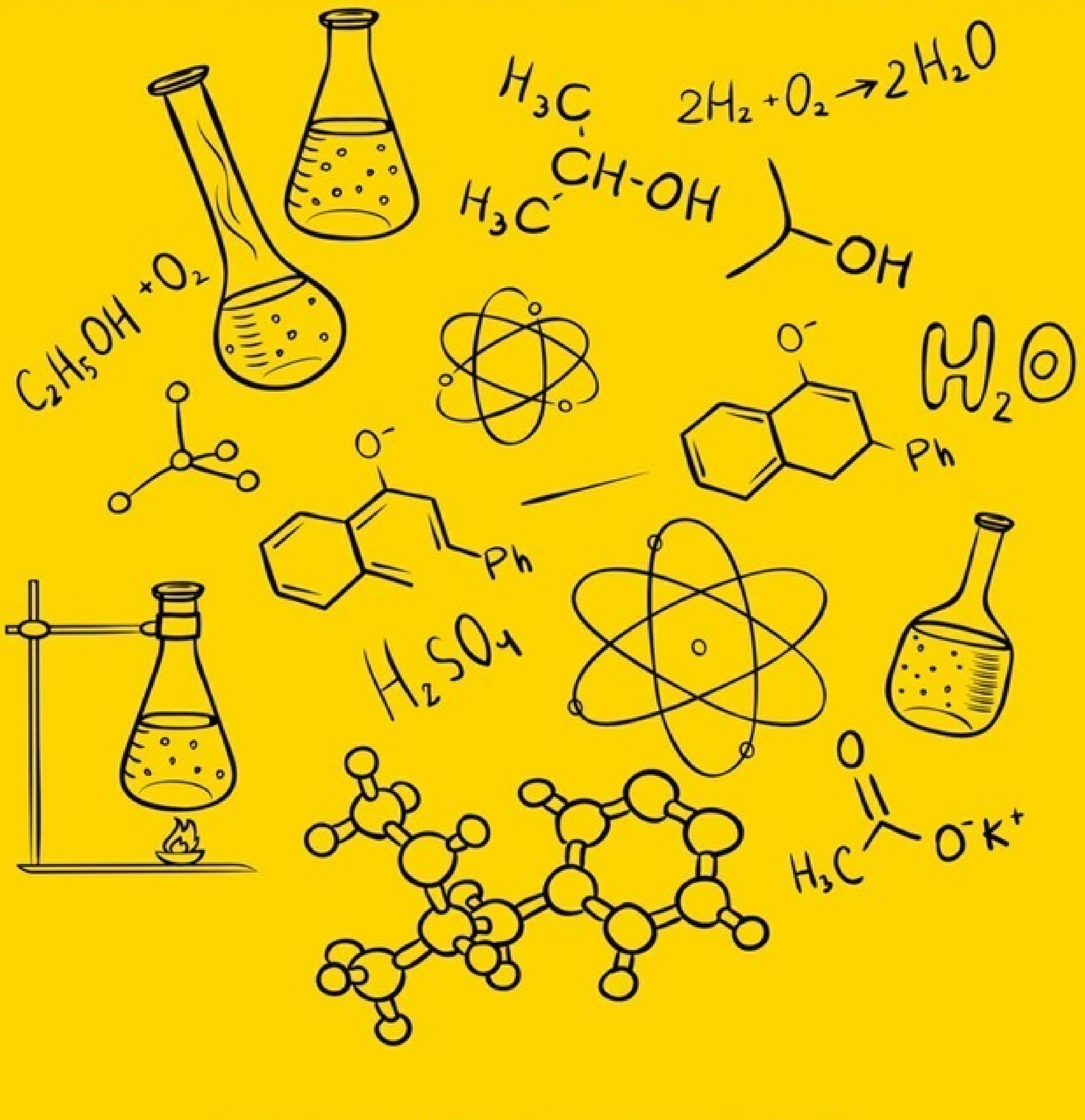
THE EASIEST WAY TO UNDERSTAND CHEMISTRY



SERGEY SKUDAEV

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The Easiest Way to Understand Chemistry. Chemistry Concepts, Problems and Solutions

«Издательские решения»

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If you are a parent struggling to help your child with chemistry homework, this is a short book that will help you. It covers key chemistry topics: Oxides, Bases, Acids, Salts, Equivalent proportions, Acid Base reactions, Weight and Volume problems, Equilibrium, Le Chatelier's Principle, Freezing and Boiling points, Balance Redox Reactions, Stoichiometry (with answers and solutions).If you are student, read this book and you will prove to yourself that you can understand chemistry!

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Содержание

The Easiest Way to Understand Chemistry Chemistry Concepts, Problems and Solutions

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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 Na2CO3 react with CaCL 2 how many grams of CaCO3 is produced?

10g? g

1. Na2CO3 + CaCL2 = CaCO3 +2NaCL

All compounds react with each other in certain proportions In a given reaction one mole of Na2CO3 produces one mole of CaCO3.

Mole is molecular mass (MW) in grams.

Atomic mass of Na = 23

Atomic mass of C = 12

Atomic mass of O = 16

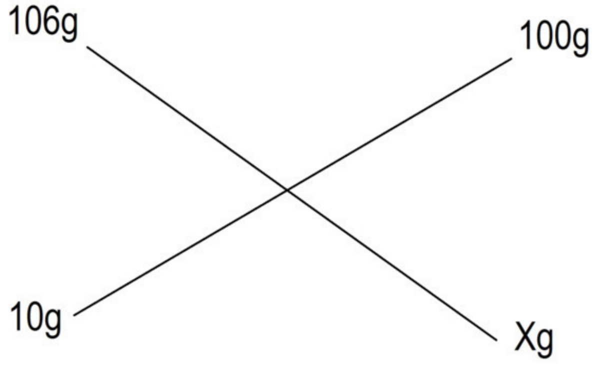
For Na2CO3 the MW is 23 *2 +12 +16*3 = 106 g. – 1 mole

For CaCO3 the MW is 40 +12 +48 = 100g. 1 mole.

106 g Na2CO3 produces 100g CaCO3

10 g Na2CO3 produces X g CaCO3

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 CaCO3

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 element́s 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 produced.

Knowing to which group and period an element belongs, a chemist can tell a lot about the element́s 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 electroń s orbital has spherical shape that is called an S orbital

When l=1 the electroń s orbital has a dumbbell shape and is called a p orbital.

When l=2 the electroń s orbital is called a d orbital.

When l=3 the electroń 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.

