Natural Science

Cebu Normal University

1st SEM | AY 2013-2014

Units and Measurements

Matter

Atoms, Elements, Compounds, Mixtures

Balancing Equations

Moles

Electron Configuration

INSTRUCTOR: Mr. Bryan Vincent E. King

NOTE: *ERRORS ARE STILL PRESENT IN THIS COPY OF THE NOTES.*

TRY YOUR BEST TO NOTE AND CORRECT THEM FOR YOUR STUDY.

UNITS AND MEASUREMENTS

In our world, we have the smallest thing-- an atom; and even a larger thing--the universe. In order to measure these quantitatively, we have to know about units.
For unit of length, we have meter.
For unit of time, second.
For unit of mass, the kilogram.

We have many derived units which we use everyday such as centimeters, feet, kilometers, light years, pounds, metric tons, milliseconds, days, months.

We will be using mostly **SI** units or what we call as **metric system** because it can be a bit difficult to remember all the conversion factors. 12 inches in a foot, 2.54 centimeters in an inch, 3 feet in a yard. See? We have so many YET we will have to know a few of them but we will go through the process together. Just so you know, the other system of measurement is the **British system** which is ironic because the British themselves don't use it much--the Americans do.

Length, time, and mass -- these are the three (3) **fundamental quantities**. We shall write length as capital L, time as T, mass as M.

LENGTH

They have this long, gold stick in the Museum of Weights and Measure in Paris and took the distance from the north pole down to the equator and that turned out to be 10 million meters and they divided their result by 10 million meters and said, "this length is going to be a meter." The problem with that is the gold stick itself.

[question] What do you think happens when you take that gold stick (which, in reality, is probably mixed with other metals) and measure something on a really hot day?

It would expand. This also explains why roads and buildings have cracks on the walls--it's because of heat forcing that expansion. In order for this problem to be solved, we took something that doesn't change--a constant, we call it and it is the **speed of light**. We now define a **meter** as *"the length it takes light to travel in vacuum in 1/299,792,458 of a second"* or almost 300 millionth of a second.

MASS

Before we continue with mass, I would like to ask another question.

[question] What is the difference between weight and mass?

[question] Follow up question: Is our mass the same here as on the moon?

Originally, a kilogram was thought to be about 0.1 m^3 of water. Now, the standard is *a platinum-iridium cylinder* kept at the French Bureau of Weights and Measurements. News reports say the mass of that cylinder has changed these past few years.

TIME

In the past, time was defined as some fraction of the average of the solar day, getting the average time it took the sun from arrival to the highest point in the sky. Of course, you can see problems with this. Depending on where you measure it, the values should vary. One reason is the tilt of the Earth allows some areas to have sun 12 hours a day and 12 hours a night, but the tilt also allows other areas such as Alaska to get sunlight almost 24 hours a day. The key word there is almost. If you were there, you can see the sun all day and the sun may set for about 2 hours.

In order to standardize how we get time today, we have a calibrated atomic clock. Cesium is bombarded with microwaves of some frequency which allows the Cs-133 atoms to undergo a transition from one state to another. In a nutshell, a second is defined as a certain number of *oscillations* of a cesium-133 atom roughly oscillating at about 9 billion cycles a second.

UNIT PREFIXES and SCIENTIFIC NOTATION

You probably have already heard about kilograms, centimeters, and all that but those words before grams and meters are called prefixes. So when we say a thousand grams, 1000g and 1 kg. So visibly you can see 1000 is a kilo. 100 centimeters makes a meter so centi is 1/100th. Doing it this way seems messy and too wordy. It is necessary, then, to introduce scientific notation.

Here are some basic examples:

$$EXAMPLE1 : 1,300,000.0 = 1.3x10^{6}$$
$$EXAMPLE2 : 0.00027 = 2.7x10^{-4}$$

The scientific notation (seen on the right hand side) is fairly simple to do and we do this because some numbers are either too large or too small to write. For example, the measured rest mass of an electron is about $9.11x10^{-31}$ kg. Writing it this way--0.000000000000000000000000000000911, is just visually unappealing and difficult to work with.

So what you do is move the decimal point in a way you only have one digit on the left. For example, 503.98. Move the decimal point 2 times and it becomes 5.0398. What about that x10? The number of times you moved it is the number that you find there. So the answer is now $5.0387x10^{2}$. But notice the second example has a negative value on its exponent. That is because if you move the decimal point to the left, that becomes negative. In effect, moving to the right makes the exponent's value positive.

Exercises:

Convert the following to scientific notation.

1.) 9437531.81	6.) 0.0929
2.) 0.0000016	7.) 9310000000.5
3.) 2390000000	8.)0.000000003281
4.) 6895	9.) 0.519
5.) 86,400	10.) 5.0

Exercises:

Convert the following to decimal notation.

1.) 6.85 x 10-5	6.) 746 x 10^0
2.) 1.67 x 10^{-27}	7.) 0.277 x 10^{-7}
3.) 1.0 x 10^4	8.) 0.02832 x 10^2
4.) 1.074 x 10^{-9}	9.) 3.788 x 10^1
5.) 30.0 x 10^6	10.) 1055

By now you have an idea how to work with scientific notation and converting them back and forth. What we have next is a way to write some of the notations in words. We can't go around saying, "oh, I weigh 6.5x10^1 kg" or to the doctor, "doc, I'm 1.43x10^{-2} centimeters". It's a bit impractical. Thus, it is necessary to know SOME of these **power of 10 prefixes**.

10^{-9} = nano	**10^3 = kilo**
10^{-6} = micro	**10^6 = mega**
10^{-3} = milli	**10^9 = giga**
10^{-2} = centi	

LENGTH:	**MASS:**
1 nm = 10^{-9} m (a few times the size of an atom)	1 ug = 10^{-6}g = 10^{-9} kg (mass of a small dust particle)
1 um = 10^{-6} m (size of living cells and bacteria)	1 mg = 10^{-3} = 10^{-6} kg(mass of grain of salt)
1 mm = 10^{-3}m (diameter of a ballpoint pen)	1 g = 10^{-3} kg (mass of paper clip)
1 cm = 10^{-2}m (diameter of your little finger)	
1 km = 10^3m (a 10-minute walk)	

TIME:
1 ns = 10^{-9} s (time for light to travel 0.3m)
1 us = 10^{-6} s (time for an orbiting space shutting to travel 8mm)
1 ms = 10^{-3} s (time for sound to travel 0.35m)

DIMENSIONAL ANALYSIS

When we place things in brackets, for example, [speed], what we mean here is the dimensions. So speed takes into account the dimension of length and time. Technically, we say

$$[speed] = \frac{[L]}{[T]} \tag{1.1}$$

Little did you know that you're now embarking the understanding of what we call **dimensional analysis.**

Several other examples:

$$[volume] = [L]^3 \tag{1.2}$$

$$[density] = \frac{[M]}{[L]^3} \tag{1.3}$$

$$[acceleration] = \frac{[L]}{[T]^2} \tag{1.4}$$

All other quantities can be derived from the three (3) fundamental quantities.

