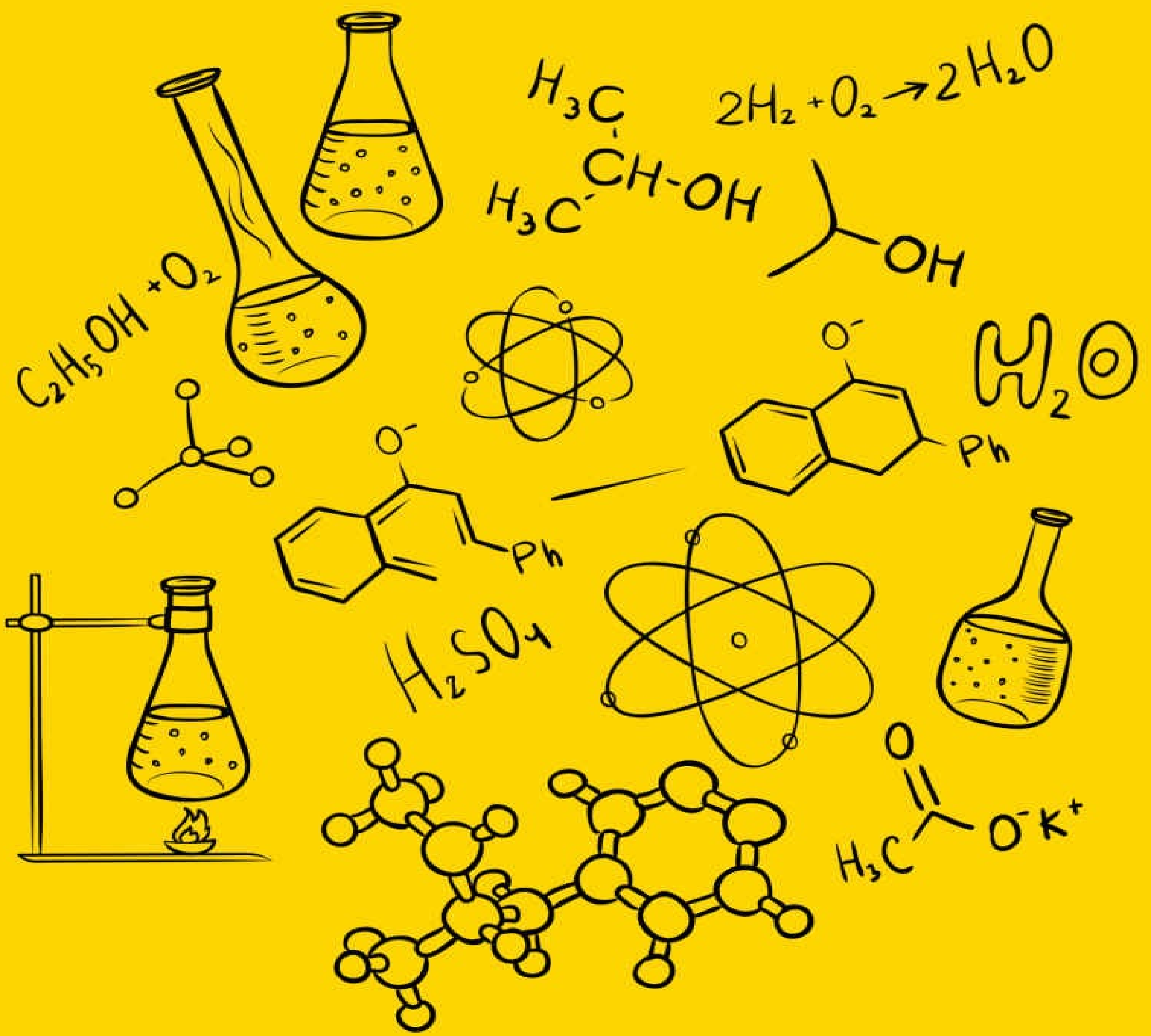
CHEMISTRY

FOR STUDENTS AND PARENTS



ROY RICHARD SAWYER

Chemistry for Students and Parents

Key Chemistry Concepts, Problems and Solutions

Roy Richard Sawyer

Table of Contents

9. $Fe_2O_3 + CO = Fe + CO_2$
10. $KClO_3 = KCl + O_2$
11. $H_2O_2 = H_2O + O_2$
12. $HBr + H_2O_2 = Br_2 + H_2O$
13. $MnCO_3 + KClO_3 = MnO_2 + KCl + CO_2$
14. $H_2S + SO_2 = S + H_2O$
15. $Sb + HNO_3 = HSbO_3 + NO_2 + H_2O$
16. $Al + CuCl_2 = AlCl_3 + Cu$
17. $Zn + CuSO_4 = ZnSO_4 + Cu$
18. $MnS + HClO_3 = MnSO_4 + HCl$
19. $H_2S + FeCl_3 = S + FeCl_2 + HCl$
20. $CuO + CO = Cu + CO_2$
21. $Bi + HNO_3 = Bi(NO_3)_3 + NO_2 + H_2O$
22. $PbS + HNO_3 = PbSO_4 + NO_2 + H_2O$
23. $C + HNO_3 = CO_2 + NO_2 + H_2O$
24. $FeSO_4 + Br_2 + H_2SO_4 = Fe_2(SO_4)_3 + HBr$
25. $Al + HCl = AlCl_3 + H_2$
26. $KMnO_4 + SO_2 + H_2O = MnSO_4 + H_2SO_4 + K_2SO_4$
27. $MnO_2 + HCl = MnCl_2 + H_2O + Cl_2$
28. $Cl_2 + KOH = KCl + KClO_3 + H_2O$
29. $KMnO_4 + NH_3 = MnO_2 + KOH + N_2 + H_2O$
30. $Mg + HNO_3 = Mg(NO_3)_2 + NH_4NO_3 + H_2O$

Answers and Solutions for Stoichiometry

1. How much Copper is produced if 200 ml of 1M $CuSO_4$ solution reacts with 1 g of iron powder?
2. How many liters of CO_2 are produced if 1 liter of C_2H_6 is burnt completely?
3. How many grams of iron are produced when 1 kg of Fe_2O_3 is completely reduced by hydrogen? How man
4. How much NaCl is produce if 100g of Na react with 10 liters of Cl_2?
6. How many grams of K_2SO_4 are produced if 0.5 Liter of 0.1M solution of KOH reacts with 0.3 Liter o
7. How many grams of $Ba(NO_3)_2$ are produced if 0.3 Liter of 0.1 M solution of HNO_3 reacts with 0.1lit
8. How many liters of 0.2M solutions of NaOH are required to produce 0.7 liters of 0.5M solution of
9. How many liters of H_2 will be produce if 10 grams of Mg reacts with 0.5

liters of 0.1M solution o

10. How many grams of Al are required to produce 3 liters of H_2 if Al reacts with of 0.1M solutions
11. How many grams of AgCl will be produce if 0.5 liters of 0.3M solution of $AgNO_3$ will react with 1
12. How many liters of 0.1 M solution of H_2SO_4 are required to produce 33 g of $ZnSO_4$ and how many gr
13. How many liters of 0.3 M solution of H_2SO_4 are required to produce 9 g of $Al_2(SO_4)_3$ and how many
14. How many liters of NH_3 are required to produce 2 liter of 0.1M solution of NH_4HCO_3
15. How many liters of CO_2 are produces if 200 grams of $CaCO_3$ react with SiO_2 in the following react
16. How many liters of O_2 are required to oxidize 60 grams of FeS_2 to Fe_2O_3?
17. How many of liters of oxygen gas will be required to completely burn 3 moles of methane?
18. Calculate number of liters of oxygen that are required to completely react with 51g of ammonia
19. Calculate the mass of silver nitrate in grams that is required to completely react with 7 mol of
20. Calculate the mass of carbon in grams that must react with oxygen to produce 12x10^23 molecules
21. How many liters of hydrogen gas are required to completely hydrogenate 952 g of 2-butene?
22. How many grams of barium chloride are required to completely precipitate barium sulfate from 1 l
23. What mass of potassium hydroxide is required to react completely with 1 liter of 0.1M solution o
24. What volume of 0.2M NaOH is required to completely neutralize 50.0 mL of 0.3M HCl?
25. How many grams of $MgCl_2$ are produce if 0.5 L of 0.5 M solution of HCL react with $Mg(OH)_2$. How mu
26. How many grams of $KClO_3$ would be required to completely decompose to produce 3 liters of O_2? How
27. How many liters of 0.5M solution of HCl are required to completely react with 25.0 g of aluminum

Introduction

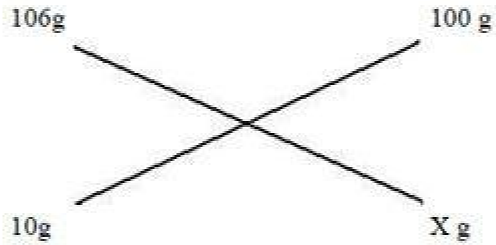
My grandma used to bake cakes.
To bake a cake for five people you have to mix:
1 cup of flour
3 eggs
1/2 cup of sugar
100 grams of butter
There was no such thing as a fat free cakes at that time. That is why they tasted so good.:)
What if you need to bake a cake for 20 people? She had the common sense to calculate proportions.
20 is 4 times greater than 5.
So, you have to use 4 times the number of cups of flour, 4 times as many number eggs and so on. As a result, you will have a new recipe.
1 * 4=4 cups of flour
3 * 4=12 eggs
1/2 * 4 = 2 cups of sugar
100 * 4 = 400 grams of butter.

In the same way you can solve a problem about a chemical reaction.
All chemical reactions occur in equivalent proportions.
If 10 grams of Na_2CO_3 react with $CaCL_2$ how many grams of $CaCO_3$ is produced?
10g ? g
1. $Na_2CO_3 + CaCL_2 = CaCO_3 + 2NaCL$

All compounds react with each other in certain proportions In a given reaction one mole of Na_2CO_3 produces one mole of $CaCO_3$.
Mole is molecular mass (MW) in grams.
Atomic mass of Na = 23
Atomic mass of C = 12
Atomic mass of O = 16
For Na_2CO_3 the MW is 23 *2 + 12 + 16*3 = 106 g. - 1 mole

For $CaCO_3$ the MW is 40 + 12 + 48 = 100g. 1 Mole.
106 g Na_2CO_3 produces 100g $CaCO_3$
10 g Na_2CO_3 produces X g $CaCO_3$

To calculate X, multiply the matched up values on the opposite ends of the diagonal and divide the product by the unmatched value as shown in the figure below.



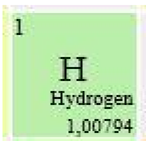
X=10 * 100 / 106 = 9.4 g of $CaCO_3$
Now you have not only solved the chemical equation problem, but also proved to yourself that you can understand chemistry.

The Periodic table

In 1869, a Russian chemist Dmitry Mendeleev published an article in which he presented his periodic table of chemical elements. He noticed a repetition of physical and chemical properties of chemical elements when he arranged them in order of their atomic weight.
Later, it was proved that physical and chemical properties of elements depending on their number of protons and since the number of protons determines an element´s atomic weight, the elements could be arranged in order of their atomic weight.
A two dimensional periodic table has vertical groups and horizontal periods.
Elements that belong to the same group have similar properties. For example, Sodium (Na) and Potassium (K) are alkaline metals that belong to the first group. These metals are so soft that they can be cut with a knife. When a small bit of sodium is placed in water, it starts dissolving and producing a colorless and odorless gas. This gas is hydrogen.
In reaction with water, alkaline metals produce alkali, a strong base. Sodium and water produce Sodium hydroxide.(NaOH)

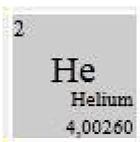
Sodium belongs to the first group and the third period.
In the 7th group of the same period we find chlorine Cl. Chlorine is a greenish poisonous gas that was used as a chemical weapon in WWI. The reaction of mixing chlorine with water produces a strong hydrochloric acid (HCl)
If you mix sodium hydroxide and hydrochloric acid a table salt will be produce.
Knowing to which group and period an element belongs, a chemist can tell a lot about the element´s properties.
As you know, an atom contains three kinds of particles: positive protons, neutral neutrons and negative electrons. Protons and neutrons comprise the atomic nucleus while electrons are located at some distance from the nucleus.
The position of the electron in the atom is described by its four quantum numbers: shell, sub-shell, orbital, spin.
Shells or the main quantum number n can be equal to any whole number 1, 2 3... It determines the electron energy and its average distance from the nucleus.
Subshell or angular momentum quantum number l (small L) describes the shape of an electron orbital.
When l=0 the electron´s orbital has spherical shape that is called an S orbital
When l=1 the electron´s orbital has a dumbbell shape and is called a p orbital.
When l=2 the electron´s orbital is called a d orbital.
When l=3 the electron´s orbital is called an f orbital.
m is a magnetic quantum number. It may change from +l (small L) to -l (small L).
As a result, there are 3 types of p orbitals (m=-1, m=0 and m=+1). Two electrons may exist on each type of p orbital. In total, 3p orbitals may have 6 electrons.
There are 5 types of d orbitals (m=-2, m=-1, m=0, m=1, m=2), two electrons may exist on each type of d orbital. In total, 5d orbitals may have 10 electrons.
There are 7 types of f orbitals (m=-3, m=-2, m=-1, m=0, m=1, m=2, m=3), two electrons may exist on each type of f orbital. In total, 7f orbitals may have 14 electrons.
s - spin projection quantum number or spin of electron can be +1/2 or - 1/2.
Imagine that you have a desk with a stack of book shelves. If you have only one book you will put it on the first shelf. You will not put it on the top shelf

near the ceiling. If you have a few books, you put them where it would be easier to reach one. In an atom, the electrons start filling orbitals with the orbital that has the lowest energy if it is not in contradiction to the Pauli Exclusion Principle.
The Pauli Exclusion Principle states that no 2 electrons in the same atom may have the same quantum numbers. For example, 2 electrons on 1S orbital in the atom of helium have opposite spins.
When 1S orbital is filled, 2S orbital will fill next.
The electronic configuration of a Hydrogen atom is:



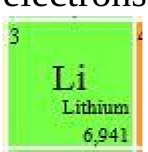
$1s^1$

It means that Hydrogen has only one electron on the first S orbital.
The electronic configuration of the Helium (He) atom is:



$1s^2$

It means that Helium has two electrons on the first S orbital.
For an He atom, n quantum number =1, l (small L) quantum number =0. There is no p orbital for l=0. S orbital is completely filled. Helium cannot have more than 2 electrons on the 1S orbital. As a result, It is a noble gas. Helium cannot form bound with any other elements.
The next element in the periodic table is Lithium (Li). Li starts the second period and has the order number of 3. It means that it has 3 protons and 3 electrons. Its electronic configuration is:



$1s^2\ 2s^1$

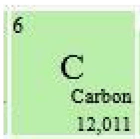
The next element, Beryllium (Be) has the order number of 4 and it has 2 electrons on the 1S orbital and 2 electrons on the 2S orbital. Two S orbitals are completely filled for Beryllium. You may wonder why Beryllium is not a noble element if it has completely filled its S orbitals? The answer is that on the second shell the completed number of electrons is 8 (2 S electrons and 6 P electrons). For Beryllium, the quantum number n=2 and the quantum number l=1. As a result, an additional p orbital appears for n=2. This orbital is not filled for Beryllium. The Beryllium electronic configuration is:

$1s^{2}\ 2s^{2}$

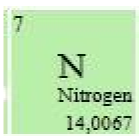
The next element is Boron (B). It has 5 electrons: 2 electrons on the 1S orbital, 2 electrons on the 2S orbital and 1 electron on the 2P orbital. Filling of the P orbital starts from Boron. Boron electronic configuration is:

$1s^{2}\ 2s^{2}\ 2p^{1}$

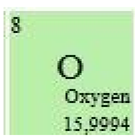
Next 5 elements have the outmost electrons on the P orbital and the number of P electrons is incremented by one for each consequential element.



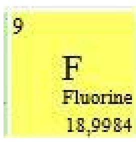
$1s^{2}\ 2s^{2}\ 2p^{2}$



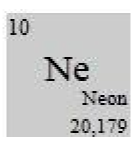
$1s^{2}\ 2s^{2}\ 2p^{3}$



$1s^{2}\ 2s^{2}\ 2p^{4}$



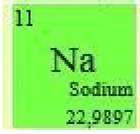
$1s^{2}\ 2s^{2}\ 2p^{5}$



$1s^{2}\ 2s^{2}\ 2p^{6}$

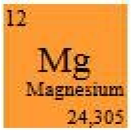
Neon (Ne) has 6 P electrons. The P orbital is completely filled for Neon. As a result, Neon is a noble gas.

The next element is Sodium (Na). Na order number is 11. It has the same electronic configuration as Neon plus additionally, it has 1 electron on the 3S orbital. The Sodium electronic configuration can be written in short form as [Ne] $3s^{1}$ or in long form:



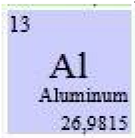
$1s^{2}\ 2s^{2}\ 2p^{6}3s^{1}$

The next element is Magnesium (Mg). Mg has 2 electrons on the 3S orbital.

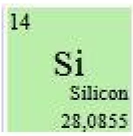


$1s^2 2s^2 2p^6 3s^2$

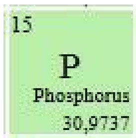
The next element is Aluminum and it has 1 electron on the 3P orbital. Again, filing of the P orbital starts from Al and for the next 5 elements the number of P electrons is incremented by one for each consequential element. Argon (Ar) has complete set of 6 electrons on the 3P orbitals and it is noble gas.



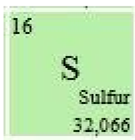
$1s^2 2s^2 2p^6 3s^2 3p^1$



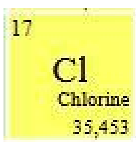
$1s^2 2s^2 2p^6 3s^2 3p^2$



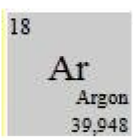
$1s^2 2s^2 2p^6 3s^2 3p^3$



$1s^2 2s^2 2p^6 3s^2 3p^4$

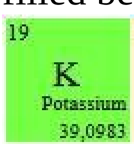


$1s^2 2s^2 2p^6 3s^2 3p^5$



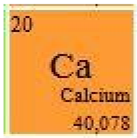
$1s^2 2s^2 2p^6 3s^2 3p^6$

For Argon the main quantum number n is 3, l is 2. Remember, we pointed out earlier when l=2 additional d orbital appeared. So we may expect that the next element, Potassium, will have the outmost electron on the 3d orbital. Actually, Potassium has one the outmost electron on the 4S orbital. The 4S orbital has a lower energy than the 3d orbital and as a result the 4S orbital is filled before the 3d orbital.



$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

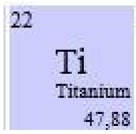
The next element Calcium (Ca) has 2 electrons on the 4S orbital.



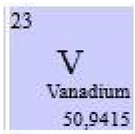
$1s^2\ 2s^2\ 2p^6 3s^2\ 3p^6 4s^2$

The 3d orbital starts filling from Scandium (Sc). Then, until Gallium (Ga), the d orbital is filling.

$1s^2\ 2s^2\ 2p^6 3s^2\ 3p^6 4s^2\ 3d^1$



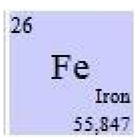
$1s^2\ 2s^2\ 2p^6 3s^2\ 3p^6 4s^2\ 3d^2$



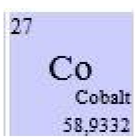
$1s^2\ 2s^2\ 2p^6 3s^2\ 3p^6 4s^2\ 3d^3$

$1s^2\ 2s^2\ 2p^6 3s^2\ 3p^6 4s^1\ 3d^5$

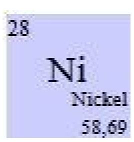
$1s^2\ 2s^2\ 2p^6 3s^2\ 3p^6 4s^2\ 3d^5$



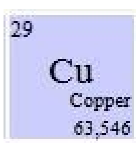
$1s^2\ 2s^2\ 2p^6 3s^2\ 3p^6 4s^2\ 3d^6$



$1s^2\ 2s^2\ 2p^6 3s^2\ 3p^6 4s^2\ 3d^7$



$1s^2\ 2s^2\ 2p^6 3s^2\ 3p^6 4s^2\ 3d^8$



$1s^2\ 2s^2\ 2p^6 3s^2\ 3p^6 4s^1\ 3d^{10}$

$1s^2\ 2s^2\ 2p^6 3s^2\ 3p^6 4s^2\ 3d^{10}$

$1s^{2}\ 2s^{2}\ 2p^{6} 3s^{2}\ 3p^{6} 4s^{2}\ 3d^{10}\ 4p^{1}$

What is interesting is that Vanadium has $3d^3$ $4S^2$ electrons and the next element, Chromium (Cr), should have $3d^4$ $4S^2$ electrons, but actually it has $3d^5 4S^1$ electrons. One electron passed from the 4S orbital to the 3d orbital.
Nickel has 8 electrons on the d orbital. The next element, Copper (Cu), should have 9 electrons on the 3d orbital and 2 electrons on the 4S orbital, but actually Copper has 10 electrons on the 3d orbital and 1 on the 4S orbital. One electron passed from the 4S orbital to the 3d orbital. The electronic configuration of Copper is [Ar] $3d^{10}4S^1$.
The complete list of electronic configurations of all the chemical elements cab be found in wikipedia http://en.wikipedia.org/wiki/Electron_configurations_of_the_elements_%28da

All elements can be divided into metals and nonmetals.
In the periodic table, metals are on the left, nonmetals are on the right.
Group number shows how many electrons are in the outermost orbital. These electrons are called valence electrons. For example, Na (sodium) is in the first group. It has one electron on the outermost orbital Na can easily give this electron to Cl (chlorine). Cl is in the seventh group. It has 7 electrons and it takes one electron from Na. As a result Na becomes a positive ion Na+ and Cl becomes negative ion Cl -. Ions with opposite charge form ionic bonds.
Ionic bonds usually form crystal structures. That is why salt is made of crystals.
Carbon C, is located in the 4th group. It has four valence electrons. As a result C forms four covalent bonds with four atoms of Cl. C does not give its electrons to Cl. Carbon and chlorine share electrons. When atoms share electrons, they form covalent bonds.

Oxides

Oxides are produced when metals or nonmetals react with oxygen.
Oxygen is located in the 6th group and has 6 valence electrons. It tends to gain 2 more electrons to become a complete octet and its valence is 2.

$2Ca + O_2 = 2CaO$
In nature, metal oxides exist in clay. Clay is a mixture of the oxides
SiO_2
Al_2O_3
K_2O
Na_2O
MgO
CaO
Fe_2O_3
TiO_2

Bases

In reaction with water metals or metal oxides produce a base:
$2Na + 2H_2O = 2NaOH + H_2$
$CaO + H_2O = Ca(OH)_2$
Bases dissociate in water and produce a negative hydroxide OH^- - ion.

Acids

Non metal oxides are NO_2, SO_3, P_2O_5
In reaction with water non metal oxides produce acids:
$H_2O + SO_3 = H_2SO_4$ - sulfuric acid
$H_2O + NO_2 = HNO_3$ - nitric acid
$H_2O + CO_2 = H_2CO_3$ - Carbonic acid
Acids dissociate in water and produce proton of hydrogen H^+

Salts

When an acid reacts with a base, a salt is produced.
$NaOH + HNO_3 = NaNO_3 + H_2O$

To calculate the percentage composition of $NaNO_3$, find the molecular mass of $NaNO_3$
23 (Na) + 12 (N) + 16*3 (O_3) = 83
The molecular weight of $NaNO_3$ = 83
83 - 100%
23 (Na) - X%
X = 23 * 100 /83 = 27.7% of Na
83 - 100%
12 (N) - X %
X = 12 * 100/83 = 14.5% of N
83 - 100%
48 (O) - X %
X = 48 * 100/83 = 57.8 % of O
Some salts are more soluble in water; some are less soluble or not soluble at all. When a non-soluble salt is produced as a result of an acid and base reaction, a precipitate is formed.
$Ca(OH)_2 + H_2CO_3 = CaCO_3 + 2H_2O$
$CaCO_3$ is not soluble in water. A white precipitate is formed.
Salts may react with each other and new salts are produced:

Equivalent proportions

All chemical reactions occur in equivalent proportions.
1. How many grams of Ca Cl_2 are spent in the following reaction:
10g ?g
Na_2CO_3 + Ca Cl_2 = $CaCO_3$ + 2NaCl
All compounds react with each other in certain proportions. In a given reaction one mole of Na_2CO_3 reacts with one mole of $CaCl_2$
A mole is MW(Molecular mass) in grams.
For Na_2CO_3 MW is 23 *2 + 12 + 48 = 106 g. = 1 mole
For $CaCl_2$ MW is 40 + 35*2 = 110g. = 1 mole.
106 g Na_2CO_3 react with 110g $CaCl_2$
10g Na_2CO_3 react with X g $CaCl_2$
X= 10 * 110 / 106 = 10.38 g $CaCl_2$
2. How many grams of $CaCO_3$ are produced if 100 ml of 0.5 M solution of Na_2CO_3 reacts with an unlimited volume of solution $CaCl_2$?

0.5 M
2. $Na_2CO_3 + CaCl_2 = CaCO_3 + 2 NaCL$
100 ml
1 liter of I M solution of Na_2CO_3 contains 106 g
How many grams of Na_2CO_3 in 1 liter of 0.5 M solution?
1 M - 106 g
0.5 M - X g
$X = 0.5 M * 106 g / 1 M = 53 g$
I liter of 0.5 M solution contains 53 grams of Na_2CO_3
How many grams of Na_2CO_3 are in 100 ml?
1 liter - 53 g
0.1 liter - X g
$X = 0.1 * 53 /1 = 5.3 g$
106 g of Na_2CO_3 produces 100 g of $CaCO_3$
5.3 g of Na_2CO_3 produces X g of $CaCO_3$
$X= 5.3 * 100 / 106 = 5 g$

Acid Base reactions

Molarity vs. Molality vs Normality

1. Let say we have 100 ml of H_2SO_4 solution and it contains 0.49 g of H_2SO_4
What is Molarity?
What is Molality?
What is Normality?
1 Molar solution contains a number of grams equal to molecular mass per one liter of solution.
MW of $H_2SO_4 = 2 + 32 + 4* 16 = 98g$
I mole = 98g/L
We have to find how many grams of H_2SO_4 given solution are contained in 1 liter.
100 ml = 0.1 L and contains 0.49 g
1 L contains X g
$X = 0.49 * 1 / 0.1 = 4.9$ g.
98g/L - 1 Mole

4.9 g/L - X Mole
X = 4.9 * 1 / 98 = 0.05 Mole
The molarity of a 100 ml solution of H_2SO_4, which contains 0.49 g of H_2SO_4, equals 0.05 Mole.
What is Molality? Molality is moles of solute / kg of solvent.
A solute is a substance dissolved in another substance.
A solvent is a substance in which another substance is dissolved
What is normality? An equivalent is the molecular mass or mass of acid or base that produce one mole of protons (H^+) or one mole of hydroxyl (OH^-) ions.
One mole of H_2SO_4 produces 2 moles of H^+ then equivalent to H_2SO_4 = MW/2 = 49g/L
49g/L is 1 Normal solution
4.9g/L solution is - X N
X= 4.9 * 1/ 49 = 0.10 N.
The normality of 100 ml solution of H_2SO_4, which contains 0.49 g of H_2SO_4, equals 0.10 N.