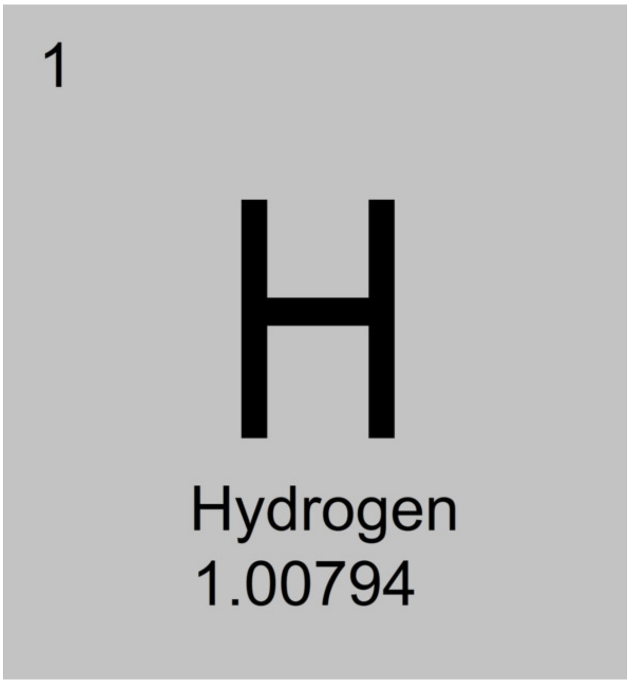
Imagine that you have a desk with a stack of book shelves. If you have only one book you will put it on the first shelf. You will not put it on the top shelf near the ceiling. If you have a few books, you put them where it would be easier to reach one. In an atom, the electrons start filling orbitals 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:

$1s^{1}$

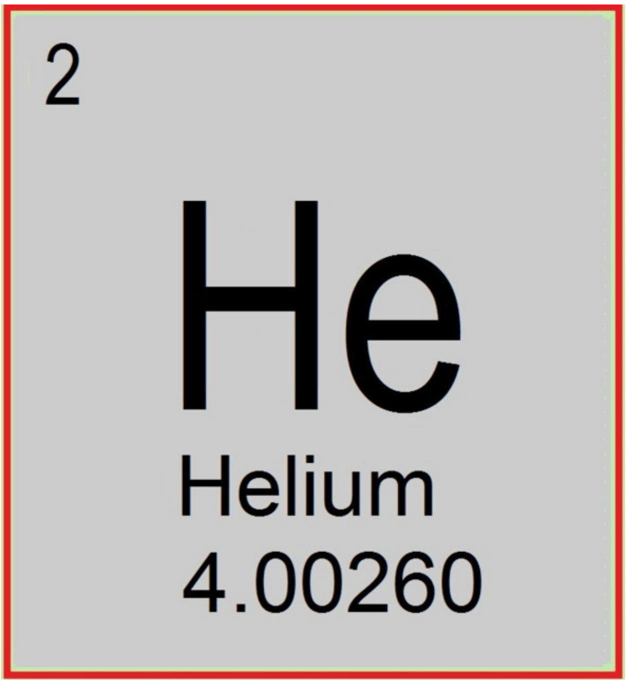


Hydrogen: $1s^{1}$

It means that Hydrogen has only one electron on the first S orbital.

The electronic configuration of the Helium (He) atom is:

$1s^{2}$



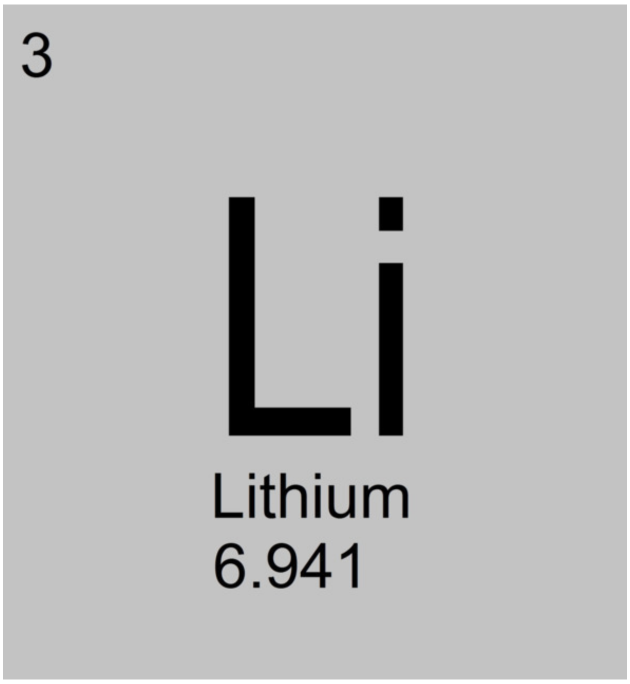
Helium: $1s^{2}$

It means that He 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:

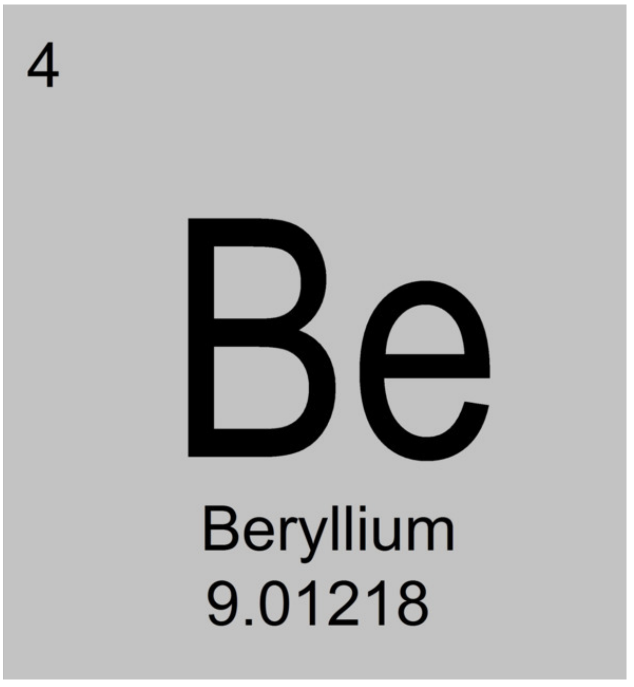
$1s^{2}\,2s^{1}$



Lithium: $1s^{2}\,2s^{1}$

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:

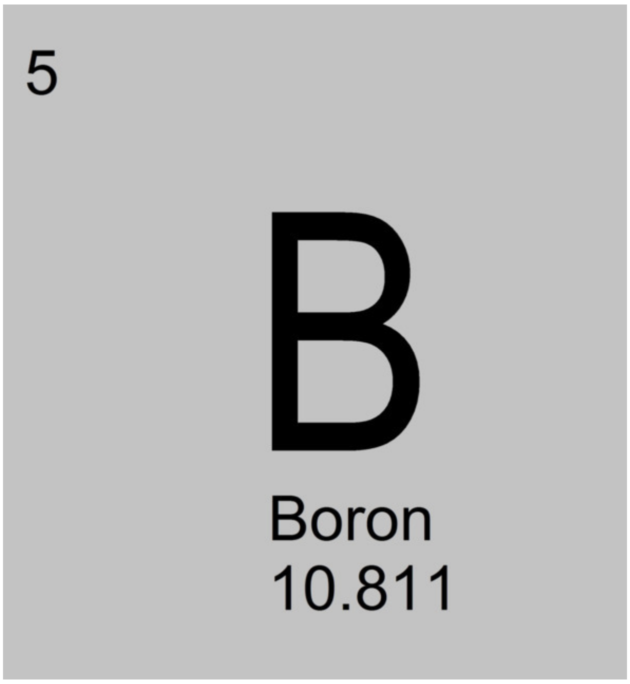
$1s^{2}\,2s^{2}$



Beryllium: $1s^{2}\,2s^{2}$

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:

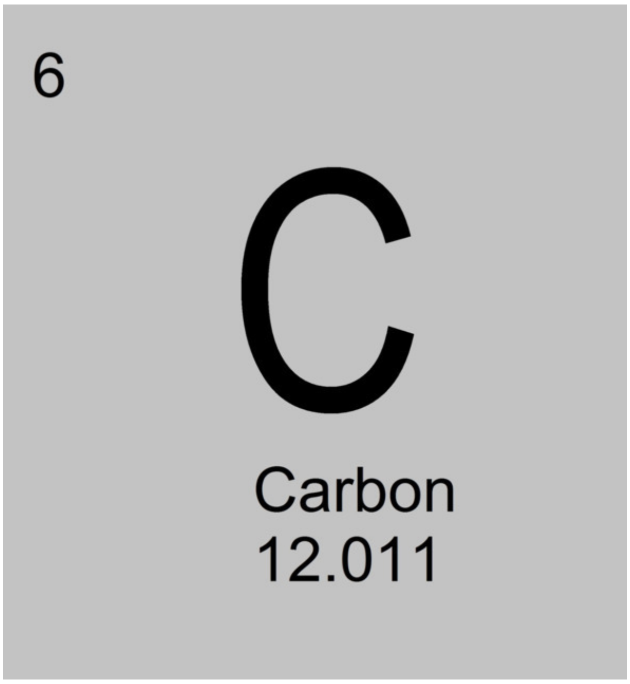
$1s^{2}\,2s^{2}\,2p^{1}$



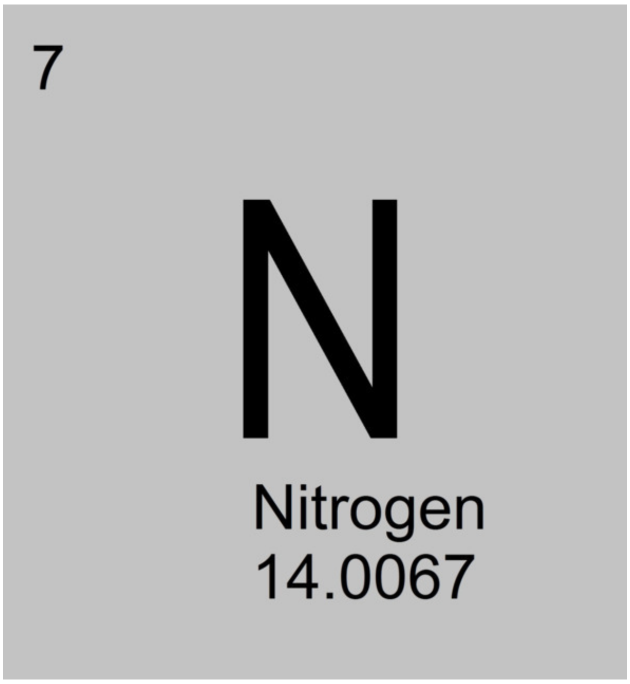
Boron: $1s^2 2s^2 2p^1$

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.