Dimensional analysis will come in useful when we do conversion.

UNIT CONVERSIONS

We cannot help it if we have to convert units. If we go to Worlds of Fun to purchase tokens, we need to exchange our 5-peso coin with a WOF Token. If we go to another country, we have to exchange our Philippine money with their money (ex. PH to US). That's why we have the Foreign Exchange Market. It has become a business of buying and selling dollar since the prices fluctuate. Buy when the dollar is low, and sell when the dollar is high. So in order for us to have this conversion and some sense of consistency (since in the PH we use Peso), we must learn about conversion.

One thing to take note is equations must be **dimensionally consistent**. In other words, if we talk about the equation, d=rt, or

$$d = rt$$

$$[L] = \frac{\frac{[L]}{[\cancel{T}]}}{[\cancel{T}]} = [L]$$

A clearer example:

$$r = 10m/s; t = 5s$$

$$d = \frac{\frac{10m}{\cancel{s}}}{5\cancel{s}} = 2m$$

Exercise: Prove the following equations using Dimensional Analysis

1.) $x = v_0t + \frac{1}{2}at^2$

2.) $v_f = v_i + at$

3.) $v_f^2 = v_i^2 + 2ax$

Before that, however, you *also* need to know some basic conversion factors. While it is impossible, for now, to know everything, here are some important ones to know.

LENGTH	**VOLUME**
1 m = 100 cm = 1000 mm 1 km = 1000 m 1 in = 2.54 cm **1 m = 3.28 ft** 1 mi = 1.609 km 1 yd = 3 feet **1 ft = 12 in**	1 liter = 1000 cm^3 1 gallon = 3.788 liters **TIME** 1 min = 60 s 1 h = 3600 s 1 d = 86,400 s
MASS 1 kg = 1000 g = 2.2 lbs*	**POWER** 1 hp = 746 W

So for example, if we were to convert 1.84 in^3 to cm^3,

$$1.84in^3 = (1.84in^3)\left(\frac{2.54cm}{1in}\right)^3$$

$$(1.84\cancel{in^3})\left(\frac{2.54cm}{1\cancel{in}}\right)\left(\frac{2.54cm}{1\cancel{in}}\right)\left(\frac{2.54cm}{1\cancel{in}}\right)$$

$$= 30.2cm^3$$

Exercise: (May be done with or without calculators for discussion purposes)

1.) 100 cm -> ft	6.) 1.00 yd -> m
2.) 1 month (30 days) -> sec	7.) 40 km/h -> m/s
3.) 1.00 km -> ft	8.) 3.0 m/s -> km/h
4.) 1.00 ft -> cm	9.) 5.0 m/s^2 -> ft/s^2
5.) 1.00 km -> mi	10.) 100.0 cm^3 -> in^3

SIGNIFICANT FIGURES

When you measure something, the number of digits will depend on the instrument you are using. For example, if you're using a regular ruler, you can only measure something by up to one decimal place. Say, a pencil box with length 12.7 cm. It can't be 12.700 because the measuring device isn't all that accurate. It is important to mention here something we call **uncertainty**. In anything you measure, big or small, there is always some uncertainty. The measurement of the pencil box, if re-measured multiple times, you are bound to get values of 12.6, 12.7, 12.7, 12.6, 12.8. We can infer from this that the *uncertainty* in this case is 0.1. We write this as 12.7 +/- 0.1 cm but not everything has a "written" uncertainty. When measuring a book's thickness, for example, at 2.91 mm, we know it has three digits. Those three digits we call **significant**. We know the first two digits are significant because we are almost sure it is at 2.9 mm but we are quite uncertain about the 0.01 mm. That may seem small but put it this way--if a given distance is about 114 km, you are certain of the first two digits but you may be uncertain by as much as 1 km.

Rules in Significant Figures

1.) All non-zero numbers (1,2,3,4,5,6,7,8,9) are always significant.

Ex. 54.3 [3 sig. fig.]

2.) All zeroes between non-zero numbers are always significant.

Ex. 120.005 [6 sig. fig.]

3.) Zeros to the right of a nonzero digit but to the left of a decimal are not significant, unless indicated to be so.

Ex. 1200 [2 sig. fig.]

4.) Zeros to the right of a nonzero digit but to the left of a decimal are not significant, unless indicated to be so.

Ex. 0.0152 [3 sig. fig.]

5.) Zeros to the right of a decimal and to the right of a nonzero digit are significant

Ex. 86.100 [5 sig. fig.]

EXERCISE How many significant figures are present in the following numbers?

Number	# Significant Figures
48,923	
3.967	
900.06	
0.0004 (= 4 E-4)	
8.1000	
501.040	
3,000,000 (= 3 E+6)	
10.0 (= 1.00 E+1)	

What is interesting to note here is if we change the number provided into scientific notation, we must also follow the number of significant digits.

Performing Operations Following Significant Figures

Addition & Subtraction: Largest uncertainty or least number of decimal places

If we measure larger things, we can use meter sticks or measuring tapes which usually have an precision of about 0.1 but with smaller items, we use the vernier caliper with precision of 0.01. Thus, if something is measured with the sum of its parts (larger lengths to very intricate and small lengths), the final answer must be *certain* only to the point of the largest uncertainty. You can't be sure the total length of an object is 55.651 cm if one measurement was just 8.4 cm.

Example:

$$35.15 + 28.901 - 8.4 = 55.651 cm$$
$$= 55.7 cm$$

$$5.18x10^5 + 3.441x10^3 - 8.04x10^1 = 5.213606x10^5$$
$$= 5.21x10^5$$

Multiplication & Division: Number with fewest significant figures

When measurements are multiplied, they can only be certain to the least number of significant figures. If we were to say the dimensions of a cube are as follows: Length--3.53cm, width--10.43cm, height--5.40cm, the maximum number of significant figures of its volume would only be three (3) since length and height have a certainty up to that amount (although technically the last digit tends to be uncertain).