2. We have 10 ml of NaOH unknown concentration. The solution was titrated with 0.10 N solution of H_2SO_4 and 15 ml were required for neutralization. What is the concentration of NaOH?
$Nb * Vb = Na * Va$
where V is volume, N is Normality, b - base and a - acid
$Nb = Na * Va / Vb = 0.10 * 15 / 10 = 0.15$ N
The concentration of NaOH = 0.15 N.

Weight and Volume problems:

1. How many liters of Hydrogen are produced from one liter of water?
$2H_2O = 2H_2 + O_2$

First, we have to find how many grams of water are spent and how many grams of H_2 are produced?
MW of H_2O = 2 + 16 = 18
If we spent 2 molecules of H_2O then we spent 18 * 2 =36 g.

MW H_2 = 2 and we got 2 molecules of H_2. 2*2 = 4g
36 g of water produces 4 g of Hydrogen
1000 g of water produces X g of Hydrogen.
X = 4 * 100 / 36 = 111.1 g
I mole of Gas under normal conditions occupies 22.4 liters.
So we have to know how many moles of H_2 are produced.
1 mole of H_2 equals 2 g
X mole of H_2 equals 111.1g
X = 111.1g / 2g = 50.6 moles of H_2
1 mole of H_2 occupies 22.4 liters
50.6 moles of H_2 occupy X liters
X = 50.6 moles * 22.4L = 1232 L

Equilibrium. Le Chatelier's Principle

Any chemical reaction goes both ways
According to Le Chatelier, if at equilibrium point we make any change in concentration, pressure or temperature the point of equilibrium will move to counteract the change.
If the reaction produces heat then heating the system will move the equilibrium to the left and cooling the system will move the equilibrium to the right. If volume of the products is greater than the volume of the reactants then increasing the pressure will move the equilibrium to the left. Decreasing the pressure will move the equilibrium to the right. Increasing concentration of reactants will move the equilibrium to the right, increasing concentration of the products will move the equilibrium to the left.
Equilibrium constant K c = [C] * [D] / [A] * [B]
where [ ] is concentration in moles
$H_2 + I_2 \Leftrightarrow 2HI$
The concentration of products and reactants is raised to the power of their respective coefficients.
K c = [HI]^2 / [H2][I2]
The concentration of products and reactants is raised to the power of their respective coefficients: a,b,c,d.
Let us calculate the equilibrium constant for the following reaction.
2Al + 6HCl + H20= 2AlCl3 + 3H2
The concentration of HCl is 0,5 M, the concentration of $AlCl_3$ is 0.2M and the concentration of H_2 is 0.2M at equilibrium point.

What is equilibrium constant?

Kc = ([0.2]^2 * [0.2]^3) / [0.5]^6

Kc = 0.04 * 0.008/0.015625

Kc=0.00032/0.015625 =0.02048

If all components of the reaction are gases, a partial pressure is used for calculation of the equivalent constant instead of concentration. To understand a partial pressure of a gas, imagine that we have a closed container with air pressure of 10 atmosphere. Let us say that the air contains 75% of Nitrogen, 23% of Oxygen, 1% of CO2 and 1% of Argon.

What is partial pressure of each gas?

The the partial pressure of N2 will be 0.75 * 10 atm =7.5 atm

The partial pressure of O2 will be 0.23* 10 atm=2.3 atm

The partial pressure of CO2 will be 0.01 * 10atm=0.1 atm

The partial pressure of Ar will be 0.01 * 10 atm=0.1 atm

The sum of partial pressures of all gases in the mixture will be equal the total air pressure.

7.5 atm + 2.3 atm + 0.1 atm + 0.1 atm=10 atm

Kp = PD^d * PC^c / PA^a * PB^b

Where PA, PB, PC and PD are the partial pressures in the atmosphere (atm) units and a, b, c, d are coefficients.

Example:

H2(g) + Cl2(g) = 2HCl(g)

The partial pressure of H2 and Cl2 will be 2 atm and the partial pressure of HCl will be 1atm.

Then Kp=1^2 / 2 * 2= 0.25

Since products of the reaction go to the numerator and initial reactants go to the denominator, the equilibrium constant is greater when the equilibrium moves to the right.

Let us solve such a problem, when the concentration at equilibrium point is known only for one product and is not known for the other product or reactant.

N2 + 3 H2 = 2 NH3

Initially we had 0.2 mole of N2 and 0.6 mole of H2. At the equivalent point we had 0.1 mole of N2. Calculate equilibrium constant.

Let us build an ICE chart. In an ICE chart or table, I stands for initial, C stands for change and E stands for equilibrium. See http://en.wikipedia.org/wiki/ICE_table

	N2	H2	NH3
Initial concentration	0.2M	0.6M	0
Change in concentration -	-X	-3X	+2X
Concentration at Equilibrium 0.1			

Let us denote the change in N2 concentration as X, then the change in H2 concentration will be -3X because one mole of N2 reacts with 3 mole of H2. The minus sign shows that the N2 and H2 concentration is decreasing because they produce NH3. The concentration of NH3 will be increasing and the change in NH3 concentration will be +2X because one mole of N2 produces 2 mole of NH3.

Initially we had 0.2M of N2. At equilibrium point concentration of N2 was 0.1M.

The change for N2 concentration is 0.2M - 0.1M= 0.1M.

Since change of N2 is defined as X, X=0.1M and 3X=0.1*3=0.3M

From the ICE table we can see that at equilibrium point the concentration of H2 becomes 0.6M - 0.3M=0.3M and concentration of NH3 becomes 0 + 0.2M = 0.2M

Kc = 0.2^2 / 0.1 * 0.3^3 = 0.04 / 0.1*0.027 =0.04/0.0027=14.8

Next problem: H2 (g) + Cl2(g) = 2HCl(g)

Let´s say initially we had 1M H2, 3M Cl2 and Kc=0.5 What are concentrations at equilibrium?

Build an ICE table

		H2	CL2	HCl
Initial concentration	1M	1M	0	
Changes in concentration	X	X	+2X	
Concentrations at Equilibrium	1-X	1-X	+2X	

The change for HCl is 2X because the coefficient for HCl is 2. It means for each mole of spent H2, 2 mole of HCl are produced.

Kc = 2X^2 / (1-X) * X = 0.5

Solve the quadratic equation and find that X=0.2M.

H2 Concentrations at Equilibrium = 1M-0.2M=0.8 M

Cl_2 Concentrations at Equilibrium =1M-0.2M = 0.8M
HCl Concentrations at Equilibrium =0.2M *2=0.4M

pH Acidity of a solution

pH = - Log [H^+]
Where [H^+] is the concentration of H^+ ions.

What is log?
log is logarithm with base 10.
log 10 = 1 because $10^1 = 10$
log100 = 2 because $10^2 = 100$.
log 1000 = 3 because $10^3 = 1000$
log1/1000 = -3 because $10^{-3} = 1/1000$
- log 1/1000 = 3.
The pH of water is 7 (neutral)
What is the pH of 0.0001 N HCl?
HCl = H^+ + Cl^-
The concentration of H^+ equals the concentration of HCl = 0.0001 N
pH = - log [$1 * 10^{-4}$] = 4

Freezing point

The freezing point constant = degree C per 1M of solute per 1000g of solvent.
A solute is a substance dissolved in another substance.
A solvent is a substance in which another substance is dissolved
For water F pk = 1.86°C kg/mol
Freezing point depression equals a number of particles into which the solute dissociated in the solvent multiplied by Freezing point constant of the solvent multiplied by number of moles of the solute per kilogram of the solvent.

Fpd = i * Fpk * m

Where Fpd is Freezing point depression
i -Van't Hoff factor (the number of solute particles)
Fpk is Freezing point constant.
m - Molality of the solution

Since one kilogram of water is the weight of one liter of water the Molarity of a water solution is the same as Molality.
1. Given: 1 M of NaCl is dissolved in one kilogram of water.
What is the freezing point?
Molality of the solution is 1 mole/kg
The number of particles is 2 (Na^+ ion and Cl^- ion)

Fpd=2 * 1mol/kg * 1.86°C kg/mol=3.72C
The freezing point of water is 0 C then the freezing point of the solution = 0 C - 3.72 C = -3.72C

2. Given: 196 g of H_2SO_4 added to 500 g of water.
What is the freezing point of the solution?
How many mole of H_2SO_4 is in 196g?
MW = 2+32+64=98g
196g/98g = 2 M
2M. is in 500g
X M is in 1000g
X = 2 * 1000 / 500 = 4 M
What is the number of particles?
H_2SO_4 dissociates in water to form two H^+ ions and one SO_4^{2-}
Fpd=3 * 4mol/kg *1.86°C kg/mol=22.32C
Frp = 0 C - 22.32C= -22.32 C
Where 0C is the freezing point of water.
The freezing point of depression is -22.32

3. 100 g of glucose $C_6H_{12}O_6$ is dissolved in 500 g of water.
What is the freezing point?
Glucose MW = 6*12 + 12*2 + 6*16=180.16g
100 g per 500g
X g per 1000g
X = 100*1000/500 = 200g

180.16g per 1000g -is 1mol/kg
200 g per 1000 is Xmol/kg

Molality of Glucose = 200g * 1mol/kg/180.16g=1.11 mol/kg

Glucose does not dissociate in water. It means the number of particles is 1.

Fpd=1 * 1.11mol/kg * 1.86°C kg/mol=2.06C
0C - 2.06C = -2.06C
The freezing point of depression is 2.06C

Boiling Point

Bp=i * Kb * m
i -Van't Hoff factor (the number of solute particles)
Kb is boiling point constant.
m - Molality of the solution
For water Kb = 0.52 °C kg/mol
1. Given: 106 g Na_2CO_3 in 500 g of water. What is the boiling point of the solution?
MW of Na_2CO_3= 23+23+12+48 = 106g
106 g in 500 g water
Xg in 1000g water
X = 106 * 1000 / 500 = 212 g
106 g/L - 1 mol/kg
212 g/L - X mol/kg
X = 212 / 106 = 2 mol/kg.
Bp. elevation = 2 mol/kg * 0.52Ckg/mole = 1.4 C
Bp = 100 C + 1.4 C = 101.4 C

2. Given: 196 g of H_2SO_4 added to 500 g of water.
What is the boiling point of the solution?
How many mole of H_2SO_4 is in 196g?
MW = 2+32+64=98g
196g/98g = 2 M
2M. is in 500g
X M is in 1000g
X = 2 * 1000 / 500 = 4 M
What is the number of particles?
H_2SO_4 dissociates in water to form two H^+ ions and one SO_4^{2-}

Bp elevation=3 * 4mol/kg *0.52°C kg/mol=6.24C
Bp = 100 C + 6.24C= 106.24 C
Where 100C is the boiling point of water.
Boiling point is 106.24 C

3. 100 g of glucose $C_6H_{12}O_6$ is dissolved in 500 g of water.
What is the boiling point?
Glucose MW = 6*12 + 12*2 + 6*16=180.16g
100 g per 500g
X g per 1000g
X = 100*1000/500 = 200g

180.16g per 1000g -is 1mol/kg
200 g per 1000 is Xmol/kg

Molality of Glucose = 200g * 1mol/kg/180.16g=1.11 mol/kg

Glucose does not dissociate in water. It means the number of particles is 1.

Bp elevation=1 * 1.11mol/kg * 0.52°C kg/mol=0.58C
100C + 0.58C =100.58C
Boiling point is 100.58C

How to Balance Redox Reactions

What is Redox Reaction? In the Redox reaction one agent is loosing electrons while another agent is gaining electrons. An agent that is loosing electrons is oxidized, an agent that is gaining electrons is reduced. Oxidation is loosing electrons, Reduction is gaining electrons. How to memorize that?
Oxidation is related to corrosion, rust. When your bicycle is rusted, then you are loosing it. It may help you to remember that oxidation is loosing. Some times it is obvious what is oxidized. For example,
$S + O_2 = SO_2$ Oxygen is a strong oxidizing agent. Any compound or element that reacts with oxygen is oxidized. Initially, S was neutral and at the end it becomes S^{4+}. How do we calculate that? SO_2 is neutral.
In SO_2, O has charge -2. Two O have charge -4. Then to make SO_2 neutral, S must have charge +4.

$X + 2 (-2) = 0$
$X - 4 = 0$
$X = +4$.
Sometimes it is not obvious what is oxidized and what is reduced.
$H_2S + FeCl_3 = S + FeCl_2 + HCl$
In the reaction above, in H_2S sulfur has charge -2. How do we get it?
Hydrogen usually has charge +1.
In H_2S we have two hydrogen atoms and their charge are +2. H_2S is neutral.
It means that S has charge –2. At the end of the reaction sulfur becomes neutral.
It is loosing 2 electrons.
$S^{2-} - 2e = S$

Fe in $FeCl_3$ has charge +3. At the end of the reaction it becomes Fe^{2+}. It is gaining one electron.
$Fe^{3+} + 1e = Fe^{2+}$
What is oxidized and what is reduced? Sulfur is oxidized because it is loosing electrons and Fe is reduced because it is gaining electrons.
Let us try to balance Redox reactions.