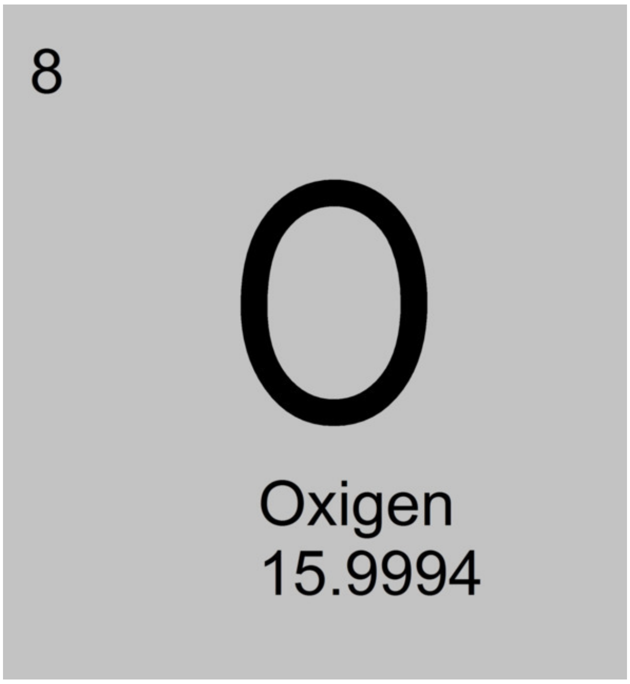
$1s^2 2s^2 2p^2$



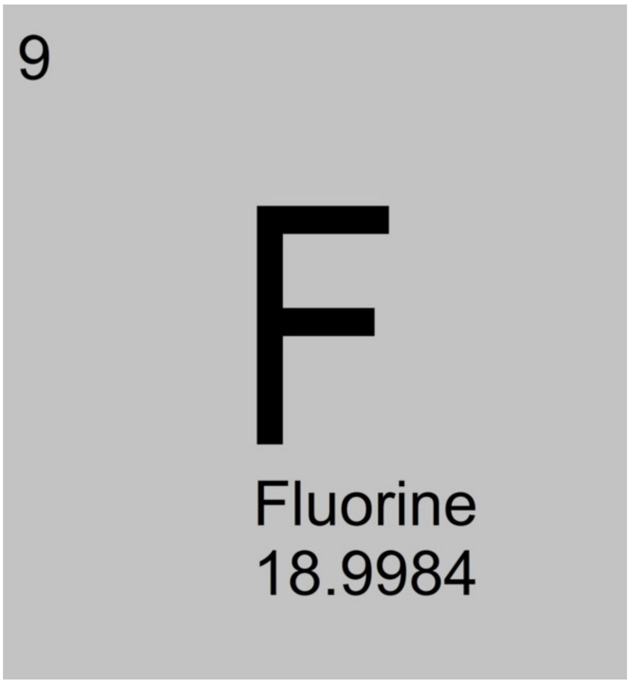
Carbon: $1s^2 2s^2 2p^2$



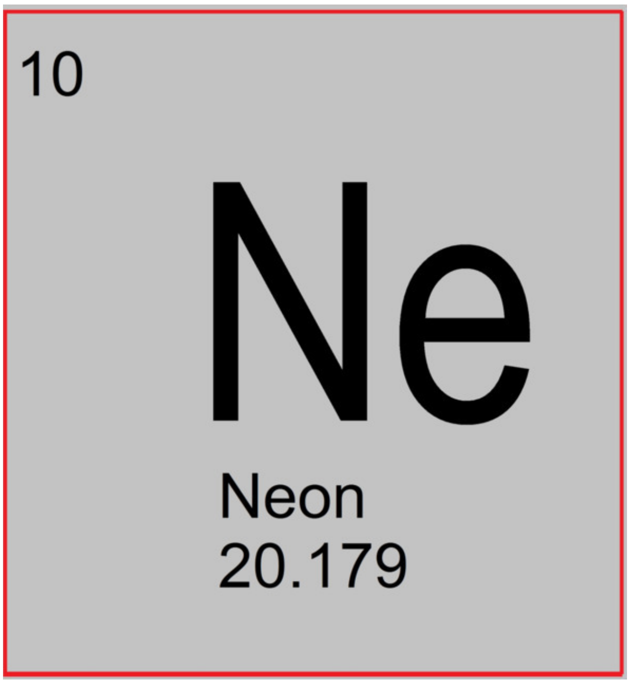
Nitrogen: $1s^{2}\,2s^{2}\,2p^{3}$



Oxigen: $1s^{2}\,2s^{2}\,2p^{4}$



Fluorine: $1s^{2}\,2s^{2}\,2p^{5}$

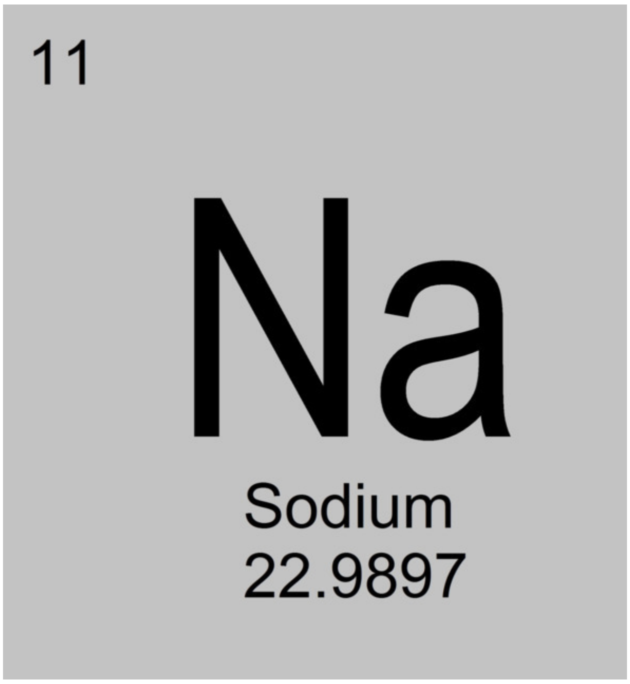


Neon: $1s^{2}\,2s^{2}\,2p^{6}$

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

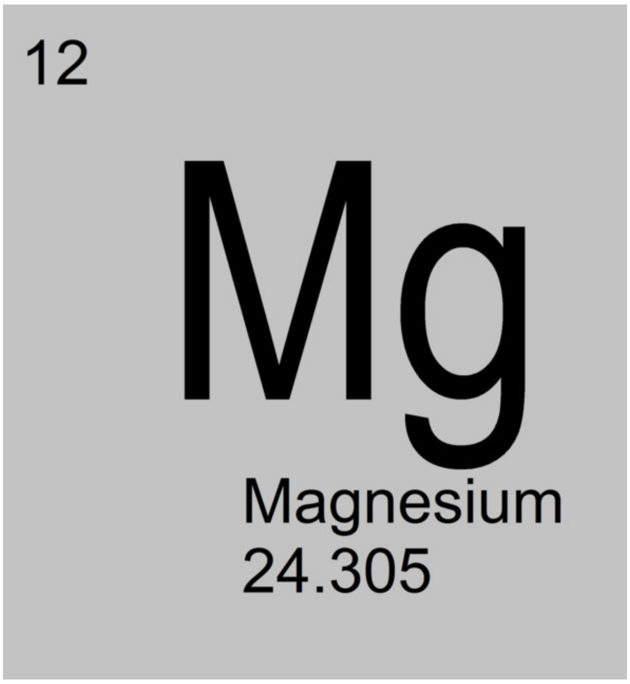
The next element is Sodium (Na). Na order number is 11. It has the same electronic configuration as Neon plus additionally, it has 1 electron on the 3S orbital. The Sodium electronic configuration can be written in short form as [Ne] $3s^1$ or in long form:

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



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

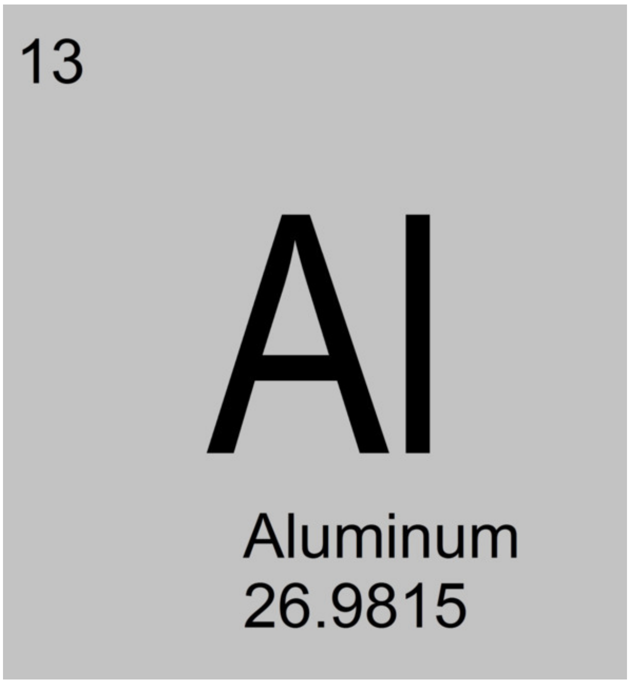
The next element is Magnesium (Mg). Mg has 2 electrons on the 3S orbital.
$1s^2 2s^2 2p^6 3s^2$



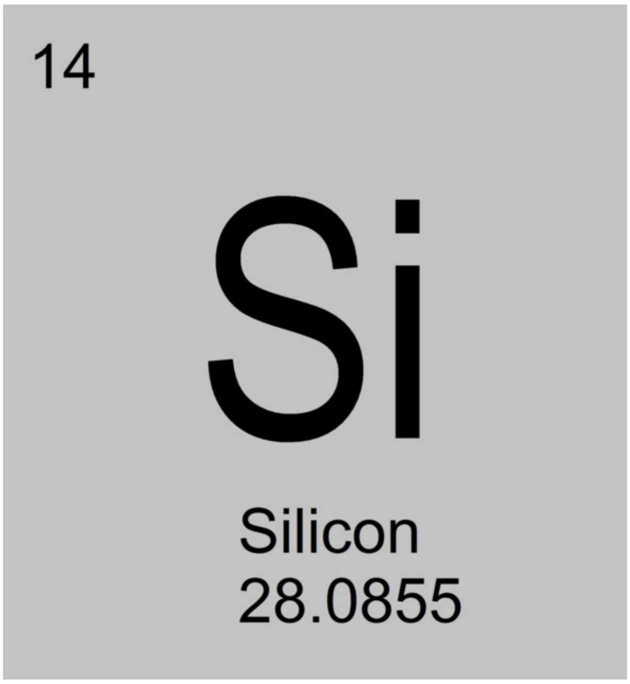
Magnesium: $1s^2 2s^2 2p^6 3s^2$

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.