Example:

$$3.53 \times 10.43 \times 5.40 = 198.8167 cm^3$$
$$= 199 cm^3$$

$$\frac{1.25x10^2 \times 3.5x10^3}{4.1x10^{-8}} = 1.06707x10^{13} = 1.1x10^{13}$$

Combination

This will look slightly difficult but it should be very doable. Like any mathematical equation, you do whatever operation must be done first. You can follow the known "MDAS", fraction, square..etc. ONLY ROUND OFF WHEN YOU ARRIVE AT THE FINAL ANSWER. Use the FEWEST number of significant figures.

EXAMPLE 1

$$\frac{5.358-0.43185}{2.14}=\frac{\underline{4.926}15}{2.14}\cdots\frac{3 decimal places}{3 sig.fig.}\cdots\frac{4 sig.fig.}{3 sig.fig}$$
$$=2.3019=2.30$$

If you now count the number of significant figures for the numerator, you will see it has a total of 4 sig. fig. The denominator only has 3. Thus the final answer, 2.30, should have only 3 sig. fig.

EXAMPLE 2

$$\frac{84.4+0.48-13.2}{17.000}=\frac{71.68}{17.000}\cdots\frac{3 sig.fig.}{5 sig.fig.}$$
$$=4.21647=4.22$$

EXAMPLE 3

Here, we do the division first before adding them.

$$412.512+\frac{61.8}{3.0};\quad 412.512+\frac{61.8}{3.0}\frac{\leftarrow 3 sig.fig.}{\leftarrow 2 sig.fig.}$$

$$412.512+20.6=\underline{43}3.112=430$$

Notice 20.6 has only 1 decimal place (thus having 3 significant figures) while 412.512 has 3 decimal places (but 6 significant figures). The final answer must have 2 significant figures and just 1 decimal place BUT the final answer is at 433.112. It is very difficult to have 2 sig. fig and a decimal place. The least number of significant figures is now just 2, of which the final answer should have 2.

PRACTICE FOR EXAM (NAT SCI)

PART I & II. Scientific Notation (S.N.) and Significant Figures
Convert to scientific notation if given the standard. Convert to standard if given the S.N.
Indicate the number of significant figures.

EXAMPLE:

GIVEN	CONVERTED	SIG. FIG.
1.15×10^{6}	1 150 000	3
1.8×10^{-6}	0.0000018	2

1.) 23,000	**6. 0.0286**
2.) 256,000	**7. −0.75 20**
3.) −1,240,000	**8.) −0.00004050**
4.) 6	**9.) −2.05**
5.) 0.008	**10). 0.040000**
1.) 3.86×10^{5}	**6.) -6.00×10^{-5}**
2.) -5.003×10^{3}	**7.) 3.00×10^{8}**
3.) 401.32×10^{-3}	**8.) 5.07×10^{6}**
4.) 8.000×10^{-4}	**9.) $300,000,000 \times 10^{0}$**
5.) 7.0×10^{-8}	**10.) 5.51×10^{-9}**

PART III. Show the following equations are dimensionally correct.

$$dist. = rate \times time$$

EXAMPLE: $$[L] = \frac{[L]}{[\not{T}]}\frac{[\not{T}]}{} = [L]$$

1.) $x = V_i t + \frac{1}{2}at^2$

2.) $a = \frac{V_f - V_i}{t}$

PART IV. Convert the following.
1.) 35 in -> __ mi
2.) 40 km/h -> __ ft/s
3.) 47 miles per gallon (mpg) -> __ kilometers per liter (km/L); 1 gallon = 3.78541 L
4.) Using only this conversion, 1 in = 2.54cm, find the number of
(4-a) kilometers in 1 mile
(4-b) feet in 1 kilometer
5.) Using only the following conversions, 1 L = 1000cm^3 and 1 in = 2.54 cm, express 0.473 L into cubic inches

PART V. Answer the equations below and follow correct number of significant figures.

1.) $\frac{(125)(3481)(14,564)}{(241)(4199)(5561)}$	4.) $\frac{3.1+15}{8}$
2.) $15.85 + \frac{123.65 - 31.1}{0.81}$	5.) $3.14159x10^{9} \div 84.3x10^{-2}$
3.) $\frac{(1.65x10^{23})(2.74x10^{16})}{(5.781x10^{-10})(8.63x10^{-9})}$	6.) Calculate the area (length x width) of a rectangular plate give length of 21.3 cm and width 9.8 cm

CHEMISTRY

We mentioned earlier that mass is the amount of "stuff" in an object. When we say **matter**, this is the "stuff" and these "stuff" have different characteristics. Water is soft to the human touch compared to a large rock. The shape circle is quite different than that of a square block of wood. To segregate them into easier chunks, we say we observe an object's **physical** and **chemical** properties. **Physical properties** are those which *stay with the material* without interacting with another substance. For example, human blood is usually dark red, the boiling point of water is at about 100 °C (at 1 atm). Color and boiling point are examples of physical properties. **Chemical properties** are those that a substance shows as *it changes into or interacts with another substance/s*. For example, how flammable and corrosive a material is--these are examples of chemical properties.

[question] Is water melting a physical or chemical reaction?

THREE STATES OF MATTER

It has become "common" knowledge of what the three states of matter are--solid, liquid, and gas. There are other states of matter but for now, we will not consider them. Since these are known, how are they defined?

[question] Define what makes a solid a solid, liquid a liquid, gas a gas.

If you have defined water to be "soft", remember water is very hard too. Think about it. Nobody jumps into a swimming pool a very high platform with arms wide open from because it would hurt. The states are actually defined by how they make use of the container they are in.

Solid - fixed shape and does not conform to the shape of the container
Liquid - conforms to the shape of the container but fills to the extent of the liquid's volume (meaning you can't fill a 1-L bottle with 500-mL of liquid)
Gas - conforms to the shape of the container (think about it--LPG tanks) but it fills the entire container thus does not form a "surface"

Physical and Chemical Change

All three physical phases may exist for a substance at the same time depending on the **temperature** and **pressure** of the surroundings. When temperature increases, substances tend to melt becoming liquids and eventually to vapor. If we reverse the process (decrease temperature), condensation occurs and later on solidification/freezing. We can infer that these **physical changes** are **reversible** and quite different from that of a **chemical change** which implies a complete change in substance such as the rusting of meta (where rust eats up the metal forming that brown and rough texture). We can summarize the changes:

- Physical change causes a change in phase/form but it is still the same substance while in chemical change may or may not visually change in phase/form but will change in composition.
- Physical change caused by temperature difference can usually be reversed but will not be the usual case for chemical change.

