in both compounds. So these two ratios show the mass of element in compound I, and the mass of element in compound II – relative to the same mass of oxygen in both compounds.

It only remains to compare the masses of element in the two compounds – relative to the same mass of oxygen in both compounds, i.e., divide the two ratios. The resulting new ratio is expected to be a ratio of small integers.

$\frac{0.9658}{0.7742}$ = 1.247, or $\frac{1.247}{1}$. Is (1.247 : 1) a ratio of small integers? A further step is required…

Multiply numerator and denominator by successive integers, as shown in the table to the right, to find which yields integers for both (to within sig.fig. via the data). The data have four sig.fig. A multiplier of FOUR gives **4.990** for the numerator. This differs from the integer FIVE by only ONE percent, and is taken as value sought.

Multiplier	numerator	denominator
1	1.247	1
2	2.495	2
3	3.742	3
4	**4.990**	**4**
5	6.237	5
etc,		

A proper statement for the Law of Multiple Proportions in this case would be:
for the same amount of oxygen in both compounds, there are FIVE element atoms in the first compound, for every FOUR in the second compound.

4. Find mass ratios of elements in the two compounds to test whether or not they are the same.

Cmpd I		Cmpd II	
cmpd	100.0	cmpd	100.0
nitrogen	–30.4	oxygen	–63.2
oxygen	69.6	nitrogen	36.8
ratio O / N	**2.289**		**1.717**

Mass ratios of O / N are not the same so the two compounds are also not the same.

The ratio of oxygen in cmpd I to oxygen in cmpd II – relative to the same amount of nitrogen in both – is…

$$\frac{O\ cmpd\ I}{O\ cmpd\ II} = \frac{2.289}{1.717} = \frac{1.333}{1}$$

Is (1.333 : 1) a small whole number ratio?

Multiply numerator and denominator by successive integers, as shown in the table to the right, to find which yields integers for both (to within sig.fig. via the data). The data have four sig.fig. A multiplier of THREE gives **3.999** for the numerator.

Multiplier	numerator	denominator
1	1.333	1
2	2.666	2
3	**3.999**	**3**
4	5.332	4
5	6.666	5
etc,		

A proper statement for the Law of Multiple Proportions in this case would be:
for the same amount of nitrogen in both compounds, there are FOUR oxygen atoms in the first compound, for every THREE in the second compound.

5.

	^{208}**Pb**	**H**	^{2}**H**	**K**$^{+}$	**Cl**$^{-}$	^{238}**U**	**Sb**$^{3+}$	**Se**$^{2-}$	**Pb-207**
protron	82	1	1	19	17	92	51	34	82
neutron	208-82= 126	1-1=0	2-1=1	39-19= 20	35-17= 18	238-92 =146	122-51= 71	79-34= 45	207-82= 125
electron	82	1	1	18	18	92	48	36	82

6.

symbol	atomic #	mass #	# electrons	# protons	#neutrons	charge	atomic weight
F^{1-}	9	19	10	9	10	–1	18.998
N	7	**14**	**7**	7	7	**0**	14.007
Al^{3+}	13	27	**10**	13	**14**	**+3**	**26.98**
S^{2-}	**16**	32	18	16	16	**-2**	32.066

Applications of Periodic Table Information

elements	Na	Cl	Ba	O	Ga	P
expected charge	+1	–1	+2	–2	+3	–3

metal / non-metal	Na & Cl	Mg & Br	K & P	Ba & As
binary compound	NaCl	$MgBr_2$	K_3P	Ba_2As_3

non-metal / non-metal	C / O	N / O	S / Cl	N / Cl
expected formula of molecular compound	**CO, CO_2, C_2O_3**	**N_2O, NO, N_2O_3, NO_2**	**S_2Cl_2, SCl_2 SCl_4**	**NCl_3**
names of molecular compounds	**carbon monoxide carbon dioxide dicarbon trioxide**	**nitrous oxide nitric oxide dinitrogen trioxide nitrogen dioxide**	**disulfur dichloride sulfur dichloride sulfur tetrachloride**	**nitrogen trichloride**

some oxyacids and corresponding oxyanions

nitric acid HNO_3	nitrate anion NO_3^{-1}
nitrous acid HNO_2	nitrite anion NO_2^{-1}
sulfuric acid H_2SO_4	sulfate anion SO_4^{-2}
phosphoric acid H_3PO_4	phosphate anion PO_4^{-3}
acetic acid $HC_2H_3O_2$	acetate anion $C_2H_3O_2^{-1}$
carbonic acid H_2CO_3	carbonate anioni CO_3^{-2}
hydrosulfuric acid H_2S	sulfide anion S^{-2}

Determine names of:

$Ca(C_3H_5O_2)_2$	KSCN	MgC_2O_4
calcium propianate	potassium thiocyanide	magnesium oxalate

$FeCl_2$	$CrBr_3$	$Ni(C_2H_3O_2)_2$	$TiCl_4$	VPO_4	$Co_2(SO_4)_3$
iron(II) chloride	chromium(III) bromide	nickel(II) acetate	titanium(IV) chloride	vanadium(III) phosphate	cobalt(III) sulfate

Isotopes and atomic weights - as they appear in the periodic table.

Atomic weights are weighted-average weights, weighted according the abundances of the isotopes that make up the element. This is shown in the following expression:

Atomic Weight = $\sum (\textit{mass of isotope})(\textit{fraction abundance of isotope})$

Although abundances are often given as percentages, they need to be reduced to decimal values (divide % by 100) before introducing them into the expression. In this form, the sum of all abundances will add to 1.000

i.

chlorine	isotope # 1	isotope # 2
mass	35	37
abundance	0.75	0.25 (approximate values to illustrate calculation)

at.wt. Cl = (35 x 0.75) + (37 x 0.25) = 35.5

Actual isotopic abundances of Cl are 0.775 and 0.225. Use of these values would result in the periodic table value for Cl, i.e., 35.45

ii. Let abundance of ^{10}B = x, and that of ^{11}B = y, then according to the above expression:

$$10.811 = (x)(10) + (y)(11)$$

A second relationship exists between abundances x and y. When expressed as fractions their sum must add to one.

$$x + y = 1.000$$

Substitution (for y) results in the expression...

$$10.811 = (x)(10) + (1.00 - x)(11)$$

and solving this shows that x = 0.189, so y = 0.811.

As percentages, Elemental boron is composed of 18.9 % of the ^{10}B isotope, and 81.1 % of the ^{11}B isotope.

Repeat for copper: 63.546 = (x)(63) + (y)(65); x = 0.727

iii. Two related expressions for silicon are:

$$28.086 = (0.9221)(27.977) + (x)(28.977) + (y)(29.974)$$

and, $x + y = 1.0000 - 0.9221 = 0.0779$

Substituting and solving shows that x = 0.0467, and y = 0.0312 as fraction abundances.