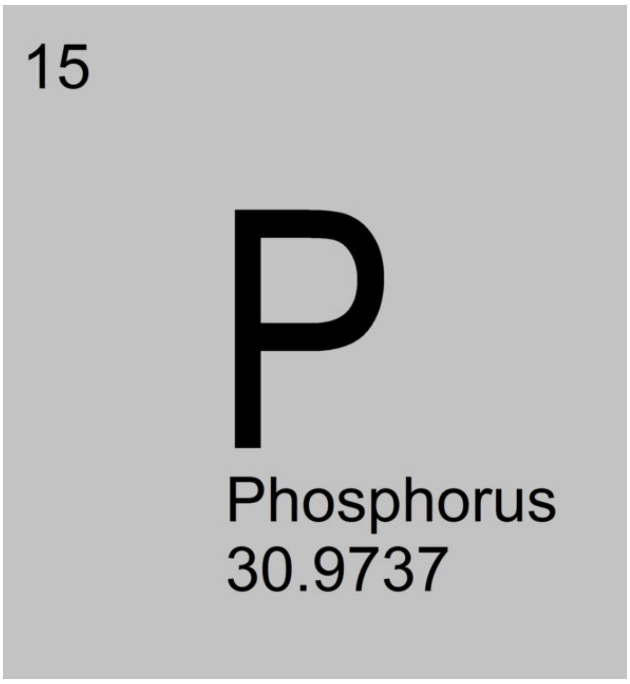
$1s^2 2s^2 2p^6 3s^2 3p^1$



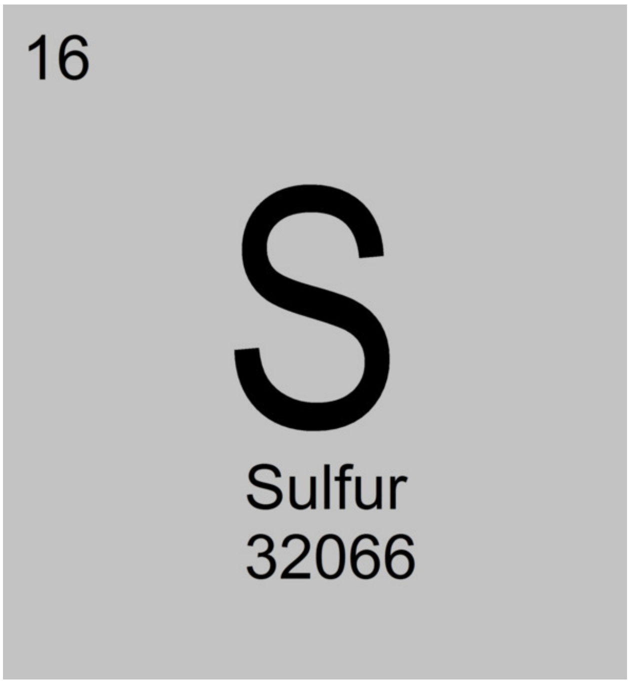
Aluminum: $1s^2\ 2s^2\ 2p^6 3s^2\ 3p^1$



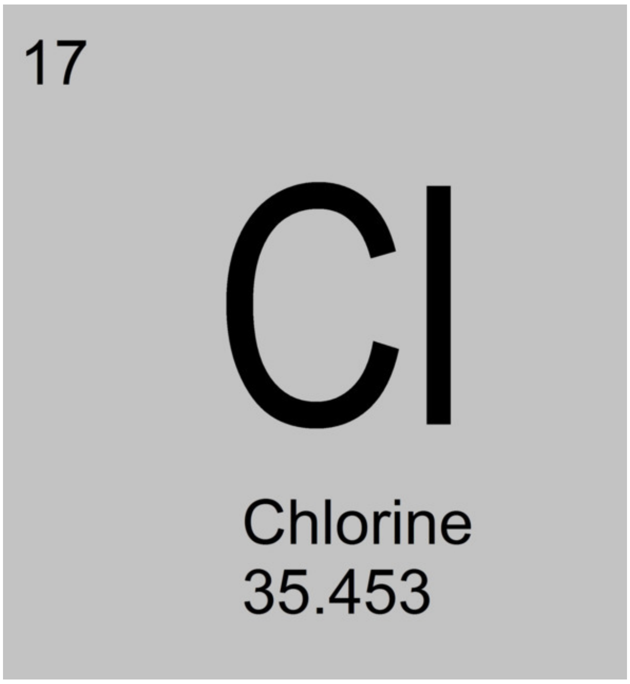
Silicon: $1s^2\ 2s^2\ 2p^6 3s^2\ 3p^2$



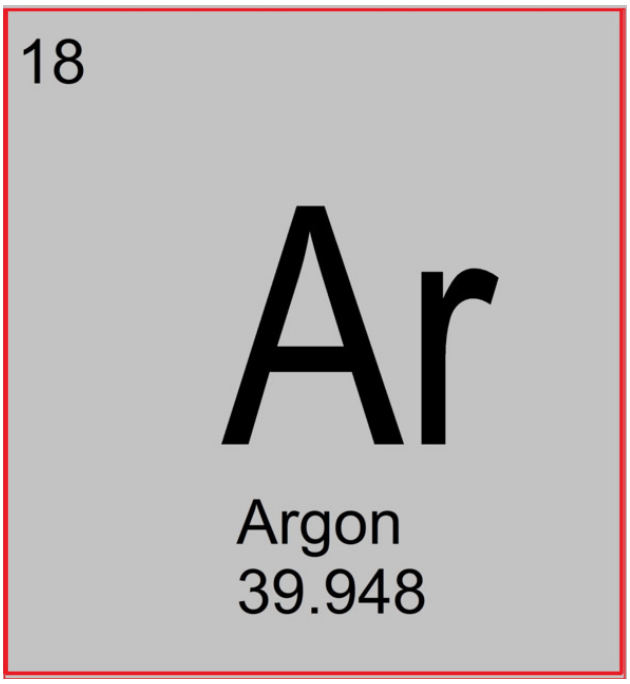
Phosphorus: $1s^2 2s^2 2p^6 3s^2 3p^3$



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

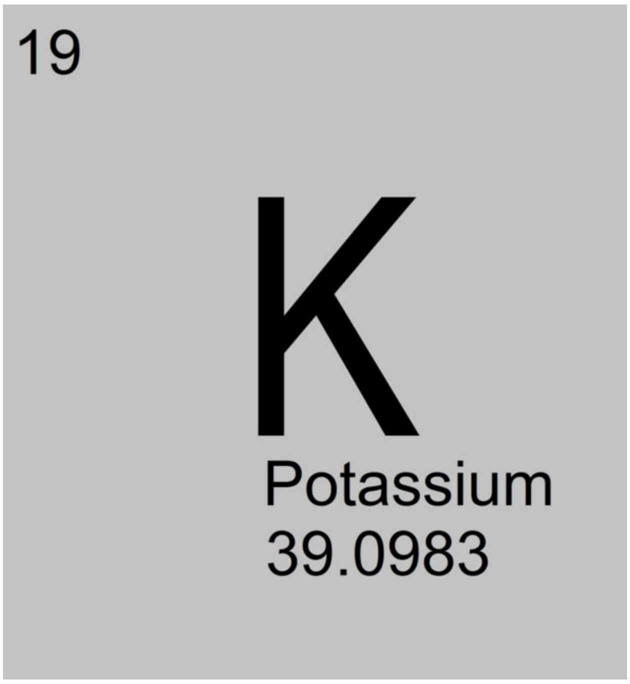


Chlorine: $1s^2 2s^2 2p^6 3s^2 3p^5$



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

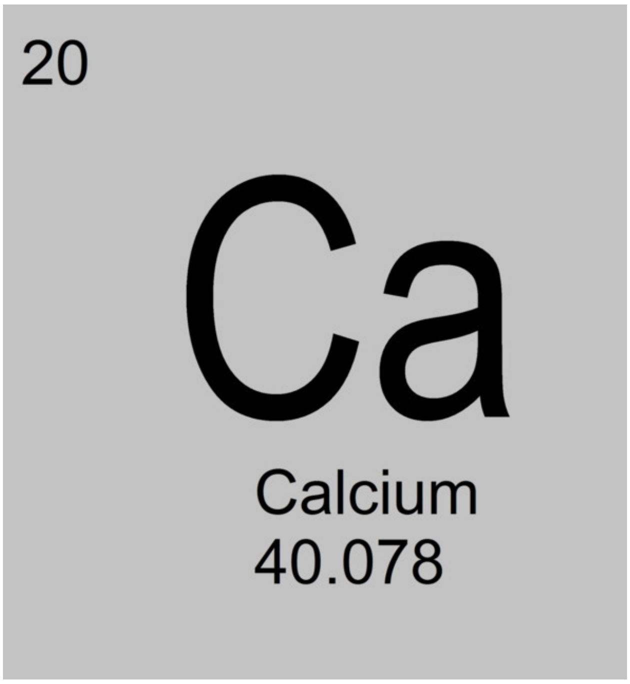
For Argon the main quantum number n is 3, l is 2. Remember, we pointed out earlier when l=2 additional d orbital appeared. So