1. $NaNO_3 = NaNO_2 + O_2$
Let us write half of the reaction of the oxidation and reduction. Initially nitrogen has a charge of +5 and at the end of the reaction it has a charge of +3.
How do we calculate that?
In $NaNO_3$, oxygen has charge -2. Sodium has charge +1. The molecule of $NaNO_3$ is neutral. It means that negative charges inside the $NaNO_3$ molecule must be equal to positive charges.
Na (+1) + O_3 (-2 x 3) = 1 - 6 = - 5.
Then nitrogen has to be + 5 to make the molecule neutral.
In $NaNO_2$, nitrogen has a charge of +3. Nitrogen must receive 2 negative electrons to change its charge from +5 to +3. 5 + (– 2) = 3
So we can write
$N^{5+} + 2e = N^{3+}$ | 2
Oxygen initially has a charge of -2.
At the end of the reaction it becomes neutral and has a charge of 0.
So, we can write

$2O^{2-}$ - 4e = O_2 | 4
Combine two half reactions and get:
N^{5+} + 2e = N^{3+} | 2
$2O^{2-}$ - 4e = O_2 | 4
Since 2 and 4 can be divided by 2, we get 1 and 2
N^{5+} + 2e = N^{3+} | 2 1
$2O^{2-}$ - 4e = O_2 | 4 2
Now switch positions of 1 and 2:
N^{5+} + 2e = N^{3+} | 2 1 2
$2O^{2-}$ - 4e = O_2 | 4 2 1
From the above, N^{5+} and N^{3+} should have a coefficient of 2.
Oxygen should have a coefficient of 1.
$2NaNO_3 = 2NaNO_2 + O_2$
Check the equation balance: from both sides of the equation. We have 2 Na, 2 N, and 6 O.
We are done.
The strongest oxidizing element is fluorine. It is stronger than oxygen. As a result, in F_2O oxygen has a charge of +2. It is very unusual for oxygen. We know that usually it has a charge of -2. In H_2O_2 oxygen also has an unusual charge of -1.
Chlorine is the third oxidizing agent after oxygen. Usually it has a charge of -1, but in compounds with oxygen it may have a positive charge.
For example, in $KClO_3$ chlorine has a charge of +5.
K has a charge of +1, O has a charge of -2. $KClO_3$ is neutral.
The sum of all charge of $KClO_3$ equals 0.
$X + 1 + (3 * -2) = 0$ Then
$X – 5 = 0$
$X = +5$.
Chlorine has a charge of +5.

Try to balance the following equations by yourself.
Detailed answers are included.
2. $Fe + H_2SO_4 = FeSO_4 + H_2$
3. $NO_2 + H_2O = HNO_3 + HNO_2$
4. $FeS_2 + HNO_3 \rightarrow Fe(NO_3)_3 + H_2SO_4 + NO_2$
5. $HgO = Hg + O_2$
6. $AgNO_3 + H_2O = Ag + HNO_3 + O_2$

7. $Fe_2O_3 + H_2 = Fe + H_2O$
8. $H_2O = H_2 + O_2$
9. $Fe_2O_3 + CO = Fe + CO_2$
10. $KClO_3 = KCl + O_2$
11. $H_2O_2 = H_2O + O_2$
12. $HBr + H_2O_2 = Br_2 + H_2O$
13. $MnCO_3 + KClO_3 = MnO_2 + KCl + CO_2$
14. $H_2S + SO_2 = S + H_2O$
15. $Sb + HNO_3 = HSbO_3 + NO_2 + H_2O$
16. $Al + CuCl_2 = AlCl_3 + Cu$
17. $Zn + CuSO_4 = ZnSO_4 + Cu$
18. $MnS + HClO_3 = MnSO_4 + HCl$;
19. $H_2S + FeCl_3 = S + FeCl_2 + HCl$
20. $CuO + CO = Cu + CO_2$
21. $Bi + HNO_3 = Bi(NO_3)_3 + NO_2 + H_2O$
22. $PbS + HNO_3 = PbSO_4 + NO_2 + H_2O$
23. $C + HNO_3 = CO_2 + NO_2 + H_2O$
24. $FeSO_4 + Br_2 + H_2SO_4 = Fe_2(SO_4)_3 + HBr$
25. $Al + HCl = AlCl_3 + H_2$
26. $KMnO_4 + SO_2 + H_2O = MnSO_4 + H_2SO_4 + K_2SO_4$
27. $MnO_2 + HCl = MnCl_2 + H_2O + Cl_2$
28. $Cl_2 + KOH = KCl + KClO_3 + H_2O$
29. $KMnO_4 + NH_3 = MnO_2 + KOH + N_2 + H_2O$
30. $Mg + HNO_3 = Mg(NO_3)_2 + NH_4NO_3 + H_2O$

Answers

2. $Fe + H_2SO_4 = FeSO_4 + H_2\uparrow$

Fe initially is neutral and at the end it becomes +2. It means that Fe lost 2 electrons.

$Fe - 2e = Fe^{2+}$ | 2

Hydrogen has a charge of + 1 in H_2SO_4 and it becomes neutral at the end.

$2H^+ + 2e = H_2$ | 2

Combine two half reactions and get:

$Fe - 2e = Fe^{2+}$ | 2

$2H^+ + 2e = H_2$ | 2

Since 2 = 2, the equation is already balanced:

$Fe + H_2SO_4 = FeSO_4 + H_2\uparrow$

3. $NO_2 + H_2O = HNO_3 + HNO_2$

In NO_2, nitrogen has a charge of +4. In HNO_3, nitrogen has a charge of +5

From NO_2 nitrogen oxidizes to HNO_3

$N^{4+} - e = N^{5+}$ | 1

Also from NO_2 nitrogen reduces to HNO_2. In NO_2 nitrogen has a charge of 4+ and in HNO_2 nitrogen has a charge of 3+.

$N^{4+} + 1e = N^{3+}$ | 1

Combine two half reactions and get:

$N^{4+} - 1e = N^{5+}$ | 1

$N^{4+} + 1e = N^{3+}$ | 1

Since 1 = 1, we should not have any coefficients, but we have to note that the same N^{4+} is used in both half reactions that is why we have to put 2 in front of it.

$2NO_2 + H_2O = HNO_3 + HNO_2$

Check the balance: On both sides we have 2 N, 5 O, and 2 H. We are done.

4. $FeS_2 + HNO_3 \rightarrow Fe(NO_3)_3 + H_2SO_4 + NO_2$

Fe has a charge of +2 in FeS_2 and +3 in $Fe(NO_3)_3$. Why?

Fe ion may have a charge of +3 or +2.

In FeS_2 it cannot have a charge of +3 because then S would have a charge of -1.5.

It is not possible.

So, Fe in FeS_2 has a charge of 2+ and S has a charge of -1.

NO_3 ion always has a charge of -1.

That is why Fe in Fe $(NO_3)_3$ has a charge of +3.

$Fe^{2+} - 1e = Fe^{3+}$ | 1

Sulfur has a charge of -1 in FeS_2 and charge of +6 in H_2SO_4 (because O has a charge of -2 and H has a charge of +1)

$+1 \times 2 + 4 \times (-2) = 2 – 8 = - 6$.

To make H_2SO_4 molecule neutral S should have a charge of + 6.

$S^{1-} - 7e = S^{6+}$ | 7

Nitrogen in HNO_3 has a charge of +5 and in NO_2 it has a charge of +4.

$N^{5+} + 1e = N^{4+}$ | 1

Combine three half reactions and get:

$Fe^{2+} - 1e = Fe^{3+}$ | 1

$2S^{1-} - 14e = 2S^{6+}$ | 14

N^{5+} +1e = N^{4+} | 1
If Fe and S give 15 electrons, then Nitrogen should receive 15 electrons
Fe^{2+} + $2S^{1-}$ -15e = Fe^{3+} + $2S^{6+}$ |15 1
N^{5+} +1e = N^{4+} | 1 15
That is why we have to put 15 in front of HNO_3.
$FeS_2 + 15HNO_3 \rightarrow Fe(NO_3)_3 + H_2SO_4 + 15NO_2$
Note that not all ions of NO_3 produce NO_2. 3 ions of NO_3 remain as they are in $Fe(NO_3)_3$
So, we have to add 3 more HNO_3 and get $18HNO_3$.
$FeS_2 + 18HNO_3 = Fe(NO_3)_3 + 2H_2SO_4 + 15NO_2 + H_2O$
Now to balance H and O add H_2O to the right side of the equation and get:
$FeS_2 + 18HNO_3 = Fe(NO_3)_3 + 2H_2SO_4 + 15NO_2 + 7H_2O$.
We are done. It was a hard one!

5. $HgO = Hg + O_2 \uparrow$

Hg^{2+} + 2e = Hg | 2 1 2
$2O^{2-}$ -4e = O_2 | 4 2 1

$2HgO = 2Hg + O_2 \uparrow$

6. $AgNO_3 + H_2O = Ag\downarrow + HNO_3 + O_2\uparrow$

Ag^{1+} + 1e = Ag |1 4
$2O^{2-}$ - 4e = O_2| 4 1

$4AgNO_3 + 2H_2O = 4Ag\downarrow + 4HNO_3 + O_2\uparrow$

7. $Fe_2O_3 + H_2 = Fe + H_2O$

Fe^{3+} + 3e = Fe |3 2
H_2 - 2e = $2H^+$|2 3

$2F_2O_3 + 6H_2 = 2Fe + 6H_2O$

8. $H_2O = H_2 + O_2$

2H+ + 2e = H2| 2 1 2
2O2- - 4e = O2| 4 2 1

2H2O = 2H2 + O2

9. Fe2O3 + CO = Fe + CO2

2Fe3+ + 6e = 2Fe |6 3 1
C2+ - 2e = C4+ |2 1 3

Fe2O3 + 3CO = 2Fe + 3CO2

10. KClO3 = KCl + O2

Cl5+ + 6e = Cl- |6 3 2
2O2- - 4e = O2 |4 2 3

2KClO3 = 2KCl + 3O2

11. H2O2 = H2O + O2

O- + 1e = O2- |1 2
2O - - 2e = O2 |2 1

2H2O2 = 2H2O + O2

12. HBr+ H2O2= Br2 + H2O

2Br- -2e = Br2 |2 1
O- +1e = O2- |1 2

2HBr + H2O2= Br2 + 2H2O

13. MnCO3 + KClO3 = MnO2 + KCl + CO2

Mn2+ - 2 e = Mn4+ |2 1 3
Cl5+ + 6e = Cl- |6 3 1

$3MnCO_3 + KClO_3 = 3MnO_2 + KCl + 3CO_2$

14. $H_2S + SO_2 = S + H_2O$

$S^{2-} - 2e = S$ |2 2 1
$S^{4+} + 4e = S$| 4 1 2

$2H_2S + SO_2 = 3S + 2H_2O$

15. $Sb + HNO_3 = HSbO_3 + NO_2 + H_2O$

$Sb - 5e = Sb^{5+}$ |5 1
$N^{5+} - 1e = N^{4+}$ |1 5

$Sb + 5HNO_3 = HSbO_3 + 5NO_2 + 2H_2O$

16. $Al + CuCl_2 = AlCl_3 + Cu$.

$Al - 3e = Al^{3+}$ | 3 2
$Cu^{2+} + 2e = Cu$ | 2 3

$2Al + 3CuCl_2 = 2AlCl_3 + 3Cu$.

17. $Zn + CuSO_4 = ZnSO_4 + Cu$

$Zn - 2e = Zn^{2+}$ | 2 1
$Cu^{2+} + 2e = Cu$ |2 1
.
The equation is balanced.

18. $MnS + HClO_3 = MnSO_4 + HCl$;

$S^{2-} - 8e = S^{6+}$ |8 4 3
$Cl^{5+} + 6e = Cl^-$ |6 3 4

$3MnS + 4HClO_3 = 3MnSO_4 + 4HCl$;

19. $H_2S + FeCl_3 = S + FeCl_2 + HCl$

$S^{2-} - 2e = S$ |2 1
$Fe^{3+} + 1e = Fe^{2+}$|1 2

$H_2S + 2FeCl_3 = S + 2FeCl_2 + 2HCl$

20. $CuO + CO = Cu + CO_2$

$Cu^{2+} + 2e = Cu$ |2 1
$C^{2+} - 2e = C^{4+}$|2 1
The equation is balanced

21. $Bi+HNO_3=Bi(NO_3)_3 + NO_2 + H_2O$

$Bi - 3e = Bi^{3+}$ |3 1
$N^{5+} + 1e = N^{4+}$ |1 3

Since 3 NO_3 are spent to $Bi(NO_3)_3$ and 3 NO_3 are required to produce 3 electrons, we have to put 6 in front of HNO_3 and not 3.

$Bi+ 6HNO_3=Bi(NO_3)_3 + 3NO_2 + 3H_2O$

22. $PbS + HNO_3 = PbSO_4 + NO_2 + H_2O$

$S^{2-} - 8e = S^{6+}$ |8 1
$N^{5+} -1e = N^{4+}$ | 1 8

$PbS + 8HNO_3 = PbSO_4 + 8NO_2 + 4H_2O$

23. $C+ HNO_3=CO_2 + NO_2 + H_2O$

$C - 4e = C^{4+}$ |4 1
$N^{5+} + 1e = N^{4+}$ |1 4

$C + 4HNO_3 = CO_2 + 4NO_2 + 2H_2O$

24. $FeSO_4 + Br_2 + H_2SO_4 = Fe_2(SO_4)_3 + HBr$

$Fe^{2+} - 1e = Fe^{3+}$ |1 2
$Br_2 + 2e = 2Br^-$ |2 1

$2FeSO_4 + Br_2 + H_2SO_4 = Fe_2(SO_4)_3 + 2HBr$

25. $Al + HCl = AlCl_3 + H_2$

$Al - 3e = Al^{3+}$ |3 2
$2H^+ + 2e = H_2$ |2 3

$2Al + 6HCl = 2AlCl_3 + 3H_2$

We have 6 in front of HCL because $(2H^+) * 3 = 6$

26. $KMnO_4 + SO_2 + H_2O = MnSO_4 + H_2SO_4 + K_2SO_4$

$Mn^{7+} + 5e = Mn^{2+}$ |5 2
$S^{4+} - 2e = S^{6+}$ |2 5

$2KMnO_4 + 5SO_2 + 2H_2O = 2MnSO_4 + 2H_2SO_4 + K_2SO_4$

27. $MnO_2 + HCl = MnCl_2 + H_2O + Cl_2$

$Mn^{4+} + 2e = Mn^{2+}$ |2 1
$2Cl^- - 2e = Cl_2$ | 2 1

Since 2 Cl^- are required to get 2 electrons and 2 Cl^- are required to produce $MnCl_2$
We have to put 4 in front of HCl.