Example:

- melting of ice - physical change because if you freeze ice and melt it again, it is still "water"
- plant growing from seed - chemical change (seed uses air, fertilizer, soil, sunlight...etc.) because you can never get back the same seed again (note that when the plant produces flowers/seeds, these flowers/seeds are its children and not considered to be the same plant)

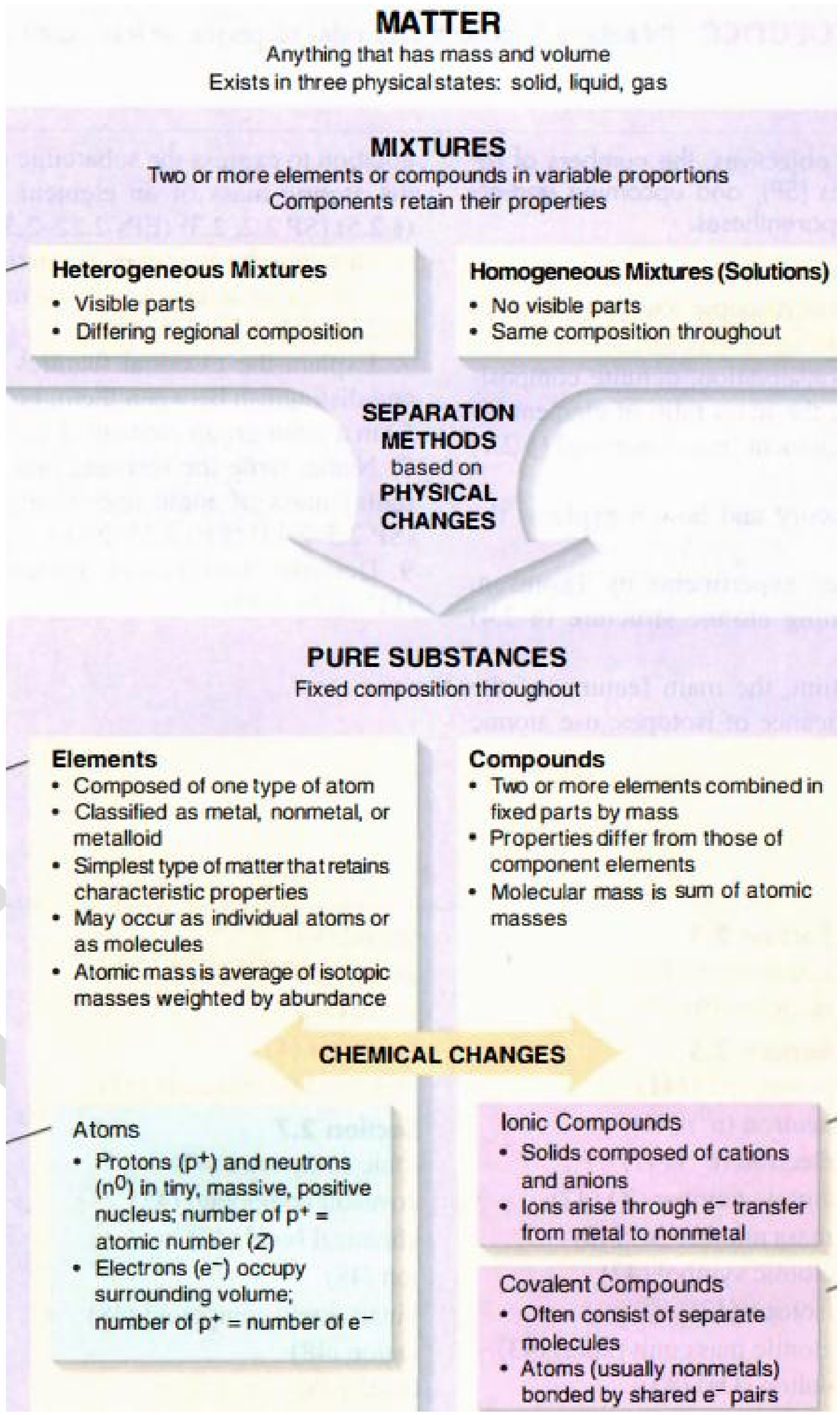
Melting - solid to liquid
Solidification/Freezing - liquid to solid
Evaporation - liquid to gas
Deposition - gas to solid
Condensation - gas to liquid
Sublimation - solid to gas

CLASSIFICATION OF MIXTURES

In this course, Natural Science (or Nat. Sci. Fund.), we shall not go into the naming of compounds as we might need several separate lectures on that. Instead, we shall proceed into the classification of mixtures.

Pure substances are very difficult to form and nearly all matter occur as some sort of mixture. Your concrete buildings are made up of mixtures and not just a pure element. Electronic devices have been 'doped' meaning 'impurities' such as antimony have been added to the semiconductors to increase the device's conductivity. We broadly categorize mixtures into two (2) namely *homogeneous* and *heterogeneous* mixtures.

A **mixture** is when you have various components into one 'thing'. A **homogeneous mixture** is when the components are not uniform and you can visually see the differences. Halo-halo is a very common example of a heterogeneous mixture as it has leche flan, ice, ice cream, bananas...etc. in one cup. A **homogeneous mixture** is where the composition of the mixture is uniform and you are unable to see visible boundaries. Small amounts of sugar mixed in water is an example. We can also call homogeneous mixtures as solutions. At this point, it may be necessary to show you a flowchart.



(Taken from Principles of General Chemistry by Silberg, p.61)

Scientists believe matter is made up of atoms. These **atoms** contain one nucleus and the electron cloud. It is interesting to note that each the atoms of each element contain a specific amount. For example, every single atom of oxygen holds 8 protons in its nucleus. The nucleus is where you find most of the atom's mass as the collective of the electron cloud do not hold much mass and for us we, can say the atom's electrons contain no mass. How many **electrons** will an atom have? For now, we assume atoms to be stable thus the *same number of positive charges should equal the number of negative ones. Thus, the number of electrons is equal to the number of protons.*

If we were to distinguish between an **atom** and an **element**, we say element is not specific about the amount. For example, if we have gold, that is gold and we are not talking about the amount. But when we deal with atoms, we mean the smallest part of the element (i.e. one gold atom).

When we have an atom, there are sub-atoms or sub-atomic particles and these are known to be the proton (p^+), electron (e^-), and neutron (n^o).