we may expect that the next element, Potassium, will have the outmost electron on the 3d orbital. Actually, Potassium has one the outmost electron on the 4S orbital. The 4S orbital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



Potassium: $1s^{2} 2s^{2} 2p^{6} 3s^{2} 3p^{6} 4s^{1}$

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

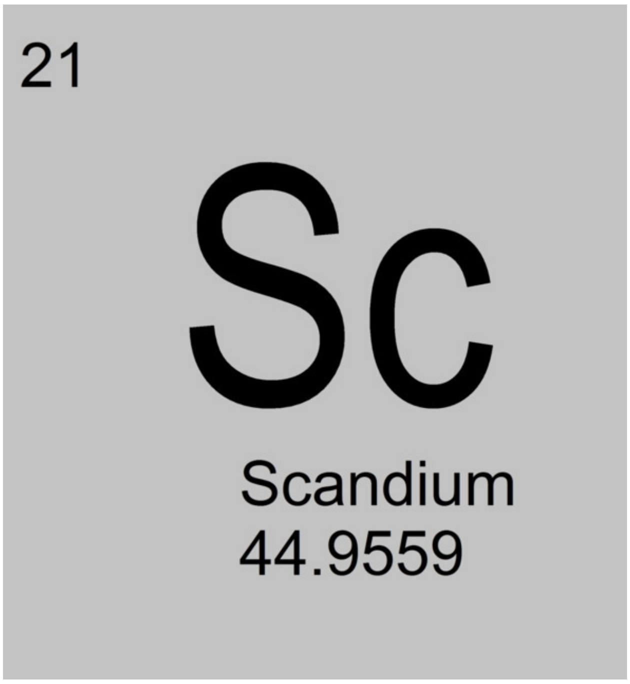
$1s^{2} 2s^{2} 2p^{6} 3s^{2} 3p^{6} 4s^{2}$



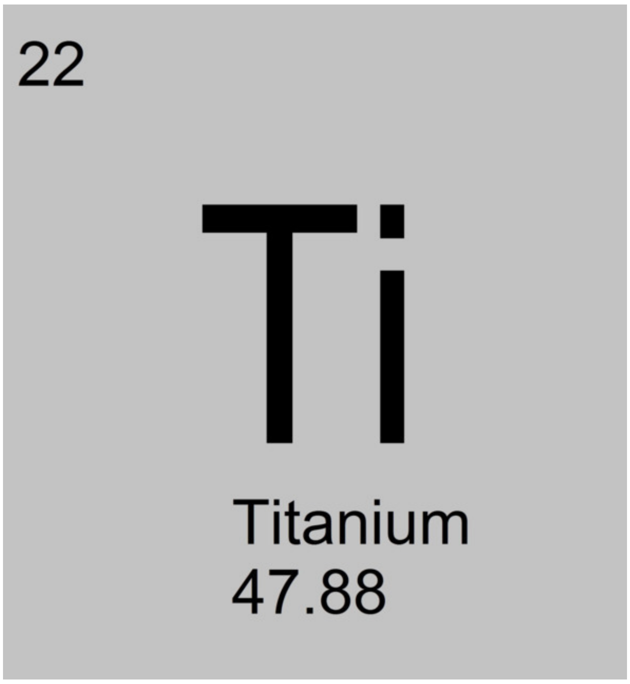
Calcium: $1s^{2} 2s^{2} 2p^{6} 3s^{2} 3p^{6} 4s^{2}$

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

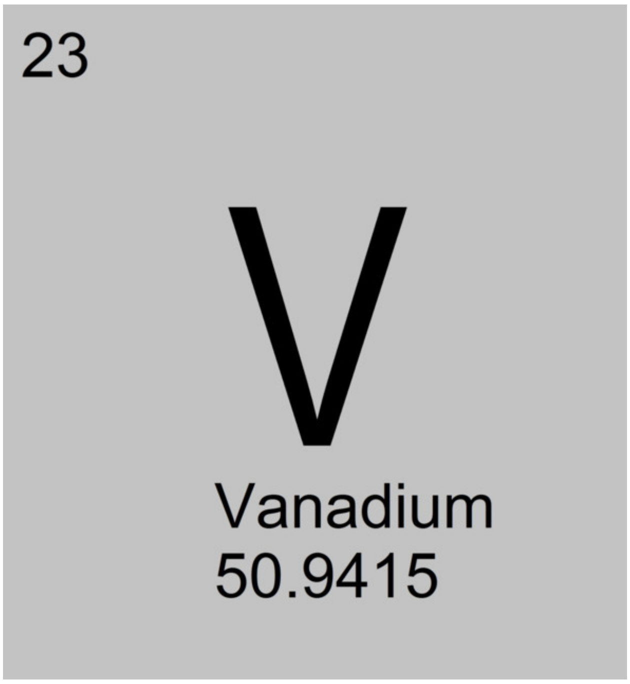
$1s^{2} 2s^{2} 2p^{6} 3s^{2} 3p^{6} 4s^{2} 3d^{1}$