$MnO_2 + 4HCl = MnCl_2 + H_2O + Cl_2$

Now balance H and O:

$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2$

28. $Cl_2 + KOH = KCl + KClO_3 + H_2O$

$Cl_2 + 2e = 2Cl^-$ |2 1 5
$Cl_2 - 10e = 2Cl^{5+}$ |10 5 1

It is a hard one!
Put 5 in front of KCl according to electronic balance.

$Cl_2 + KOH = 5KCl + KClO_3 + H_2O$
Now we have 1 K on the left and 6 K on the right. Put 6 in front of KOH

$Cl_2 + 6KOH = 5KCl + KClO_3 + H_2O$

Now balance Cl

$3Cl_2 + 6KOH = 5KCl + KClO_3 + H_2O$

And balance H and O

$3Cl_2 + 6KOH = 5KCl + KClO_3 + 3H_2O$

29. $KMnO_4 + NH_3 = MnO_2 + KOH + N_2 + H_2O$

$Mn^{7+} + 3e = Mn^{4+}$ |3 1 2
$2N^{3-} - 6e = 2N$ |6 2 1

$2KMnO_4 + 2NH_3 = 2MnO_2 + 2KOH + N_2 + 2H_2O$

30. $Mg + HNO_3 = Mg(NO_3)_2 + NH_4NO_3 + H_2O$

$Mg - 2e = Mg^{2+}$ |2 1 4
$N^{5+} + 8e = N^{3-}$ | 8 4 1

$4Mg + HNO_3 = 4Mg(NO_3)_2 + NH_4NO_3 + H_2O$

Balance NO_3

$4Mg + 10HNO_3 = 4Mg(NO_3)_2 + NH_4NO_3 + H_2O$

Balance H and O

$4Mg + 10HNO_3 = 4Mg(NO_3)_2 + NH_4NO_3 + 3H_2O$

Stoichiometry
30 problems with answers and solutions

1. How much Copper is produced if 200 ml of 1M $CuSO_4$ solution reacts with 1 g of iron powder?
$CuSO_4 + Fe = FeSO_4 + Cu$.

2. How many liters of CO_2 are produced if 1 liter of C_2H_6 is burnt completely?
$2C_2H_6 + 7O_2 = 4CO_2 + 6H_2O$

3. How many grams of iron are produced when 1 kg of Fe_2O_3 is completely reduced by hydrogen? How many liters of hydrogen are required?
$Fe_2O_3 + 3H_2 = 2Fe + 3H_2O$

4. How much NaCl is produced if 100g of Na react with 10 liters of Cl_2? Which initial reactant will be left over?
$2Na + Cl_2 = 2NaCl$
5. How many grams of Na_2SO_4 are produced if 1 Liter of 1M NaOH reacts with 1 Liter of 0.5 M H_2SO_4? Which initial reactant will be left over?
$2NaOH + H_2SO_4 = Na_2SO_4 + 2H_2O$.

6. How many grams of K_2SO_4 are produced if 0.5 liters of 0.1M solution of KOH reacts with 0.3 liters of 0.2 M solution of H_2SO_4? Which initial reactant will be left over?
$H_2SO_4 + 2KOH = K_2SO_4 + 2H_2O$

7. How many grams of $Ba(NO_3)_2$ are produced if 0.3 liters of 0.1 M solution of HNO_3 reacts with 0.1 liters of 0.3 M solution of $Ba(OH)_2$. Which initial

reactant will be left over?

$2HNO_3 + Ba(OH)_2 = Ba(NO_3)_2 + 2H_2O$;

8. How many liters of 0.2M solutions of NaOH are required to produce 0.7 liters of 0.5M solution of Na3PO4 in the following reaction

$H_3PO_4 + 3NaOH = Na_3PO_4 + 3H_2O$

How many moles of H3PO4 will be spent?

9. How many liters of H2 will be produced if 10 grams of Mg reacts with 0.5 liters of 0.1M solution of H2SO4? Which initial reactant will be left over?

$Mg + H_2SO_4 = MgSO_4 + H_2$

10. How many grams of Al are required to produce 3 liters of H2 if Al reacts with 0.1M solutions of HCl? How many liters of solution of HCl will be spent?

$2Al + 6HCl = 2AlCl_3 + 3H_2$

11. How many grams of AgCl will be produce if 0.5 liters of 0.3M solution of AgNO3 reacts with 1 liter of 0.5M solution of CaCL2? Which initial reactant will be left over?

$2AgNO_3 + CaCl_2 = 2AgCl + Ca(NO_3)_2$

12. How many liters of 0.1 M solution of H2SO4 are required to produce 33 g of ZnSO4 and how many grams of Zn(OH)2 are spent?

$Zn(OH)_2 + H_2SO_4 = ZnSO_4 + 2H_2O$

13. How many liters of 0.3 M solution of H2SO4 are required to produce 9 g of Al2(SO4)3 and how many grams of Al(OH)3 are spent?

$2Al(OH)_3 + 3H_2SO_4 = Al_2(SO_4)_3 + 6H_2O$

14. How many liters of NH3 are required to produce 2 liters of 0.1M solution of NH4HCO3

How many liters of CO2 will be spent in the following reaction?

$NH_3 + CO_2 + H_2O = NH_4HCO_3$

15. How many liters of CO2 are produced if 200 grams of CaCO3 react with SiO2 in the following reaction?

$CaCO_3 + SiO_2 = CaSiO_3 + CO_2$

16. How many liters of O2 are required to oxidize 60 grams of FeS2 to Fe2O3?
4FeS2 + 11O2 = 2Fe2O3 + 8SO2

17. How many liters of oxygen gas will be required to completely burn 3 moles of methane?
18. Calculate the number of liters of oxygen that are required to completely react with 51g of ammonia.
4NH3 + 5O2 = 4NO + 6H2O

19. Calculate the mass of silver nitrate in grams that is required to completely react with 7 mole of lead?
Pb +2AgNO3 -> Pb(NO3)2 +2Ag

20. Calculate the mass of carbon in grams that must react with oxygen to produce 12x10^23 molecules of Carbon Dioxide (CO2)
C + O2 = CO2

21. How many liters of hydrogen gas are required to completely hydrogenate 952 g of 2-butene?
CH3-CH=CH-CH3 + H2 = CH3-CH2-CH2-CH3

22. How many grams of barium chloride are required to completely precipitate barium sulfate from 1 liter of 0.3M H2SO4?
H2SO4 + BaCl2 -= BaSO4 + 2HCl

23. What mass of potassium hydroxide is required to react completely with 1 liter of 0.1M solution of sulfuric acid to produce potassium sulfate? How many grams of K2SO4 will be produced?
2KOH + H2SO4 → 2H2O + K2SO4

24. What volume of 0.2M NaOH is required to completely neutralize 50.0 mL of 0.3M HCl?

25. How many grams of MgCl2 are produced if 0.5 liters of 0.5 M solution of HCL react with Mg(OH)2. How much Mg(OH)2 is spent?
Mg(OH)2 + 2HCl = MgCl2 + 2H2O

26. How many grams of $KClO_3$ would be required to completely decompose to produce 3 liters of O_2? How many grams of KCl is produced?
$2KClO_3 = 3O_2 + 2KCl$

27. How many liters of 0.5M solution of HCl are required to completely react with 25.0 g of aluminum? How many liters of H_2 are produced?
$2Al + 6\ HCl = 2AlCl_3 + 3H_2$

28. How many grams of nitrogen would be required to completely react with 11.2 liters of hydrogen to give ammonia? How many grams of ammonia are produced?
$N_2 + 3\ H_2 = 2\ NH_3$

29. Calculate the volume of 0.5 M sulfuric acid in milliliters that is required to completely neutralize 100 ml of 1 M solution of KOH?
$H_2SO_4 + 2KOH = K_2SO_4 + 2H_2O$
What is the K^+ ion concentration at the end of the reaction?

30. How many grams of Fe_2O_3 are required to completely react with 3 moles of Al?
$2Al + Fe_2O_3 = 2Fe + Al_2O_3$

Answers and Solutions

1. How much Copper is produced if 200 ml of 1M $CuSO_4$ solution reacts with 1 g of iron powder?
$CuSO_4 + Fe = FeSO_4 + Cu$.

Solution: The mass of one mole of $CuSO_4$ is 64 + 32 + 16*4 = 160g. How did we get it?
The mass of Cu is 64, mass of S is 32 and mass of O is 16. (16*4=64)
A IM solution of $CuSO_4$ has one mole per liter. It means, one liter of $CuSO_4$ contains 98 g of H_2SO_4.
We have 200 ml of $CuSO_4$. How many gram of $CuSO_4$ in 200 ml?
1000ml is 160g
200 ml is X g

X = 200ml * 160g/ 1000ml = 32 g. $CuSO_4$
Mass of Cu is 64. One mole of Cu is 64 g.
From this equation we can see that one mole of $CuSO_4$ produces one mole of Cu.
160 g of $CuSO_4$ produce 64 g of Cu.
32 g of $CuSO_4$ produce X gram of Cu
X = 32g * 64g / 160g =12.8 g Cu
If we have enough Fe, then 32 g $CuSO_4$ can produce 12.8 g Cu.
Do we have enough Fe to completely react with 32 g of H_2SO_4?
The mass of Fe is 56. One mole of Fe is 56g.
From the equation we see that one mole of H_2SO_4 requires one mole of Fe.
160 g of $CuSO_4$ requires 56 g of Fe,
We have 32 g of $CuSO_4$. How many gram of Fe do we need for a complete reaction?
160 g $CuSO_4$ - 56g Fe
32g $CuSO_4$ - Xg Fe
X = 32 * 56 / 160 = 11.2 g of Fe is required.
We have only 1 g of Fe. It means that not all H_2SO_4 will react with 1 g of Fe and we cannot get 12.8 g of Cu. Before calculating how much Cu is produced, we have to determine which reactant is limited and which reactant is in excess. How can we do that? We should start our solution with the proportion:
32 g of $CuSO_4$ required 11.2 g of Fe
X g of $CuSO_4$ required 1 g of Fe
X = 32 * 1 /11.2 = 2.86 g $CuSO_4$
Only 2.86 g of $CuSO_4$ will participate in a reaction with 11.2g of Fe. We have an excess of $CuSO_4$ and Fe is limited reactant.
We should use for calculation limited reactant to calculate how much Cu is produced.
One mole of Fe produces one mole of Cu.
56 g of Fe produces 64 g of Cu.
1 g of Fe produces X g of Cu
X = 1 * 64 / 56 = 1.14g of Cu.

Answer: 1.14g of Cu is produced.

2. How many liters of CO_2 are produced if 1 liter of C_2H_6 is burnt

completely?

$2C_2H_6 + 7O_2 = 4CO_2 + 6H_2O$

Solution: From the chemical equation we can see that 2 moles of C_2H_6 produce 4 moles of CO_2.

In normal conditions, the volume of one mole of gas is 22.4 liters. Two moles of C_2H_6 equals

22.4 * 2 = 44.8 liters.

4 moles of CO_2 equal 22.4 * 4 = 89.6 liters

44.8 liters of C_2H_6 produce 89.6 liters of CO_2

1 liter of C_2H_6 produces X liters of CO_2

X = 1 * 89.6 / 44.8 = 2 liters of CO_2

Answer: 2 liters of CO_2 is produced.

3. How many gram of iron is produced when 1 kg of Fe_2O_3 is completely reduced by hydrogen?

How many liters of hydrogen are required?

$Fe_2O_3 + 3H_2 = 2Fe + 3H_2O$

From the equation, we can see that one mole of Fe_2O_3 produces 2 mole of Fe.

One mole of Fe_2O_3 is 56*2 + 16*3=160g.

One mole of Fe is 56g. Two mole of Fe are 56*2=112g.

160g of Fe_2O_3 produce 112g of Fe 1 kg = 1000 g.

1000g of Fe_2O_3 produce Xg of Fe.

X= 1000 * 112/ 160 = 700g of Fe is produced.

How many liters of H_2 are required?

From the equation we see that one mole of Fe_2O_3 requires 3 mole of H_2

One mole of Fe_2O_3 is 56*2 + 16*3=160g.

3 mole of H_2 is 6 g

160 g of Fe_2O_3 consume 6 g of H_2

700 g of Fe_2O_3 consume X g of H_2 X = 700 g * 6 g / 160 g =26.3 g

I mole of H_2 is 2 g and occupies 22.4 L (1 mole of any gas occupies 22.4 L)

26.3 g of H_2 occupies X L

X = 26.3 g * 22.4 L / 2 g = 294 L of H_2

Answer: 700g Fe is produced and 294 L of H_2 are required

4. How much NaCl is produced if 100g of Na reacts with 10 liters of Cl_2? Which initial reactant will be left over? $2Na + Cl_2 = 2NaCl$

First we have to determine, which reactant is limited and which will be left over.

From the equation we see that 2 mole of Na react with one mole of Cl_2.

2 mole of Na are 23*2=46g. One mole of Cl_2 is 35*2=70g.

46 g of Na react with 70g of Cl_2.

How many g of Cl_2 do we have?

One mole of gas is 22.4L. It means that

70g of Cl_2 is 22.4 L

X g of Cl_2 is 10 L

X = 70 * 10 / 22.4 = 31.25g. 10 L of Cl_2 is 31.25g.

2 mole of Na react with one mole of Cl_2

46 g of Na react with 70 g of Cl_2. We have 100 g of Na. How much Cl_2 is required in grams?