MASS AND CHARGE OF SUBATOMIC PARTICLES

Subatomic Particle	Charge	Mass (in amu)
Proton	+1	1
Neutron	0	1
Electron	-1	0

For our case, we assume the neutron to have a very close mass value to that of the proton (in reality, they differ but not by very much).

MASS NUMBER

The larger number we see in the periodic table for every element (i.e. for oxygen, 7.99), *we round that up* to 8. This number is the **mass number** which is the sum of the number of protons and neutrons.

ATOMIC NUMBER

The "smaller" number tells us the number of protons. Oxygen has the number 8, thus its atomic number is 8 and it also has 8 protons. Since the elements are said to be stable, it also has 8 electrons.

NUMBER OF NEUTRONS

To obtain the number of neutrons: We know the mass number is the sum of the number of p^+ and n^o and we know now the atomic number tells us the number of p^+. To get the number of neutrons:

# of neutrons = mass number - atomic number

Capitalization

What is of high importance when writing element symbols is the capitalization of the first letter. When we say calcium, that is Ca and not ca. Cobalt is written as Co, and not co.

Example:

Gold (Au) - 79 protons; 197 mass number; 197 - 79 = 118 neutrons; 79 electrons

Exercises:

1.) Find the number of protons, electrons, and neutrons for the element Silicon (Si), which is a major component of sand, and for the element Argon (Ar), which is found in most lightbulbs.

2.) What element has 17 protons?

3.) What element has 6 neutrons?

4.) What element has 8 electrons?

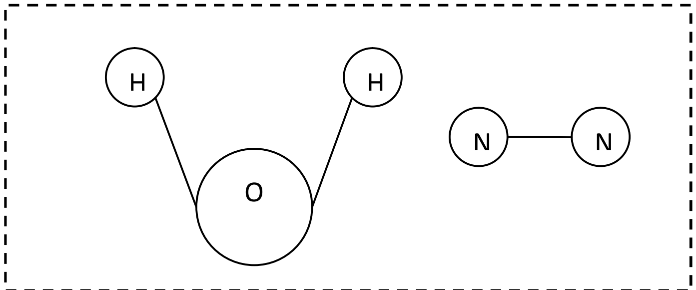
5.) How many elements have 15 protons?

6.) What is the atomic number of Manganese (Mn)?

7.) What is the atomic mass of Uranium (U)?

MOLECULE

A **molecule** is a combination of two or more atoms that are joined together usually through bonding. These can either be of the same element or of different ones. Example:



H_2O **N_2**

Water nitrogen gas

You can see there are at least **two atoms** for a molecule. There is one molecule of water above and one molecule of nitrogen gas.

COMPOUND

A **compound** is made up of at least two atoms of two different elements. For example, oxygen (O_2) is a molecule but not a compound. NaCl--we can have one molecule of this compound. Another example is H_2SO_4 (sulfuric acid). You can have many molecules of this acid and this is also a compound.

Example:

H_2SO_4

\# of atoms - 7 (2 H, 1 S, 4 O)
Is it a compound - yes
Is it a molecule - yes

Exercises:

1.) How many atoms are there in H_2O_2 (hydrogen peroxide which you can find in many pharmacies)? How many elements? Is it a compound? Is it a molecule?
2.) Which of the following are molecules? Xe, HNO_3, O_2, CO
3.) What is the minimum number of atoms in a molecule?
4.) What is the minimum number of elements in a compound?
5.) Do three atoms of hydrogen bond together to form a molecule, compound, or element? (HINT: element)

REVIEW: Matter exists either as an element, a compound, or a mixture.

IONS

An **ion** is an atom that has either gained or lost electrons. In general, elements the left of the periodic table lose electrons while those to the right gain them.

Positive and Negative Ions

A **positive ion** can be formed when an atom *loses* one or more electrons and is given a positive (+) charge. Just think of it when giving someone a hand at doing some work. It's a positive thing to "give". For **negative ions**, they *accept* electrons. Although you can have the analog of accepting things this way: "it is always better to give than to receive"; in this case, it is not that pleasant to hear but it works.

Examples:

Sodium	Na	11 protons	11 electrons	12 neutrons
Sodium ion	Na^+	11 protons	10 electrons	12 neutrons

Remember that when you have a positive ion, the element GIVES off electrons. In this case, it has a charge of +. Usually, a number is indicated. For example, Al^{3+}. This means the aluminum ion gives off three (3) electrons. But in this case, if it is just Na^+, it means +1.

Similarly,

Chlorine	Cl	17 protons	17 electrons
Chlorine ion	Cl^-	17 protons	18 electrons

Chlorine here gains 1 electron with a charge of "-" implying -1.

Forming Compounds from Ions

Perhaps a major focus in dealing with chemistry are compounds and how they form. Positive ions and negative ions will attract creating new compounds. When writing the chemical formulas, we will follow some basic rules:

- Positive ion comes first in the formula
- The number of negative charges must equal the number of positive ones
- Subscripts are added when necessary to have this equal number of negative & positive charges

Ex. H_2O is made of H^+ and O^{2-}. In order to remove the charges, these will be subscripts to the other ion. O's charge (-2) will be a subscript of H thus becoming H_2 without the negative sign. For H, since it has a charge +1, O will just be O_1 or O (since without any subscript, it is understood to be 1.)

For water, you now know it is H_2O but what does this tell us? There are 2 hydrogen atoms and 1 oxygen atom for every molecule of water. CO_2 has 1 carbon and 2 carbon atom for every molecule of carbon dioxide.

Other examples:

Al^{3+} and Cl^{-}	$AlCl_3$
Mg^{2+} and O^{2-}	Mg_2O_2, or better yet, MgO

The last example shows us simplification. We have 2 atoms of magnesium and 2 atoms of oxygen. By ratio and proportion, we can say for every one atom of magnesium we have one oxygen atom. We simply say, then, MgO instead of Mg_2O_2 and this simplification should be done whenever possible.

Exercises:

1.) Fe^{3+} and Cl^{-}
2.) Mg^{2+} and S^{2-}
3.) Ba^{2+} and N^{3-}
4.) Al^{3+} and O^{2-}
5.) Ca^{+} and O^{2-}

Also, how many atoms do you have in total?

A little more complex

Not all the time will we be dealing with two elements forming a compound (also known as **binary compoud**... ex. NaCl or salt). At times we will have something like H_2SO_4. SO_4^{2-}, NH_4^{+}, and NO_2^{-} are examples of what we call **polyatomic ions** which are defined as a grouping of two or more elements which stay together and act as a single ion unit.