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

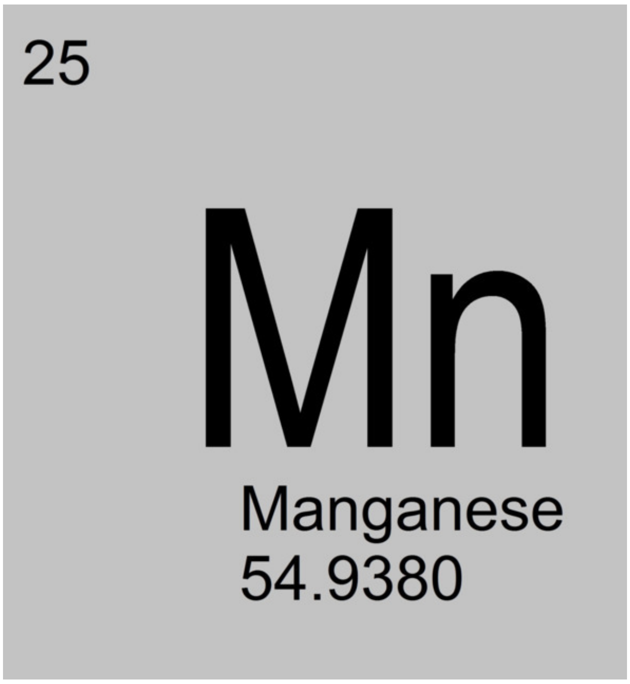


Titanium: $1s^{2}\ 2s^{2}\ 2p^{6}3s^{2}\ 3p^{6}4s^{2}\ 3d^{2}$

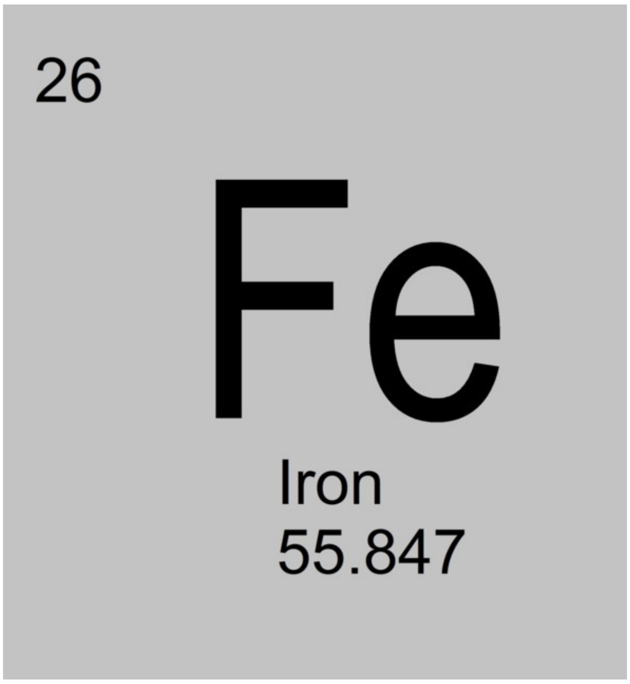


Vanadium: 1*s* ^{2} 2*s* ^{2} 2*p* ^{6}3*s* ^{2} 3*p* ^{6}4*s* ^{2} 3*d* ^{3}

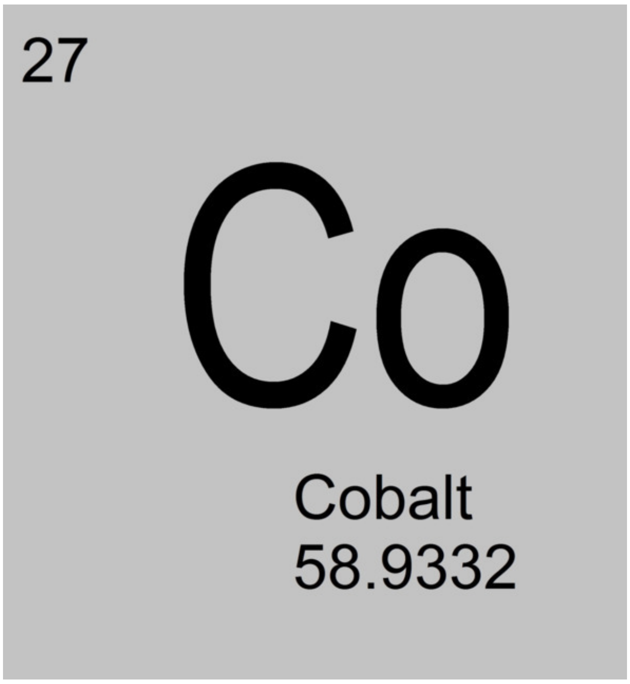
Chronium: 1*s* ^{2} 2*s* ^{2} 2*p* ^{6}3*s* ^{2} 3*p* ^{6}4*s* ^{1} 3*d* ^{5}



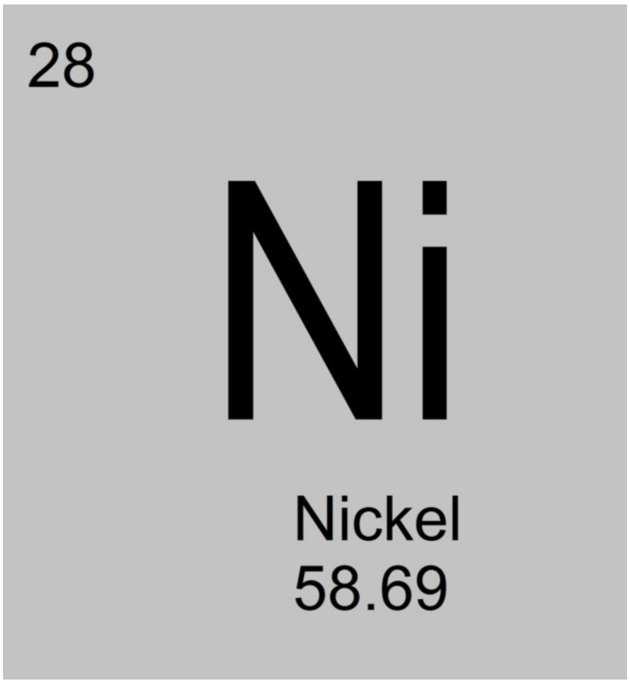
Manganese: $1s^2\ 2s^2\ 2p^6 3s^2\ 3p^6 4s^2\ 3d^5$