100 g of Na react with X g of Cl_2

X = 100 g * 70 g /46 g = 152 g of Cl_2

Per reaction we need 152 g of Cl_2, but we have only 31.25g. It means Cl_2 is limited and Na will be left over. To calculate how much NaCl is produced we have to use the limited reactant, which is Cl_2.

From the equation, we see that one mole of Cl_2 produces 2 mole of NaCl.

One mole of Cl_2 is 35*2=70 g and two mole of NaCl is (23 + 35)*2=116g

1 mole of Cl_2 produces 2 moles of NaCl.

70g of Cl_2 produce 116g of NaCl

31.25g of Cl_2 produce X g of NaCl

X = 31.25 * 116 / 70 =51.79 g of NaCl

Answer: 51.79 g of NaCl is produced. Na will be left over

5. How many grams of Na_2SO_4 are produced if 1 liter of 1M NaOH reacts with 1 Liter of 0.5 M H_2SO_4? Which initial reactant will be left over?

$2NaOH + H_2SO_4 = Na_2SO_4 + 2H_2O$.

First, let us calculate how many grams of NaOH and H_2SO_4 we have. Then determine which reactant is limited.

Mass of one mole of NaOH is 23 + 16 + 1=40g.

1 liter of 1M of NaOH contains 40g of NaOH
The mass of one mole of H_2SO_4 is 2 + 32 + 16*4 = 98g
1 liter of 1M solution of H_2SO_4 contains 98g H_2SO_4.
We have 0.5M solution of H_2SO_4.
1 L of 1 M of H_2SO_4 contains 98g
1 L of 0.5M of H_2SO_4 contrains X g
X=0.5 * 98 / 1 = 49g. H_2SO_4.

From equation, we see that two mole of NaOH react with one mole of H_2SO_4
One mole of NaOH is 40g, 2 mole are 80g
80g NaOH react with 98g of H_2SO_4
40g NaOH react with X g of H_2SO_4
X = 40g * 98g /80g = 49g H_2SO_4.
We found that for an existing amount of NaOH (40g) we need 49 g of H_2SO_4.
Since, 1 L of 0.5M solution of H_2SO_4 contains 49g H_2SO_4 we have enough H_2SO_4 for complete reaction with existing amount of NaOH. No one reactant is left over. It means we can use either one to calculate how much Na_2SO_4 will be produced. Let us use NaOH.
The mass of one mole of Na_2SO_4 is 23*2 + 32 + 16*4=46 + 32 + 64= 142g
From the equation, we see that 2 mole of NaOH produce one mole of Na_2SO_4
80g NaOH produce 142g of Na_2SO_4
40g NaOH produce X g Na_2SO_4
X = 40 * 142 /80 = 71g

Answer: 71 g of Na_2SO_4 is produced.

6. How many grams of K_2SO_4 are produced if 0.5 liter of 0.1M solution of KOH reacts with 0.3 Liter of 0.2 M solution of H_2SO_4? Which initial reactant will be left over?
H_2SO_4 + 2KOH = K_2SO_4 + $2H_2O$
Let us calculate how much KOH and H_2SO_4 we have in grams.
Mass of one mole of KOH is 39 + 16 + 1 = 56g
1 L of 1M solution of KOH contains 56g of KOH.
1 L of 1 M of KOH - 56 g

1 L of 0.1M of KOH - X g X = 56 g * 0.1 M/1 M = 5.6g of KOH
Then 1 L of 0.1 M solution will contain 5.6 g KOH.
We have 0.5 L of KOH solution.
1 L of KOH - 5.6 g
0.5 L of KOH - X g
X = 0.5L * 5.6g / 1 L= 2.8 g KOH. So, we have 2.8 g KOH
The mass of H_2SO_4 is 2 + 32 + 16*4=98 g
1 L of 1 M of H_2SO_4 solution contains 98g
1 L of 0.2 M of H_2SO_4 solution contains X g
X = 0.2 * 98 /1 = 19.6 g of H_2SO_4
1 L of 0.2 M solution contains 19.6 g H_2SO_4
0.3 L of 0.2 M solution contains X g
X= 0.3 * 19.6 / 1 = 5.8 g. We have 5.8 g of H_2SO_4
We have 2.8 g of KOH and 5.8 g H_2SO_4. Which reactant is limited?
From our equation, 2 mole of KOH react with one mole of H_2SO_4
56 * 2 = 112 g KOH reacts with 98 g of H_2SO_4
2.8 g of KOH react with X g of H_2SO_4
X = 2.8g * 98 g / 112 g = 2.45 g H_2SO_4
For 2.8 g KOH we need 2.45 g H_2SO_4 and we have 5.8 g H_2SO_4.
It means that H_2SO_4 will be left over.
KOH is a limited reactant and we have to use KOH to calculate how much K_2SO_4 is produced.
The mass of one mole of K_2SO_4 is 39*2 + 32 + 64 = 174 g
Two mole of KOH produce one mole of K_2SO_4.
112 g KOH produce 174g K_2SO_4
2.8 g KOH produce X g K_2SO_4
X = 2.8 g * 174 g /112 g = 4.35 g K_2SO_4

Answer: KOH is limited reactant. 4.35 g K_2SO_4 is produced.

7. How many grams of $Ba(NO_3)_2$ are produced if 0.3 liter of 0.1 M solution of HNO_3 reacts with 0.1 liter of 0.3 M solution of $Ba(OH)_2$. Which initial reactant will be left over?
$2HNO_3 + Ba(OH)_2 = Ba(NO_3)_2 + 2H_2O$;

Let us calculate how much HNO_3 and $Ba(OH)_2$ we have in grams.
The mass of one mole of HNO_3 is 1 + 14 +16*3= 63 g

1 L of 1M solution of HNO3 contains 63 g.
0.3 L of 1 M solution of HNO3 contains X g
X = 0.3 * 63 /1 = 18.9 g of HNO3
0.3 L of 1 M solution of HNO3 contains 18.9 g
0.3 L of 0.1 M solution of HNO3 contains X g
X = 0.1 M * 18.9 g /1 M= 1.89 g
So, we have 1.89 g of HNO3.
The mass of one mole of Ba(OH)2 = 137 + 2 * (16 + 1) = 171 g
1 L of 1 M solution of Ba(OH)2 contains 171 g
1 L of 0.3 M solution of Ba(OH)2 contains X g
X = 0.3 M * 171 g /1 M = 51.3 g

1 L of 0.3 M solution of Ba(OH)2 contains 51.3 g
0.1 L of 0.3 M solution of Ba(OH)2 contains X g
X = 0.1 L * 51.3 g/ 1 L = 5.13 g
So, we have 5.13 g of Ba(OH)2 and 1.89 g of HNO3. Which reactant is limited and which will be left
over?
From the equation, we see that 2 mole of HNO3 react with one mole of Ba(OH)2
One mole of HNO3 is 63 g. Two mole are 63 * 2 = 126 g.
One mole of Ba(OH)2 is 171 g
126 g of HNO3 react with 171 g of Ba(OH)2
1.89 g of HNO3 react with X g of Ba(OH)2
X = 1.89g * 171g / 126g = 2.57 g Ba(OH)2.
Since we have 5.13 g of Ba(OH)2 and we need only 2.57g, this reactant will be left over.
We should use HNO3 to calculate how much Ba(NO3)2 is produced.
The mass of one mole of Ba(NO3)2 is 137 + 2(14 + 15*3) = 137 + 2 (14 + 48) = 261 g
Two mole of HNO3 produce one mole of Ba(NO3)2
126 g of HNO3 produces 261 g Ba(NO3)2
1.89 g of HNO3 produce X g of Ba(NO3)2
X = 1.89 * 261 /126 = 3.92 g

Answer: 3.92 g of Ba(NO3)2 is produced. HNO3 is a limited reactant, Ba(OH)2 will be left over.

8. How many liters of 0.2M solutions of NaOH are required to produce 0.7 liters of 0.5M solution of Na3PO4 in the following reaction
H3PO4 + 3NaOH = Na3PO4 + 3H2O
How many moles of H3PO4 will be spent?
First, let us calculate how many grams in 0.7 L of 0.5M solution of Na3PO4.
The mass of one mole of Na3PO4 is 23 * 3 + 31 + 16*4 = 164 g
1 L of 1M solution of Na3PO4 contains 164 g of Na3PO4.
1 L of 0.5 M solution of Na3PO4 contains X g of Na3PO4
X = 0.5 M * 164g / 1 M = 82 g of Na3PO4
1 L of 0.5 M solution of Na3PO4 contains 82 g
0.7 L of 0.5 M solution of Na3PO4 contains X g
X = 0.7 L * 82 g /1 L = 57.4 g of Na3PO4
So, 57.4 g of Na3PO4 is produced
How many grams of NaOH we need for that?
From the equation 3 mole of NaOH are required to produce one mole of Na3PO4.
The mass of one mole of NaOH is 23 + 16 + 1 = 40 g. 3 mole are 40 * 3 = 120g
120 g of NaOH produce 164 g of Na3PO4
X g of NaOH produce 57.4 g of Na3PO4
X= 120 g * 57.4 g /164 g = 42 g
We need 42 g of NaOH to produce 57.4 g of Na3PO4
Let us calculate how many grams of NaOH are in 1 L of 0.2 M solution of NaOH.
1 L of 1 M solution of NaOH contains 40 g of NaOH
1 L 0.2 M solution of NaOH contains X g of NaOH.
X = 0.2 M * 40g / 1 L = 8g
Now we can calculate how many liters of 0.2 M solution of NaOH we need
1 L contains 8 g NaOH
X L contain 42 g NaOH
X = 1 * 42 / 8 = 5.25 L

Answer: 5.25 L of 0.2M solutions of NaOH are required to produce 0.7 liters of 0.5M solution of Na3PO4

9. How many liters of H2 will be produce if 10 grams of Mg reacts with

0.5 liters of 0.1M solution of H_2SO_4? Which initial reactant will be left over?
$Mg + H_2SO_4 = MgSO_4 + H_2$
Let us calculate how much H_2SO_4 we have in grams.
The mass of one mole of H_2SO_4 is 2 + 32 + 64 = 98 g. H_2SO_4
1 L of 1M solution contains 98 g H_2SO_4. We have only 0.5 L
0.5 L of 1M solution contains X
X =0.5L * 98 g / 1 L = 49 g. H_2SO_4
1 M solution contains 49 g H_2SO_4
0.1 M solution contains X g H_2SO_4
X = 0.1 M * 49g/1 M = 4.9 g H_2SO_4
So, 0.5 L of a 0.1 M solution contains 4.9 g of H_2SO_4.
Let us calculate how much H_2SO_4 we need to completely react with 10 g of Mg?
From the equation, one mole of Mg reacts with one mole of H_2SO_4.
The mass of one mole of Mg is 24 g.
24 g of Mg react with 98 g of H_2SO_4
10 g of Mg react with X g of H_2SO_4
X = 10g * 98g / 24g =40.8 g

We have 4.9 g of H_2SO_4 but we need 40.8 g. It means that H_2SO_4 is limited and Mg will be left over.
To calculate how many liters of H_2 are produced we have to use H_2SO_4.
From the equation one mole of H_2SO_4 produces one mole of H_2 and one mole of H_2 is 22.4 L
98 g of H_2SO_4 produce 22.4 L H_2
4.9 g of H_2SO_4 produce X L of H_2
X=4.9 * 22.4 / 98 = 1.12 L H_2
Answer: 1.12 L H_2 is produced. Mg is left over.

10. How many grams of Al are required to produce 3 liters of H_2 if Al reacts with of 0.1M solutions of HCl? How many liters of solution of HCl will be spent?
$2Al + 6HCl = 2AlCl_3 + 3H_2$
Let us calculate how much Al is required to produce 3 L of H_2
From equation we see that 2 mole of Al produce 3 mole of H_2.
2 mole of Al equal 27 * 2 = 54 g. 3 mole of H_2 is equal to 3*22.4 L = 67.2 L

56 g of Al produce 67.2 L of H_2
X g of Al produce 3 L H_2
X = 56 g * 3L /67.2 L = 2.5 g Al
Now let us calculate how much HCl is required to produce 3 L of H_2.
From the equation, 6 mole of HCL produce 3 mole of H_2
The mass of one mole of HCl is 1 + 35 = 36g. 6 mole is 36 g * 6 = 216 g.
We calculated before that 3 mole of H_2 is 67.2 L
216 g of HCl produce 67.2 L H_2
X g of HCl produce 3 L of H_2
X = 216 g * 3 L/67.2 L = 9.6 g
If 1 L of 1M solution of HCL is 36 g/L, then 1 L of 0.1 M solution is 3.6 g/L
3.6 g of HCl is in 1 L of 0.1 M solution
9.6 g of HCl is in X L of 0.1 M solution.
X = 9.6 g * 1L/ 3.6 g = 2.67 L
Answer: 2.5 g Al and 2.67 L of 0.1 M solution of HCl are required to produce 3 L of H_2

11. How many grams of AgCl will be produced if 0.5 liters of 0.3M solution of $AgNO_3$ reacts with 1 liter of 0.5M solution of $CaCL_2$? Which initial reactant will be left over?
$2AgNO_3 + CaCl_2 = 2AgCl + Ca(NO_3)_2$
Let us calculate how much of each reactant we have in grams. Let us start with $AgNO_3$.
Mass of one mole of $AgNO_3$ is 108 + 14 + 48 = 170 g.
1 L of 1M solution of $AgNO_3$ is 170g
0.5 L of 1M solution is X g X = 0.5L * 170g /1L=85 g
1 M solution contains 85g
0.3 M solution contains X g
X = 0.3 * 85 / 1 = 25.5g
0.5 L of 0.3 M solution of $AgNO_3$contains 25.5 g $AgNO_3$
Let us calculate how much of $CaCl_2$ we have in grams.
The mass of one mole of $CaCl_2$ is 40 + 35*2=110g
1 L of 1M solution contains 110g
1 L of 0.5M solution contains X g
X = 0.5M * 110g/1M = 55g
1 L of 0.5 M solution of $CaCl_2$ contains 55g of $CaCl_2$
From the equation 2 mole of $AgNO_3$ react with one mole of $CaCl_2$

340g (170 *2) $AgNO_3$ react with 110 g $CaCl_2$
25.5 g $AgNO_3$ react with X g $CaCl_2$
X = 25.5 * 110 /340 = 8.25 g $CaCl_2$
Since to complete the reaction of 25.5 g $AgNO_3$, 8.25 g $CaCl_2$ are required and we have 55g, $CaCl_2$ will be left over. $AgNO_3$ is limited reactant and we should use $AgNO_3$ to calculate how much AgCl is produced.
The mass of one mole of AgCl is 108 + 35=143 g
From the equation, 2 mole of $AgNO_3$ produce 2 mole of AgCl
340 g $AgNO_3$ produce 286 g AgCl
25.5 $AgNO_3$ produce X g AgCl
X = 25.5 * 286 /340 = 21.45 g
Answer: 21.45 g AgCl are produced. $CaCl_2$ will be left over.