To distribute the charges and subscripts properly, we make use of parenthesis. Example:

Al^{3+} and SO_4^{2-} together is $Al_2(SO_4)_3$

It may seem as if we are supposed to distribute the 3 in SO_4 similar to how we do it in math but many cases, it is not necessary. Also, you may be asked to identify how many atoms of aluminum, sulfur, and oxygen present in the compound. You can see there are now 2 atoms of aluminum, but how do you get S and O? If you were to distribute mentally the 3 in SO4, you would now see you have 3 S and 12 O because for O, you multiply 3 by 4 O's.

Other examples:

Ca^{2+} and PO_4^{3-}	$Ca_3(PO_4)_2$	3 Ca; 2 P; 8 O
$Li^{+}SO_3^{2-}$	Li_2SO_3	2 Li; 1 S; 3 O

Exercise:

1.) Ca^{2+} and OH^{1-}
2.) Ba^{2+} and NO_3
3.) NH_4+ and PO_4^{3-}

Also show how many atoms there are for each element.

THE CHEMICAL EQUATION

A chemical equation is a statement of what is happening in a chemical reaction using chemical formulas.

$$C + O_2 \quad -> \quad CO_2$$

In short,

Reactants yield -> products

The equation above (with the product, CO_2) tells us to create CO_2 or carbon dioxide, we see that carbon, C, (or charcoal) reacts with oxygen to produce carbon dioxide. Of course, charcoal alone won't really react with oxygen gas by itself as many of you probably have realized you need to "burn" the charcoal to produce CO_2.

Balancing Equations

You have probably heard of the law of conservation of energy... the law of conservation of momentum... the **law of conservation of mass**. For now, we are most interested in the latter which implies *mass is neither created nor destroyed in a physical or chemical reaction*. In a nutshell, the amount of reactants should be equal to the amount of products.

At this point, you might wonder "doesn't something disappear? what if we burn paper? or boil water? we lose some of the original material, don't we?" These questions are all valid. The answers are simple--whatever is seemed to be lost was converted to something else. In burning paper, we get ashes and probably some gas and that is where the "lost" material went. In boiling water, some of the boiled water "vaporized" or turned into gas and our human eyes can't really "see" gas.

Take for example the creation of water. When you combine hydrogen gas (H_2) and oxygen gas (O_2), we produce water. If you were to write it this way with blanks,

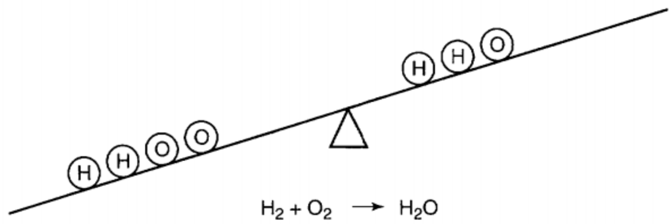
$$\_\_H_2 \quad + \quad \_\_O_2 \quad => \quad \_\_H_2O$$

But when you count both the reactants side and the product side, they would differ. On the reactant (left) side, you have 2 H and 2 O. On the product side (right), you have 2 H but only 1 O. To balance them out, we add a **coefficient**.

$$\underline{\;2\;}H_2 \quad + \quad \_\_O_2 \quad => \quad \underline{\;2\;}H_2O$$

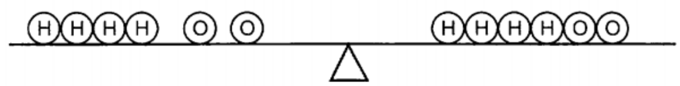
Now, on the reactant side, we have 4 H and 2 O. On the product side, we have 4 H and 2 O.

Think of it this way:



$H_2 + O_2 \rightarrow H_2O$

Unbalanced equation



$2H_2 + O_2 \rightarrow 2H_2O$

Balanced equation

This is called **balancing equations** telling us what to mix and what the quantities are for each. Balancing may take you a little work--trial and error, mix and match. It is suggested you use pencil when writing your "draft" answers before using a pen. Practice will greatly help you especially during quiz time.

Exercise:

1.)	**_CH_4**	+	**_O_2**	->	**_CO_2**	+	**_H_2O**
2.)	**_C_2H_5OH**	+	**_O_2**	->	**_CO2**	+	**_H_2O**
3.)	**_NO**			->	**_N_2O**	+	**_NO_2**
4.)	**_$Ba(NO_3)_2$**	+	**_KF**	->	**_BaF_2**	+	**_KNO_3**
5.)	**_HCl**	+	**_$Ca(OH)_2$**	->	**_$CaCl_2$**	+	**_H_2O**

a.) How many carbon atoms are on the left? How many are on the right?
b.) How many hydrogen atoms are on the left? On the right?
c.) How many oxygen atoms are on the left? On the right?
d.) Balance the equations.

For #1, you have balanced it correctly if the following table is true:

Reactant	Product
1 C	1C
4 H	4 H
4 O	4 O

NOTE: In some books, they allow you to have fractional coefficients. For our class, however, we shall NOT be utilizing them as the final answer. You may use them ONLY for partial solutions.

MOLE

The mole is the "dozen" for chemist. When we say dozen, we mean 12 pieces. For example, a dozen donuts, pencils, and chairs all mean 12 of each of the respective item. Specifically, chemists has the number **$6.02x10^{23}$** and usually the units are molecules. Let us take water or H_2O.

Before we jump into moles, let us go into getting first the molar mass of substances.

ELEMENT	# of Atoms	Atomic mass	Partial total mass
H	2	1	2
O	1	16	16
		Molar mass of water	**18**

Try it for yourself. Battery water, H_2SO_4 has a molar mass of 98. How did we get this? What about Zinc? H_3PO_4? $(NH_4)_2S$?

Getting deeper into the concept of mole, remember when chemists say mole, they remember $6.02x10^{23}$. But what defines **A** mole or **1** mole?

Molar Mass	Avogadro's Number	# of moles
170 g of $AgNO_3$	$6.02x10^{23}$ molecules	1
18 g of H_2O	$6.02x10^{23}$ molecules	1
65 g of Zn	$6.02x10^{23}$ atoms	1
130 g of <u>2</u>Zn	$6.02x10^{23}$ atoms x 2	2

*We now see that 1 mole of a substance equals its molar mass. Also, we can have this relationship--mole-gram. For example, the molar mass of water (H_2O) is 18 grams/mole. For Zinc, if we have just 1 mole of it, we have 65 g of Zn but if we have 2 moles of Zn indicated by the coefficient <u>2</u>, there are 130 g of Zn.

