Homework 16.

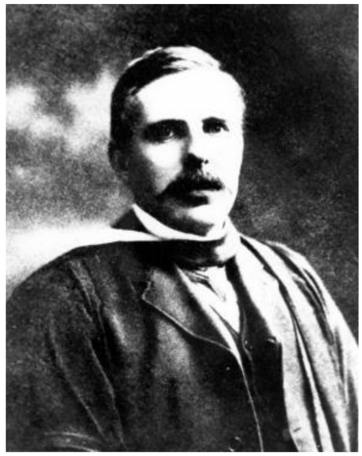
Atom. Periodic table of elements. Atomic number. Atomic weight.

We started discussing the structure of atoms.
Electromagnetic forces, second strongest force in nature, play a crucial role in the world which surrounds us. As we know, the atoms exist due to electrical attraction between negatively charged electrons and positively charged protons in the atomic nuclei. The idea about small particles which are "the nature‟s building blocks" for all the objects around us appeared very long time ago in ancient Greece and India. First subatomic particle, electron, was discovered by British physicist J.J.Thomson in 1897.

Joseph John Thomson (1856-1940).

Based on this discovery he suggested the "plum pudding model" of an atom. According to this model the electrons are like negatively charged particle –"plums" sitting in a positively charged substance – "pudding". In 1906 J.J.Thomson was awarded a Nobel Prize for his discoveries.

In 1909, another British physicist and chemist, former student of J. J. Thomson, Ernest Rutherford (He was awarded a Nobel Prize in Chemistry, 1908 for his work on the chemistry of radioactive substances), performing (together with Hans Geiger and Ernest Marsden) experiment on scattering of heavy and positively charged alpha particles by atoms of gold, found, to his great surprise, that some of the particles were reflected back. He said that "*It was almost as incredible as if you fired a 15-inch shell at a piece of tissue paper and it came back and hit you."*



Ernest Rutherford (1871-1937).

This indicated that positive charge of an atom as well as most of the atom's mass was concentrated in a small volume, which did not agree with the plum pudding model.

As the explanation of the experiment results, Rutherford put forward another model which is called "planetary model" of atom. According to this model the electrons are revolving around a small positively charged nucleus similar to planets revolving around the Sun.

Now we know that this model is not quite correct either. Later we will discuss it in more details.

The atomic nucleus consists of positively charged protons and neutral neutrons. Both proton and neutron have close masses: ~1,673 x 10^{-27}kg (proton) and ~1,675 x 10^{-27}kg (neutron). The electron"s mass more than 1000 times smaller: 9.1 x 10^{-31}kg.

Periodic table of elements

Chemical elements are the "building blocks" of nature. All the objects around us are "constructed" from chemical elements. In spite of great variety of the objects and substances around us there are only 118 chemical elements (some of them are not shown in the table below). They are systematized and arranged in the table which is called *periodic table of elements*.

hydrogen 1 **H** 1.0079																		helium 2 **He** 4.0026
lithium 3 **Li** 6.941	beryllium 4 **Be** 9.0122												boron 5 **B** 10.811	carbon 6 **C** 12.011	nitrogen 7 **N** 14.007	oxygen 8 **O** 15.999	fluorine 9 **F** 18.998	neon 10 **Ne** 20.180
sodium 11 **Na** 22.990	magnesium 12 **Mg** 24.305												aluminium 13 **Al** 26.982	silicon 14 **Si** 28.086	phosphorus 15 **P** 30.974	sulfur 16 **S** 32.065	chlorine 17 **Cl** 35.453	argon 18 **Ar** 39.948
potassium 19 **K** 39.098	calcium 20 **Ca** 40.078		scandium 21 **Sc** 44.956	titanium 22 **Ti** 47.867	vanadium 23 **V** 50.942	chromium 24 **Cr** 51.996	manganese 25 **Mn** 54.938	iron 26 **Fe** 55.845	cobalt 27 **Co** 58.933	nickel 28 **Ni** 58.693	copper 29 **Cu** 63.546	zinc 30 **Zn** 65.39	gallium 31 **Ga** 69.723	germanium 32 **Ge** 72.61	arsenic 33 **As** 74.922	selenium 34 **Se** 78.96	bromine 35 **Br** 79.904	krypton 36 **Kr** 83.80
rubidium 37 **Rb** 85.468	strontium 38 **Sr** 87.62		yttrium 39 **Y** 88.906	zirconium 40 **Zr** 91.224	niobium 41 **Nb** 92.906	molybdenum 42 **Mo** 95.94	technetium 43 **Tc** [98]	ruthenium 44 **Ru** 101.07	rhodium 45 **Rh** 102.91	palladium 46 **Pd** 106.42	silver 47 **Ag** 107.87	cadmium 48 **Cd** 112.41	indium 49 **In** 114.82	tin 50 **Sn** 118.71	antimony 51 **Sb** 121.76	tellurium 52 **Te** 127.60	iodine 53 **I** 126.90	xenon 54 **Xe** 131.29
caesium 55 **Cs** 132.91	barium 56 **Ba** 137.33	57-70 *	lutetium 71 **Lu** 174.97	hafnium 72 **Hf** 178.49	tantalum 73 **Ta** 180.95	tungsten 74 **W** 183.84	rhenium 75 **Re** 186.21	osmium 76 **Os** 190.23	iridium 77 **Ir** 192.22	platinum 78 **Pt** 195.08	gold 79 **Au** 196.97	mercury 80 **Hg** 200.59	thallium 81 **Tl** 204.38	lead 82 **Pb** 207.2	bismuth 83 **Bi** 208.98	polonium 84 **Po** [209]	astatine 85 **At** [210]	radon 86 **Rn** [222]
francium 87 **Fr** [223]	radium 88 **Ra** [226]	89-102 **	lawrencium 103 **Lr** [262]	rutherfordium 104 **Rf** [261]	dubnium 105 **Db** [262]	seaborgium 106 **Sg** [266]	bohrium 107 **Bh** [264]	hassium 108 **Hs** [269]	meitnerium 109 **Mt** [268]	ununnilium 110 **Uun** [271]	unununium 111 **Uuu** [272]	ununbium 112 **Uub** [277]		ununquadium 114 **Uuq** [289]				