12. How many liters of 0.1 M solution of H_2SO_4 are required to produce 33 g of $ZnSO_4$? How many grams of $Zn(OH)_2$ are spent?
$Zn(OH)_2 + H_2SO_4 = ZnSO_4 + 2H_2O$
Let us calculate how much H_2SO_4 we have in 1 L of 0.1 M solution in grams.
The mass of H_2SO_4 is 2 + 32 + 64 = 98 g.
1 L of 1 M solution contains 98g
1 L of 0.1 M solution contains X g
X = 0.1 M * 98g / 1M = 9.8g
The mass of one mole of $ZnSO_4$ is 65 + 32 + 64 = 161 g
From the equation one mole of H_2SO_4 produces one mole of $ZnSO_4$
98 g H_2SO_4 produce 161 g $ZnSO_4$
X g H_2SO_4 produce 33 g $ZnSO_4$
X = 98g * 33g /161g = 20 g of H_2SO_4

1 L of 0.1 M solution contains 9.8 g H_2SO_4
X L of 0.1 M solution contains 20g H_2SO_4
X = 1 L * 20 g /9.8 g = 2 L H_2SO_4
How many grams of $Zn(OH)_2$ is spent?
The mass of one mole of $Zn(OH)_2$ is 108 + (16 + 1)*2 = 142 g.
From the equation, one mole of $Zn(OH)_2$ produce one mole of $ZnSO_4$
142 g of $Zn(OH)_2$ produce 161 g of $ZnSO_4$
X g of $Zn(OH)_2$ produce 33 g of $ZnSO_4$
X = 142g * 33g / 161g =29.1 g of $Zn(OH)_2$

Answer: 2 L of 0.1 M solution of H_2SO_4 and 29.1 g of $Zn(OH)_2$ are required to produce 33 g of $ZnSO_4$

13. How many liters of 0.3 M solution of H_2SO_4 are required to produce 9 g of $Al_2(SO_4)_3$ and how many grams of $Al(OH)_3$ are spent?
$2Al(OH)_3 + 3H_2SO_4 = Al_2(SO_4)_3 + 6H_2O$
Let us calculate how much H_2SO_4 we have in 1 L of 0.3 M solution in grams.
The mass of H_2SO_4 is 2 + 32 + 64 = 98 g.
1 L of 1 M solution contains 98g
1 L of 0.3 M solution contains X g of H_2SO_4
X = 0.3 M * 98g / 1M = 29.4g
The mass of one mole $Al_2(SO_4)_3$ is 27*2 + (32 + 64) * 3 = 342 g
From the equation, 3 mole of H_2SO_4 required to produce one mole of $Al_2(SO_4)_3$
98 * 3 g H_2SO_4 produce 342 g $Al_2(SO_4)_3$
X g H_2SO_4 produce 9 g $Al_2(SO_4)_3$
X = 9g * 98g /342g=2.58 g
1 L of 0.3M solution of H_2SO_4 contains 29.4 g
X L of 0.3 M solution of H_2SO_4 contains 2.58 g
X = 1L * 2.58 g/29.4 g = 0.09 L
How many grams of $Al(OH)_3$ is spent?
The mass of one mole of $Al(OH)_3$ is 27 + 17*3 = 78 g
From the equation, 2 mole of $Al(OH)_3$ are required to produce one mole of $Al_2(SO_4)_3$
156 g (2*78) of $Al(OH)_3$ produce 342 g of $Al_2(SO_4)_3$
X g of $Al(OH)_3$ produce 9 g of $Al_2(SO_4)_3$
X = 156 g * 9 g / 342 g = 4.1 g of $Al_2(SO_4)_3$
Answer: To produce 9 g of $Al_2(SO_4)_3$, 0.09 L of 0.3M H_2SO_4 and 4.1 g of $Al(OH)_3$ are required.

14. How many liters of NH_3 are required to produce 2 liter of 0.1M solution of NH_4HCO_3
How many liters of CO_2 will be spent in the following reaction?
$NH_3 + CO_2 + H_2O = NH_4HCO_3$
When you need to find an answer in liters it is not always necessary to calculate how many grams of

reactant is spent or produced. Some times, it is enough to calculate now many moles are involved.
In this problem we calculate moles and knowing that one mole of gas occupies 22.4 L, we can calculate
liters.
1 L of 0.1M solution of NH_4HCO_3 contains 0.1 mole of NH_4HCO_3
2 L of 0.1 M solutions of NH_4HCO_3 contain X mole of NH_4HCO_3
X = 2L * 0.1 mol/1L = 0.2 mol
From the equation, one mole of NH_3 produces one mole of NH_4HCO_3
1 mole NH_3 produces 1 mole NH_4HCO_3
X mole of NH_3 produce 0.2 mole of NH_4HCO_3
X = 1 mole * 0.2 mol/1 mole = 0.2 mol
1 mole of NH_3 occupies 22.4 L
0.2 mole of NH_3 occupies X L
X = 0.2 mole * 22.4 L /1mole = 4.48 L
How many liters CO_2 is spent? The solution is the same as for NH_3
From the equation, one mole of CO_2 produces one mole of NH_4HCO_3
X mole of CO_2 produce 0.2 mole of NH_4HCO_3
X = 0.2 mole and volume is 4.48 L
Answer: 4.48 L NH_3 and 4.48 L of CO_2 are required to produce 2 liters of a 0.1M solution of NH_4HCO_3

15. How many liters of CO_2 is produces if 200 grams of $CaCO_3$ reacts with SiO_2 in the following reaction?
$CaCO_3 + SiO_2 = CaSiO_3 + CO_2$
Again, we don't have to calculate grams. From the equation, one mole of $CaCO_3$ produces one mole of CO_2
Let us calculate how many mole of $CaCO_3$ there are in 100 g.
The mass of one mole of $CaCO_3$ is 40 + 12 + 48=100 g
We have 200 g $CaCO_3$ and it means that we have two mole of $CaCO_3$
Two mole of $CaCO_3$ produce two mole of CO_2 and 2 mole of CO_2 is 22.4 L * 2 = 44.8 L
Answer: 44.8 L of CO_2 is produce from 200 g of $CaCO_3$
16. How many liters of O_2 are required to oxidize 60 grams of FeS_2 to Fe_2O_3?
$4FeS_2 + 11O_2 = 2Fe_2O_3 + 8SO_2$

Let us calculate how many moles of FeS_2 we have in 100 g.
The mass of one mole of FeS_2 is 56 + 32*2 =120 g
We have 60 g of FeS_2 and it is 0.5 mol.
1 mole – 120 g
X mole – 60 g
X = 1*60/120 = 0.5 mol
From the equation, 4 mole of FeS_2 required 11 mole of O_2
0.5 mole of FeS_2 required X mole of O_2
X = 0.5mole * 11 mole /4 mole = 1.38 mol
1 mole of O_2 occupies 22.4 L
1.38 mole occupies X L
X = 1.38 mole * 22.4 L /1 mole = 30.9 L O_2
Answer: 30.9 L O_2 is require to oxidize 60 grams of FeS_2 to Fe_2O_3

17. How many of liters of oxygen gas will be required to completely burn 3 moles of methane?
$CH_4 + 2O_2 = CO_2 + 2H_2O$
From the equation, one mole of CH_4 required 2 mole of O_2
3 mole of CH_4 required X mole of O_2
X = 3 mole * 2 mol/1 mole = 6 mole of O_2
One mole of O_2 occupies 22.4 L
6 mole of O_2 occupies X L
X = 6 mole * 22.4 L / 1 mole =134 L O_2
Answer: 134 L of O_2 are required to completely burn 3 mole of CH_3

18. Calculate the number of liters of oxygen that are required to completely react with 51g of ammonia.
$4NH_3 + 5O_2 = 4NO + 6H_2O$
Let us calculate how many mole of NH_3 are in 51 g.
The mass of one mole of NH_3 is 14 + 3 = 17 g
17 g is 1 mol
51 g is X mol
X = 51 g * 1 mole / 17 g = 3 mol
From equation 4 mole of NH_3 required 5 mole of O_2

3 mole of NH_3 required X mole of O_2
X = 3 mole * 5 mole / 4 mole =3.75 mol.

1 mole of O_2 occupies 22.4 L
3.75 mole of O_2 occupy X L
X = 3.75 mole * 22.4 L / 1 mole = 84 L
Answer: 84 L of O_2 is required to completely react with 51 g of NH_3

19. Calculate the mass of silver nitrate in grams that is required to completely react with 7 mole of lead?
$Pb + 2AgNO_3 \rightarrow Pb(NO_3)_2 + 2Ag$
The mass of one mole of $AgNO_3$ is 108 + 14 +48=170 g
From the equation, one mole of Pb requires 2 mole of $AgNO_3$
7 mole of Pb require X mole of $AgNO_3$
X = 7mole * 2mole/1 mole = 14 mole of $AgNO_3$
1 mole of $AgNO_3$ is 170 g
14 mole of $AgNO_3$ is X g
X = 14 mole * 170 g/1mole =2380 g
Answer: 2380 g of $AgNO_3$ is required to completely react with 7 mole of Pb

20. Calculate the mass of carbon in grams that must react with oxygen to produce 12x10^23 molecules of Carbon Dioxide
(CO_2) $C + O_2 = CO_2$
One mole of any substance contains Avogadro number of particles and it is 6.022*10^23 per gram mol.
We have 12*10^23 of CO_2 and it is approximately 2 mole of CO_2
The mass of one mole of CO_2 is 12 + 32=44 g.
Then mass of 2 moles of CO_2 is 88 g.
The mass of one mole of C is 12 g
From the equation, one mole of C produces one mole of CO_2
12 g C produce 44 g of CO_2
X g C produces 88 g of CO_2
X = 12 g * 88 g / 44 g = 24 g C
Answer: 24 g of C is required to produce 12*10^23 molecules of CO_2

21. How many liters of hydrogen gas are required to completely hydrogenate 952 g of 2-butene?
$CH_3-CH=CH-CH_3 + H_2 = CH_3-CH_2-CH_2-CH_3$
Let us calculate how many mole of $CH_3-CH=CH-CH_3$ we have.

The mass of one mole of CH_3-CH=CH-CH_3 is 12 + 3 + 12 +1 + 12 + 1 + 12 +3=56 g
1 mole is 56 g
X mole is 952 g

X = 1 mole * 952 g/ 56 g = 17 mol
From the equation, one mole of H_2 is required to one mole of CH_3-CH=CH-CH_3.
X mole of H_2 is required to 17 mole of CH_3-CH=CH-CH_3
X = 1 mole * 17 mole / 1 mole = 17 mole of H_2
I mole of H_2 occupies 22.4 L
17 mole of H_2 occupy X L
X = 17 mole * 22.4 L/ 1 mole = 380.8 L
Answer: 380.8 L of H_2 is required to completely hydrogenate 952 g of CH_3-CH=CH-CH_3.