The better ways to understand the concept of mole is to have some more examples.

Example 1. If there are 23 moles of water in a barrel, how many grams are there?

$$23 \ \cancel{\text{moles of water}} \times \frac{18 \text{ grams of } H_2O}{1 \ \cancel{\text{mole of } H_2O}} = 414 \text{ grams of } H_2O$$

Here, you are told you have 23 moles of water in a barrel. In terms of grams, you have 414g of H_2O. To help you visualize, lets assume 414 grams of water is equivalent to 414 mL of water. So this almost fills up a bottle of water. In other words, 23 moles of water almost fills a 500-mL bottle container.

Example 2. A roll of aluminum foil weighs 96 grams. How many moles of Al is that?

$$96 \ \cancel{\text{grams of Al}} \times \frac{1 \text{ mole of Al}}{27 \ \cancel{\text{grams of Al}}} = 3.6 \text{ moles of Al}$$

Here, you are given the initial amount of grams given a certain "element"--96 grams of it. Since 1 mole of Al is 27 grams, and you have more than 27 grams, the answer (in terms of moles) must be greater than 1... even 2 (27 x 2 = 54). So it must be around 3+ (since 27 x 3 = 81 grams).

Example 3. Nitrogen is responsible for bends and is a potential and fatal problem for deep-sea divers. How many moles of nitrogen gas (being diatomic, N_2) are there in 9.5×10^{18} molecules of N_2?

$$9.5 \times 10^{18} \ \cancel{\text{molecules}} \times \frac{1 \text{ mole}}{6.02 \times 10^{23} \ \cancel{\text{molecules}}} = 1.58 \times 10^{-5} \text{ mole}$$

Example 4. The mercury ore cinnabar (HgS) was used to make bright red paint by Renaissance painters. What is the weight of 50 molecules of cinnabar?

$$\text{s } 50 \text{ molecules HgS} \times \frac{1 \text{ mole}}{6.02 \times 10^{23} \text{ molecules}} \times \frac{233 \text{ grams}}{1 \text{ mole}} = 1.94 \times 10^{-20} \text{ gram of HgS}$$

The answer, as you might notice, is very small. Remember! You are being ask the mass of 50 molecules. A single molecule should be very light. 50 molecules would weigh almost nothing! And it takes 10^{23} molecules/atoms to make a single mole!

Exercises:

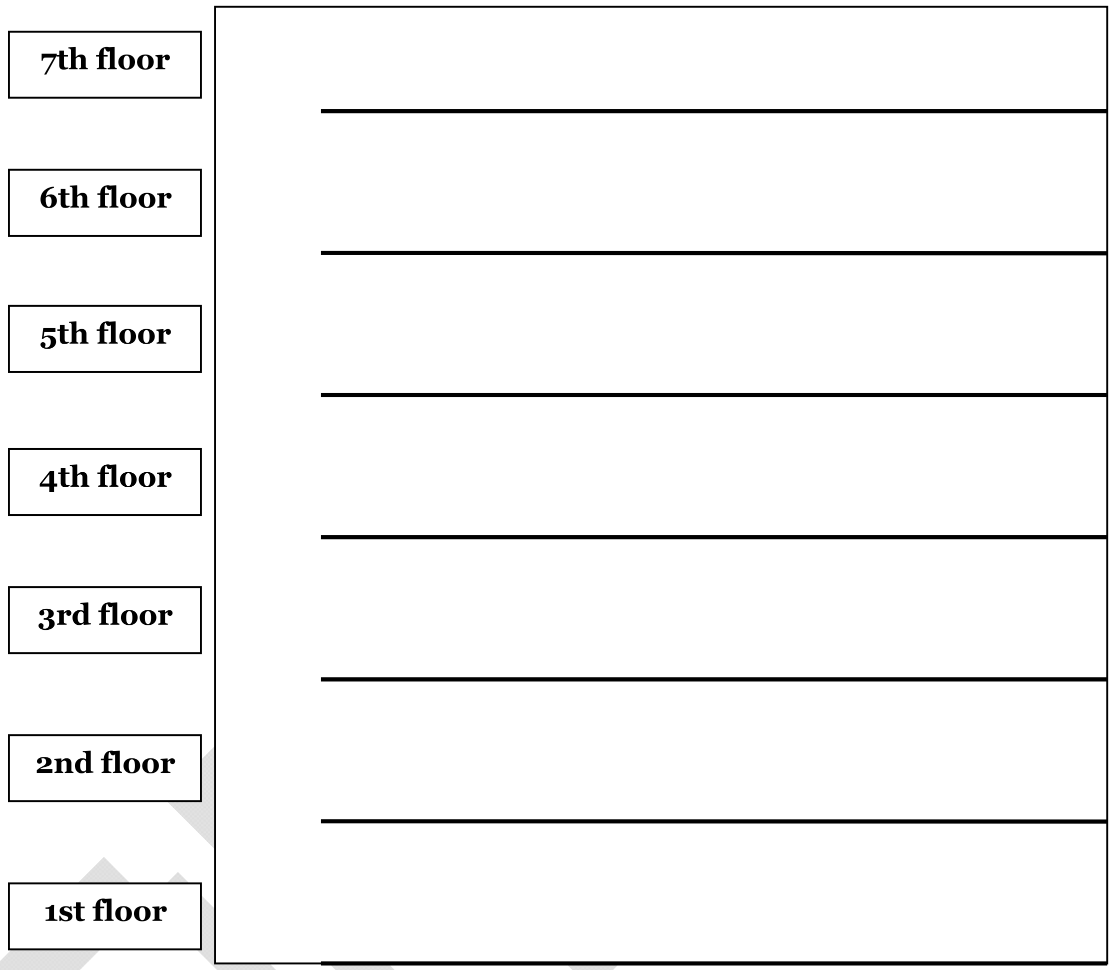
1.) Baking soda ($NaHCO_3$) is part of the recipe for biscuits. How many molecules of $NaHCO_3$ are there in 25 grams?

2.) If a nail contains 1.5 moles of iron, how many grams is that?

3.) How many grams of caffeine ($C_8H_{10}N_4O_2$) are necessary to have 1,000,000 caffeine molecules?