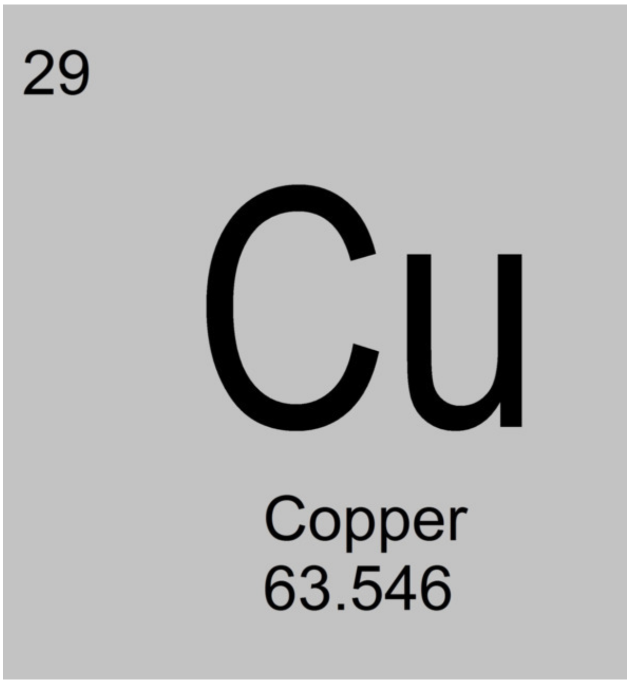
Iron: $1s^2\ 2s^2\ 2p^6 3s^2\ 3p^6 4s^2\ 3d^6$



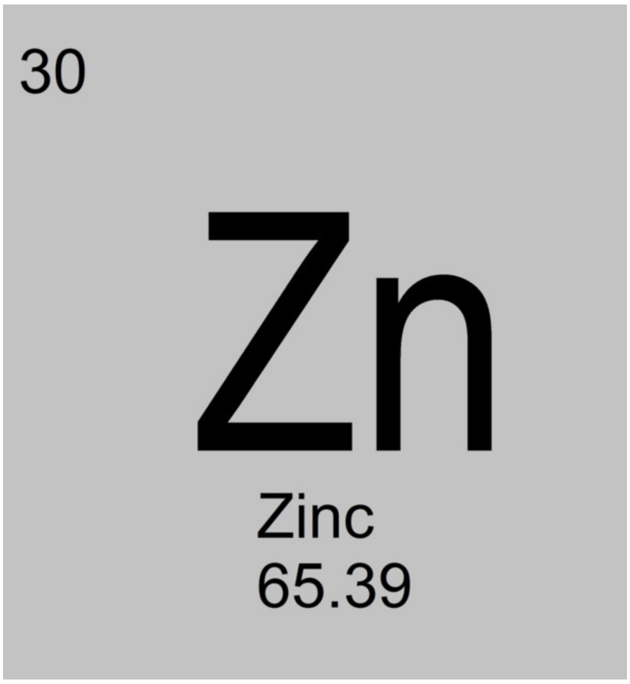
Cobalt: $1s^2\ 2s^2\ 2p^6 3s^2\ 3p^6 4s^2\ 3d^7$



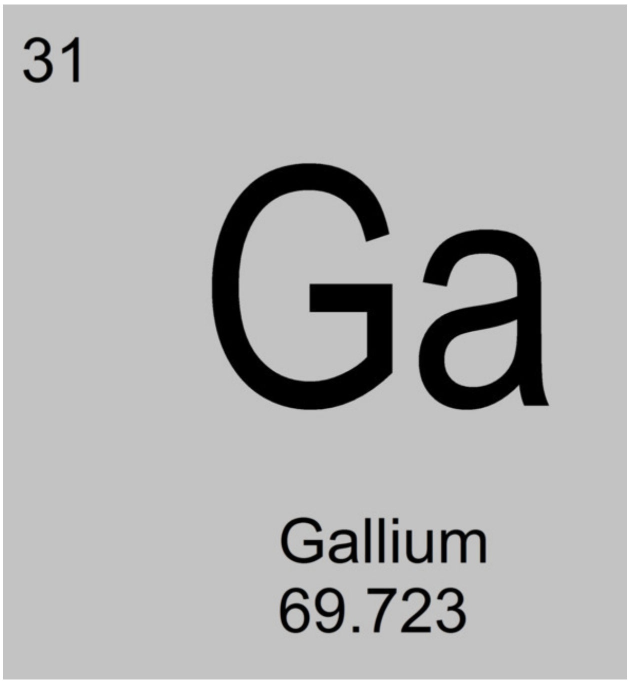
Nickel: $1s^2\ 2s^2\ 2p^6 3s^2\ 3p^6 4s^2\ 3d^8$



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



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



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

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_%28data_page%29

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 Cl2 are spent in the following reaction:

10g?g

Na2CO3 + Ca Cl2 = CaCO3 +2NaCl

All compounds react with each other in certain proportions. In a given reaction one mole of Na2CO3 reacts with one mole of CaCl2

A mole is MW (Molecular mass) in grams.

For Na2CO3 MW is 23 *2 +12 +48 = 106 g. = 1 mole

For CaCl2 MW is 40 +35*2 = 110g. = 1 mole.

106 g Na2CO3 react with 110g CaCl2

10g Na2CO3 react with X g CaCl2

X= 10 * 110 / 106 = 10.38 g CaCl2

2. How many grams of CaCO3 are produced if 100 ml of 0.5 M solution of Na2CO3 reacts with an unlimited volume of solution CaCl2?

0.5 M

2. Na2CO3 + Ca Cl2 = CaCO3 +2 NaCL

100 ml

1 liter of I M solution of Na2CO3 contains 106 g

How many grams of Na2CO3 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 Na2CO3

How many grams of Na2CO3 are in 100 ml?

1 liter – 53 g

0.1 liters – X g

X = 0.1 * 53 /1 = 5.3 g

106 g of Na2CO3 produces 100 g of CaCO3

5.3 g of Na2CO3 produces X g of CaCO3

X= 5.3 * 100 / 106 = 5 g

Acid Base reactions

Molarity. Molality. Normality

1. Let say we have 100 ml of $H2SO4$ solution and it contains 0.49 g of $H2SO4$

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 $H2SO4 = 2 +32 +4* 16 = 98g$

I mole = 98g/L

We have to find how many grams of H2SO4 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 moles

$X = 4.9 * 1 / 98 = 0.05$ moles

The molarity of a 100 ml solution of H2SO4, which contains 0.49 g of H2SO4, equals 0.05 moles.

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 H2SO4 produces 2 moles of H+ then equivalent to H2SO4 = 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 H2SO4, which contains 0.49 g of H2SO4, equals 0.10 N.

2. We have 10 ml of NaOH unknown concentration. The solution was titrated with 0.10 N solution of H2SO4 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?

2H20 = 2H2 +02

First, we have to find how many grams of water are spent and how many grams of H2 are produced?

MW of H20 = 2 +16 = 18

If we spent 2 molecules of H20 then we spent 18 * 2 =36 g.

MW H2 = 2 and we got 2 molecules of H2. 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 H2 are produced.
1 mole of H2 equals 2 g
X mole of H2 equals 111.1g
X = 111.1g / 2g = 50.6 moles of H2
1 mole of H2 occupies 22.4 liters
50.6 moles of H2 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

H2 + I2 <=> 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 AlCl3 is 0.2M and the concentration of H2 is 0.2M at equilibrium point.

Конец ознакомительного фрагмента.