22. How many grams of barium chloride are required to completely precipitate barium sulfate from 1 liter of 0.3M H_2SO_4?
H_2SO_4 + $BaCl_2$ -= $BaSO_4$ + 2HCl
Let us calculate how many gram of H_2SO_4 we have.
The mass of one mole of H_2SO_4 is 98 g.
1 L of 1 M solution contains 98 g of H_2SO_4
1 L of 0.3 M solution contains X g of H_2SO_4
X =0.3M * 98 g/1 M = 29.4 g
The mass of one mole of $BaCl_2$ is 137 + 35*2 = 207 g.
From the equation, one mole of H_2SO_4 reacts with one mole of $BaCl_2$
98 g H_2SO_4 required 207 g of $BaCl_2$
29.4 g of H_2SO_4 required X g of $BaCl_2$
X = 29.4 g * 207 g / 98 g = 62.1 g $BaCl_2$
Answer: 62.1 g of $BaCl_2$ is required to completely precipitate $BaSO_4$ from 1 L of 0.3M H_2SO_4

23. What mass of potassium hydroxide is required to react completely with 1 liter of 0.1M solution of sulfuric acid to produce potassium sulfate?
How many grams of K_2SO_4 will be produced?
2KOH + H_2SO_4 → $2H_2O$ + K_2SO_4

Let us calculate how many grams of H_2SO_4 we have.
The mass of one mole of H_2SO_4 is 98 g
1 L of 1M solution contains 98 g of H_2SO_4
1 L of 0.1 M solution contains X g of H_2SO_4
X = 0.1 M * 98 g / 1 M = 9.8 g
From the equation, 2 mole of KOH react with one mole of H_2SO_4
The mass of one mole of KOH is 39 + 17 = 56 g,
Then 2 mole of KOH is 112g
112 g of KOH react with 98 g of H_2SO_4
X g of KOH reacts with 9.8 g of H_2SO_4

X = 112g * 9.8g /98 g = 11.2 g KOH
How many grams of K_2SO_4 are produced?
The mass of one mole of K_2SO_4 is 39 + 39 + 32 +64=174 g
From the equation, one mole of H_2SO_4 produces one mole of K_2SO_4
98 g H_2SO_4 produce 174 g of K_2SO_4
9.8 g H_2SO_4 produce X g K_2SO_4
X = 9.8 g * 174 g / 98 g = 17.4 g K_2SO_4
Answer: 11.2 g KOH is required to completely react with 1 L of 0.1 M H_2SO_4
17.4 g of K_2SO_4 is produced.
24. What volume of 0.2M NaOH is required to completely neutralize 50.0 mL of 0.3M HCl?
NaOH + HCl = NaCl + H_2O
From the equation, one mole of NaOH neutralizes one mole of HCl
How many mole of HCl are in 50 ml 0.3 M solution?
1 L of 1 M solution contains 1 mole of HCl
0.05 L of 1 M solution contains X mole of HCl
X = 0.05 L * 1 mol/ 1 L = 0.05 mol.
0.05 L of 1 M solution contains 0.05 mol
0.05 L of 0.3 mole solution contains X mol
X = 0.3 M * 0.05 mol/1M = 0.015 mole HCl
50.0 mL of 0.3 M solution contain 0.015 mole of HCl
1 L of 1 M NaOH solution contains 1 mole of NaOH
1 L of 0.2 M solution contains X mole of NaOH
X = 0.2 M * 1 mol/1M = 0.2 mol.
We need only 0.015 mole of NaOH. How many ml of NaOH solution we

need?
1 L of 0.2 M solution contains 0.2 mol
X L of 0.2 M solution contains 0.015 mol.
X = 1 L * 0.015 mol/ 0.2 mole = 0.075 L
Answer: 0.075 L (75mL) of NaOH is required to completely neutralize 50.0 mL of 0.3M HCl

25. How many grams of MgCl2 are produce if 0.5 L of 0.5 M solution of HCL react with Mg(OH)2. How much Mg(OH)2 is spent?
Mg(OH)2 + 2HCl = MgCl2 + 2H2O

Let us calculate how much HCl we have in grams?
The mass of one mole of HCl is 36g
1 L of 1 M solution contains 36 g.
1 L of 0.5 M solutions contain X g
X = 0.5 M * 36 g / 1M = 18 g HCl
1 L contains 18 g
0.5 L contains X g
X = 0.5 L * 18 g / 1L = 9 g
The mass of one mole of MgCl2 is 24 + 70 = 94 g
From the equation, two mole of HCl produce 1 mole of MgCl2
36*2=72 g of HCl produce 94 g of MgCl2. We have only 9 g of HCl.
9 g of HCl produce X g of MgCl2
X = 9 g * 94 g / 72 g = 11.75 g of MgCl2
How much Mg(OH)2 is spent?
The mass of one mole of Mg(OH)2 is 24 + 17*2=58 g
From equation, 1 mole of Mg(OH)2 produce 1 mole of MgCl2
58 g of Mg(OH)2 produce 94 g of MgCl2
X g of Mg(OH)2 produce 11.75 g of MgCl2
X = 58 g * 11.75 g / 94 g = 7.25 g
Answer: 11.75 g of MgCl2 is produce if 0.5 L of 0.5 M solution of HCL react with Mg(OH)2 7.25 g of Mg(OH)2 are spent

26. How many grams of KClO3 would be required to completely decompose to produce 3 liters of O2? How many grams of KCl are produced?
2KClO3 = 3O2 + 2KCl

Let us calculate how much O_2 we have in grams? I mole of gas occupies 22.4 L

The mass of one mole of O_2 is 32g.

32 g occupy 22.4 L

X g occupy 3 L X = 32 g * 3 L / 22.4 L = 4.29 g of O_2

The mass of one mole of $KClO_3$ is 39 + 35 + 48 =122 g of $KClO_3$

The mass of one mole of KCl is 39 + 35 = 74 g of KCl

From the equation, 2 mole of $KClO_3$ produce 3 mole of O_2 and 2 mole of KCl.

122*2=244 g of $KClO_3$ produce 16*3=48 g of O_2

X g of $KClO_3$ produce 4.29 g of O_2

X = 244 g * 4.29 g / 48g = 21.8 g of $KClO_3$ is required.

How many grams of KCl are produced?

From the equation 2 mole of $KClO_3$ produce 2 mole of KCl

244 g of $KClO_3$ produce 148 g of KCl

21.8 g of $KClO_3$ produce X g of KCl

X = 21.8g * 148 g/244g = 13.2 g of KCl

Answer: 21.8 g of $KClO_3$ is required to produce 3 L of O_2. 13.2 g of KCl is produced.

27. How many liters of 0.5M solution of HCl are required to completely react with 25.0 g of aluminum? How many liters of H_2 are produced?

2Al + 6 HCl =2$AlCl_3$ + 3H_2

Let us calculate how much HCl is in 1 L of O.5 M solution?

The mass of one mole of HCl is 35+1=36 g.

1 L of 1M solution contains 36 g of HCl

1 L of 0.5 M solution contains X g of HCl

X = 0.5 M * 36 g / 1 M = 18 g per liter.

The mass of one mole of Al is 27 g.

From the equation 2 mole of Al react with 6 mole of HCl

27*2=54 g of Al are required 6*36=216 g of HCl

25 g of Al are required X g of HCl

X = 25g * 216 g /54 g = 100g HCl is required.

1 L of 0.5 M solution contains 18 g of HCl

X L of 0.5 M solution contains 100g of HCl

X = 1 L * 100 g / 18 g = 5.6 L of HCl is required to completely react with 25

g of Al
How many liters of H_2 are produced?
From the equation, 2 mole of Al produce 3 mole of H_2
We have 25 g of Al. How many mole of Al do we have?
27 g is 1 mol
25 g is X mol. X = 25 g * 1 mol/27 g = 0.93 mol
2 mole of Al produce 3 mole of H_2
0.93 mole of Al produce X mole of H_2
X = 0.93 mole * 3 mol/2 mole = 1.39 mole of H_2

1 mole of H_2 occupies 22.4 L
1.39 mole of H_2 occupy X L
X = 1.39 mole * 22.4 L /1 mole = 31.1 L
Answer: 5.6 L of HCl are required to completely react with 25 g of Al
31.1 L of H_2 are produced.

28. How many grams of nitrogen would be required to completely react with 11.2 liters of hydrogen to produce ammonia? How many grams of ammonia produced?
$N_2 + 3 H_2 = 2 NH_3$
Let us calculate how many grams of H_2 we have.
The mass of one mole of H_2 is 2 g
I mole of H_2 occupies 22.4 L
2 g of H_2 occupies 22.4 L
X g of H_2 occupies 11.2 L
X = 2 g * 11.2 L / 22.4 L = 1 g.
The mass of one mole of N_2 is 14*2=28 g
The mass of one mole of NH_3 is 14+3=17 g
From the equation, one mole of N_2 reacts with 3 mole of H_2 and it produces 2 mole of NH_3
28 g of N_2 react with 6 g of H_2
X g of N_2 react with 1 g of H_2
X = 28 g * 1 g / 6 g = 4.7 g of N_2 are required for 11.2 L (1 g) of H_2
How many grams of ammonia are produced? From the equation, one mole of N_2 produces 2 mole of NH_3.
28 g of N_2 produce 17*2=34 g of NH_3
4.7 g of N_2 produce X g of NH_3

X = 4.7 g * 34 g /28 g = 5.7 g of NH_3

Answer: 4.7 g of N_2 are required to completely react with 11.2 L (1 g) of H_2

5.7 g of NH_3 is produced.

29. Calculate the volume of 0.5 M sulfuric acid in milliliters that is required to completely neutralize 100 ml of 1 M solution of KOH?

$H_2SO_4 + 2KOH = K_2SO_4 + 2H_2O$

What is the K^+ ion concentration at the end of the reaction?

Let us calculate how many moles of H_2SO_4 are in 1 L of 0.5 M solution?

1 L of 1 M solution of H_2SO_4 contains 1 mol

1 L of 0.5 M solution contains X mol

X = 0.5 M * 1 mole / 1 M = 0.5 mol.

How many moles of KOH we have?

1 L of 1 M solution of KOH contains 1 mol

0.1 L of 1M solution of KOH contains X mol

X = 0.1 L * 1 mole / 1 L = 0.1 mol.

From the equation 1 mole of H_2SO_4 reacts with 2 mole of KOH

X mole of H_2SO_4 react with 0.1 mole of KOH

X = 1 mole * 0.1 mole / 2 mole = 0.05 mole of H_2SO_4 is required

1 L of 0.5 M solution of H_2SO_4 contains 0.5 mol.

X L of 0.5 M solution of H_2SO_4 contains 0.05 mol.

X = 1 L * 0.05 mole / 0.5 mole = 0.1 L = 100 mL of 0.5 M H_2SO_4 is required.

What is the K^+ ion concentration at the end of the reaction?

We calculated above that initially we had 0.1 mole of KOH in a 100 ml of solution.

Then we added 100 mL of H_2SO_4. The total volume becomes 100ml + 100 ml = 200 ml.

Initially we had 0.1 mole of KOH.

What is K^+ concentration in M if we have 0.1 mole per 200 ml?

0.1 mole per 200 ml

X mole per 1 L

X = 0.1 mole * 1 L / 0.2 L = 0.5 mole per 1 Liter or 0.5 M

Answer: 100 mL of 0.5 M H_2SO_4 is required to neutralize 100 mL of 1 M solution of KOH. The K^+ concentration at the end of the reaction is 0.5 M

30. How many grams of Fe_2O_3 are required to completely react with 3moles of Al?
$2Al + Fe_2O_3 = 2Fe + Al_2O_3$

The mass of one mole of Fe_2O_3 is 56 * 2 + 16*3 = 160
The mass of one mole of Al is 27
From the equation 2 mole of Al react with one mole of Fe_2O_3
54 g of Al (2 mole) react with 160 g of Fe_2O_3
81 g of Al (3 mole) react with X g of Fe_2O_3
X = 81 g * 160 g /54 g = 240 g of Fe_2O_3

Answer: 240 g of Fe_2O_3 are required to completely react with 3 mole of Al.

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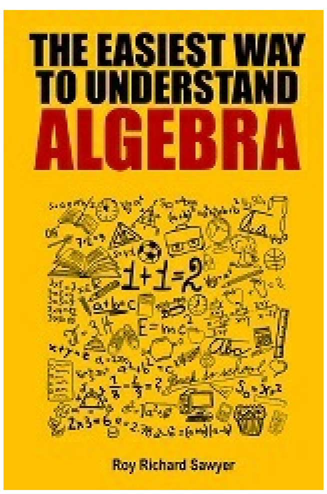

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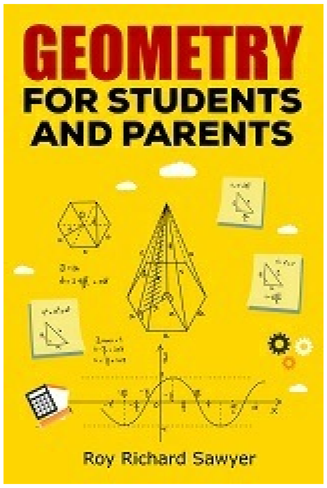

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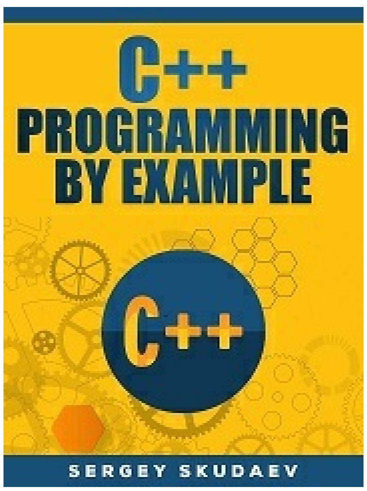

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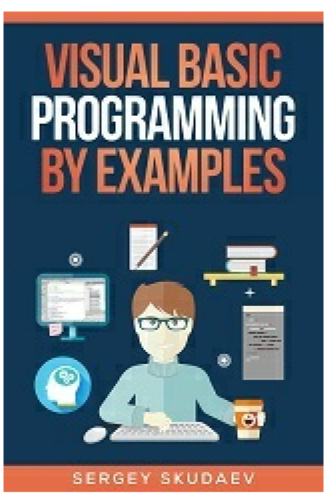

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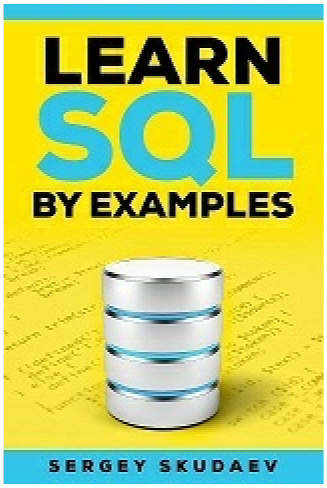

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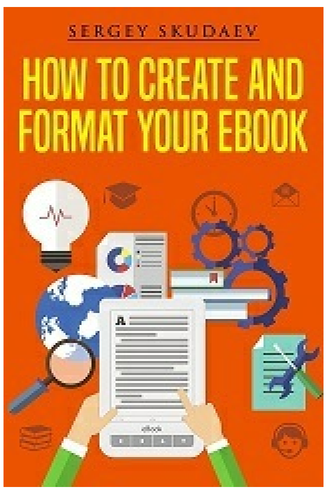

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