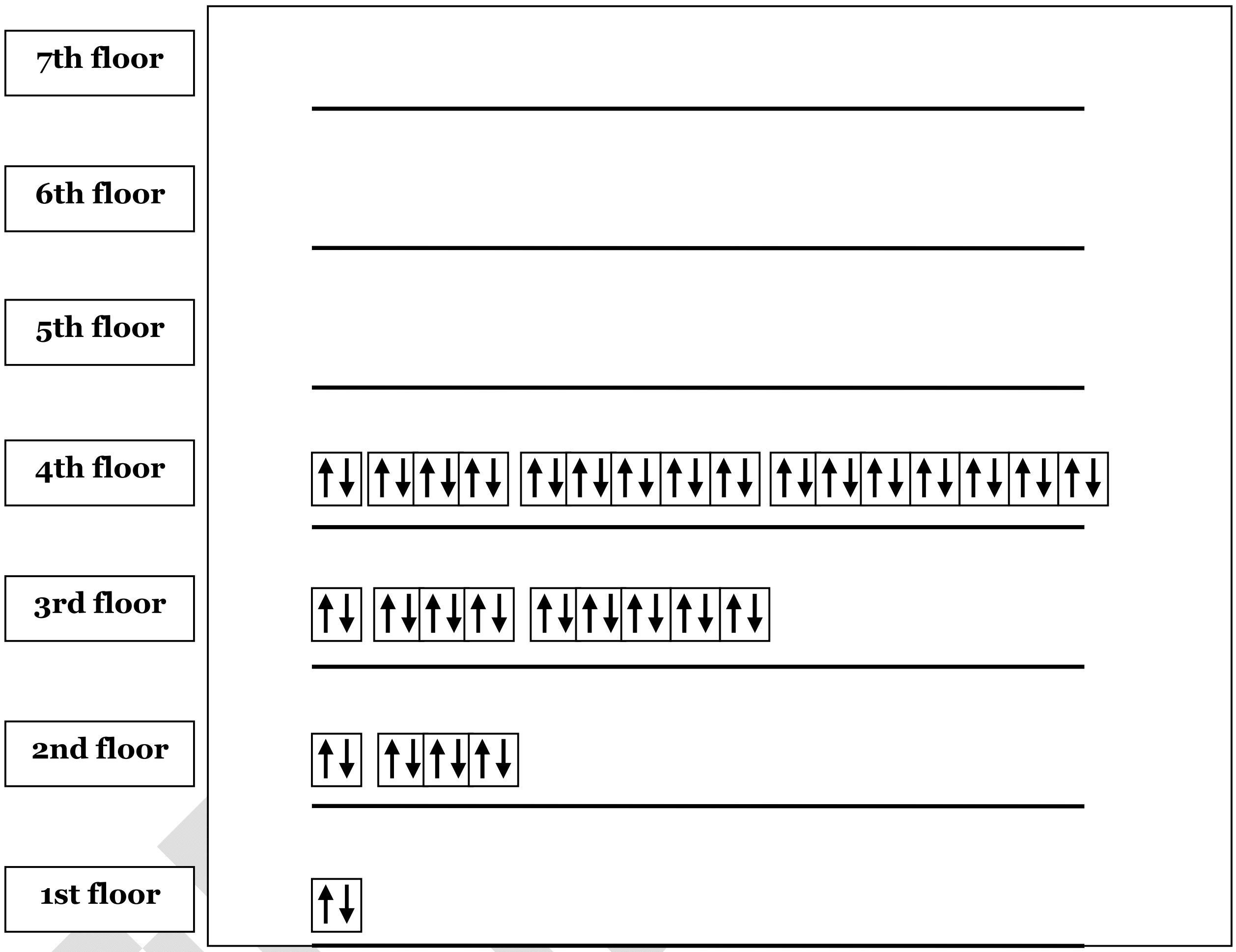
ELECTRON CONFIGURATION

Suppose you have a minor in HRM or you have a subject in HRM. A plan is laid out for you to establish your own hotel in the city. The raw plan follows



**discussion in class*

When we finally set the entire hotel up (or at least the first 4 floors), we get something like this



And as you recall in class discussions,

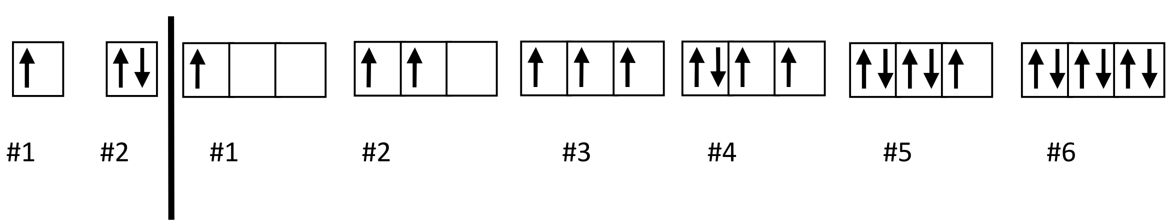
1st floor - lobby, reception, cafeteria

2nd floor - function rooms, casinos

3rd floor - utility room

4th floor - more rooms

And how we fill the beds up.



And also recall,

s - single (2)

p - party room (6)

d - despedida (10)

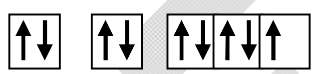
f - full house (14)

This tells us the capacity (maximum number of people but in our case electrons) for each room/orbital.

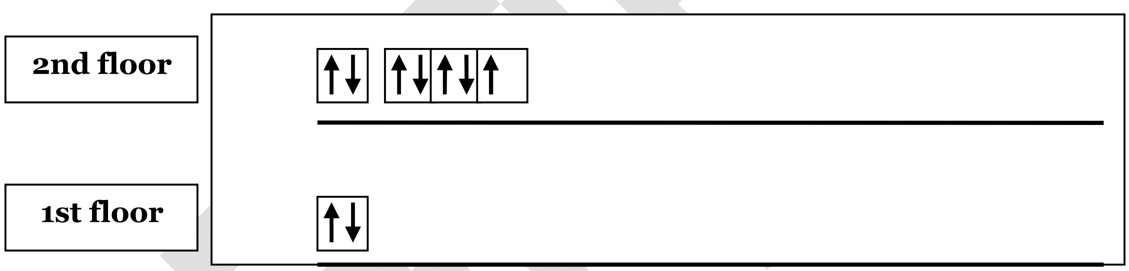
Example

Say we need the electron configuration of **Fluorine**. It has 9 electrons. $1s^2\ 2s^2\ 2p^5$

What about illustrating it?



And if we illustrate using our hotel design,



Exercise Write the electron configuration, illustrate, and illustrate again using the hotel design.
1.) Calcium
2.) Vanadium
3.) Mercury
4.) Argon
5.) Xenon

-end-