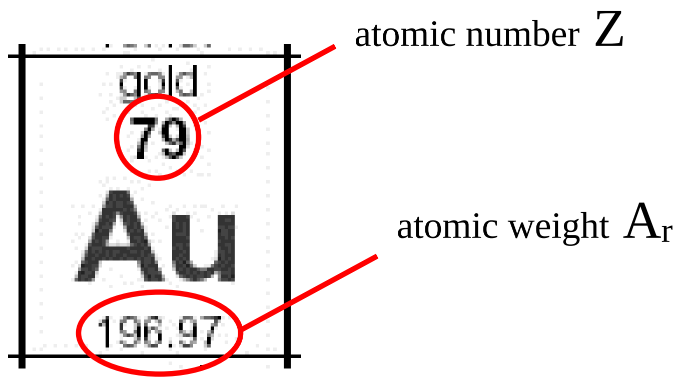
*Lanthanide series	lanthanum 57 **La** 138.91	cerium 58 **Ce** 140.12	praseodymium 59 **Pr** 140.91	neodymium 60 **Nd** 144.24	promethium 61 **Pm** [145]	samarium 62 **Sm** 150.36	europium 63 **Eu** 151.96	gadolinium 64 **Gd** 157.25	terbium 65 **Tb** 158.93	dysprosium 66 **Dy** 162.50	holmium 67 **Ho** 164.93	erbium 68 **Er** 167.26	thulium 69 **Tm** 168.93	ytterbium 70 **Yb** 173.04
**Actinide series	actinium 89 **Ac** [227]	thorium 90 **Th** 232.04	protactinium 91 **Pa** 231.04	uranium 92 **U** 238.03	neptunium 93 **Np** [237]	plutonium 94 **Pu** [244]	americium 95 **Am** [243]	curium 96 **Cm** [247]	berkelium 97 **Bk** [247]	californium 98 **Cf** [251]	einsteinium 99 **Es** [252]	fermium 100 **Fm** [257]	mendelevium 101 **Md** [258]	nobelium 102 **No** [259]

Periodic table of elements.

The periodic table was first suggested by a Russian chemist Dmitri Mendeleev in 1869. He found that if the chemical elements are arranged according their atomic weight, their chemical properties exhibit periodicity, that is why it is called “periodic”.

Dmitri Mendeleev (1834-1907).

Only two of the chemical elements – mercury and bromine - are liquids at normal conditions (T=300K, atmospheric pressure), eleven elements are gases. The other elements are solids except nine elements (109-111 and 113-118) in the end of the table whose chemical properties are still unknown. The most important parameter which determines chemical properties of an element is the atomic number *Z*. The atomic number is the number of protons in the atomic nucleus.



The number of neutrons in the nucleus is denoted as $\boldsymbol{N}$. The sum of $\boldsymbol{Z}$ and $\boldsymbol{N}$ gives the mass number $\boldsymbol{A}$.

$$\boldsymbol{N+Z=A}$$

Since the proton and neutron have approximately same mass we can estimate the mass of the atom by multiplying the atomic number A to the proton (or neutron) mass. In this estimation we neglected the total mass of electrons (which is much smaller than the mass of protons) and another correction which is called "mass defect". The number of neutrons in the atomic nucleus has just a weak effect on the chemical properties of the substance. Atoms having same $\boldsymbol{Z}$ but different $\boldsymbol{N}$ are called isotopes. A typical way to refer to a certain isotope is to place the mass number after the element's name. For example: *iodine-131* or *uranium-238*. Since the number of protons is the same in all isotope nuclei of a certain element, we can find in the periodic table as an atomic number. For example, this number for the isotope uranium-238 is 92. So this particular isotope has 238-92=146 neutrons.

Most of the natural elements are mixture of isotope atoms which have different mass. Average of the atomic masses of the isotopes gives *atomic weight* $\boldsymbol{A_r}$.

Atomic weights are given in the periodic table (see figure above). In what units are they expressed? The unit which is used is called "unified atomic mass unit". It is equal to 1/12 of free atom of a carbon isotope *carbon-12* which is 1.66×10^{-27}kg.

Problems:

1. In spite of the planetary model of atom is oversimplified, it can be used for some estimations. Use planetary model to estimate the energy, which is required to rip off the electron from a

hydrogen atom. The size of the hydrogen atom is 1.1 x 10-10m. The charge of electron is 1.6 x 10-19C.

2. The alpha particle is a positively charged particle with the mass of ~ 6.64 x 10-27kg the electric charge equal to 3.2 x 10-19C. The alpha particle consists of 4 smaller particles. Estimate the electrical repulsion force between protons in an alpha particle. Take the size of the alpha particle as ~ 2 x 10-15m.

3. Imagine that we suddenly “turned off” nuclear force which holds the protons in an alpha particle together. Calculate the velocities of the protons as they will be far away from each other.

4. Find the number of protons and neutrons in the nucleus of Caesium-137.

5. One of the alchemist dreams was making gold (Au) out of lead (Pb). How we should change the atom of lead to obtain the atom of gold?
6. What element we will obtain if we merge nuclei of two isotopes helium-3 and helium 4?