

Pre-lab

The Origin of the Elements

Introduction

Have you ever wondered where all the matter around us comes from? It must have been created somewhere in this universe. In this exercise you will learn where and how matter is created. You'll be surprised to find out where all the stuff that humans are made of comes from...

Most of the matter around us is made out of molecules. It was known since antiquity that mixing different types of liquids, gases and solids could produce other matter with different characteristics. So how does matter transform and how do we understand this? It was only about 200 years ago, that John Dalton, an English chemist, suggested that all compounds and molecules are made out of atoms, and that new molecules are formed when those atoms are rearranged. Molecules are basically clusters of atoms that are bound together by electromagnetic forces. (For example, water is a cluster of three atoms, one oxygen atom, and two hydrogen atoms. Similarly, sugar is an arrangement of 6 carbon, 12 hydrogen, and 6 oxygen atoms.) Atoms and molecules may undergo chemical reactions, forming yet other types of molecules.

About 130 years ago, Dmitri Mendeleev, a Russian scientist arranged the different types of atoms in a particular fashion, He ordered them by increasing mass, but he placed atoms with similar chemical properties in the same columns. This was the first periodic table, and the atoms were referred to as elements, presumably because it was believed that these are the most elementary things matter is made of. In any case, at the time, this periodic table contained empty spaces, suggesting that other types of elements still needed to be discovered. The properties of undiscovered elements could be predicted from their positions in this table, and thus additional elements such as gallium, scandium, and germanium were discovered.

So then, what are atoms? Are they really the smallest objects in the universe? If not, what are they made of? Around the turn of the century, Thompson discovered the electron and its association with atoms. In the early 20th century, Rutherford discovered that the atoms are made mostly of "empty space," but that they have a positively charged small nucleus. This gave rise to the model of protons surrounded by a swarm of electrons, equal in number to the amount of protons. Electromagnetic forces hold these together, with the electrons being negatively, and the protons being positively charged.

In the 1930's Chadwick discovered an additional particle in the nucleus, whose function was to "dilute" the repulsive effects between the protons in the nucleus and make the nucleus heavier. Since this particle does not have a charge, it was called a neutron. Thus it was shown that atoms are made out of electrons, protons and neutrons. They were called "elementary particles," presumably because they are the smallest and most fundamental particles in the universe.

As far as the structure of the atom is concerned, electrons occupy the outer regions of the atom and are equal in number to the protons in the nucleus. The simplest model was proposed by Bohr, who made

further statements about possible orbits of the electron in the atom, which he was able to couple to the energy state of the atom. Heavier elements are more complicated. Each element in the periodic table was identified by the number of protons in the atom's nucleus, ranging from 1 for hydrogen through 92 for uranium. Today we also know of trans-uranium elements, which have been created in nuclear laboratories.

While the number of protons in the nucleus identifies an element, the number of neutrons that also occupy the nucleus identifies different isotopes of that element. Each element has a number of isotopes; for example, hydrogen exists as hydrogen-1, hydrogen-2 (called deuterium), and hydrogen-3 (called tritium). Deuterium has a neutron in the nucleus along with its proton, while hydrogen-1 only has a proton in its nucleus. Tritium has two neutrons in its nucleus. The relative abundances of these isotopes on Earth are 99.985% hydrogen-1, 0.015% hydrogen-2, and only traces of hydrogen-3. Similarly, uranium-238 has 92 protons and 146 neutrons, while uranium-240 has 92 protons and 148 neutrons.

Generally, only one of the isotopes of each element is stable. The others decay — emitting radiation. This is called radioactive decay. All elements have radioactive isotopes, and only two elements (technetium and promethium) behave like trans-uranium elements that have only radioactive isotopes.

Radioactive isotopes possess a quantity called half-life. There is a certain probability associated with radioactive decay. We refer to the time it takes for half of all isotopes of an element to decay as its half-life. Some of the radioactive isotopes of an element may decay very rapidly, while others may have half-lives of millions of years (ever hear of radio-active dating commonly used in geology?).

Helium, for example, has two stable isotopes, helium-3 and helium-4. Helium-6 decays with a half-life of less than one second, so after a few minutes, none of the helium-6 remains.

A basic question about elements is, “Are the types of elements found on Earth equally common in the universe?” It turns out that spectroscopic studies of the Sun revealed 67 elements. Other spectroscopic studies demonstrate that these elements are widely distributed in the universe.

Most of the spectra of stars show roughly 2% of elements other than hydrogen. When this is less, the stars are identified as metal-poor population II stars. These are the oldest that were formed when “heavier elements” had not yet been produced.

Most elements are produced in the hot cores of stars. This process is called thermo-nuclear fusion. All elements up to iron are produced in stellar interiors. When a high mass star (or low mass binary) comes to the end of its evolution and explodes as a supernova, these elements (up to iron) are dispersed into the interstellar medium. During this explosion, the heavier elements are formed. Some isotopes of those elements survive, while others get destroyed through fission (opposite of fusion) or radioactive decay.

In this exercise, you will learn how the elements are produced in the cores of stars and during supernova — just imagine, that these elements may then form molecules, and eventually human beings. Did you know that our bodies are made out of the debris of stars?

Understanding the Periodic Table

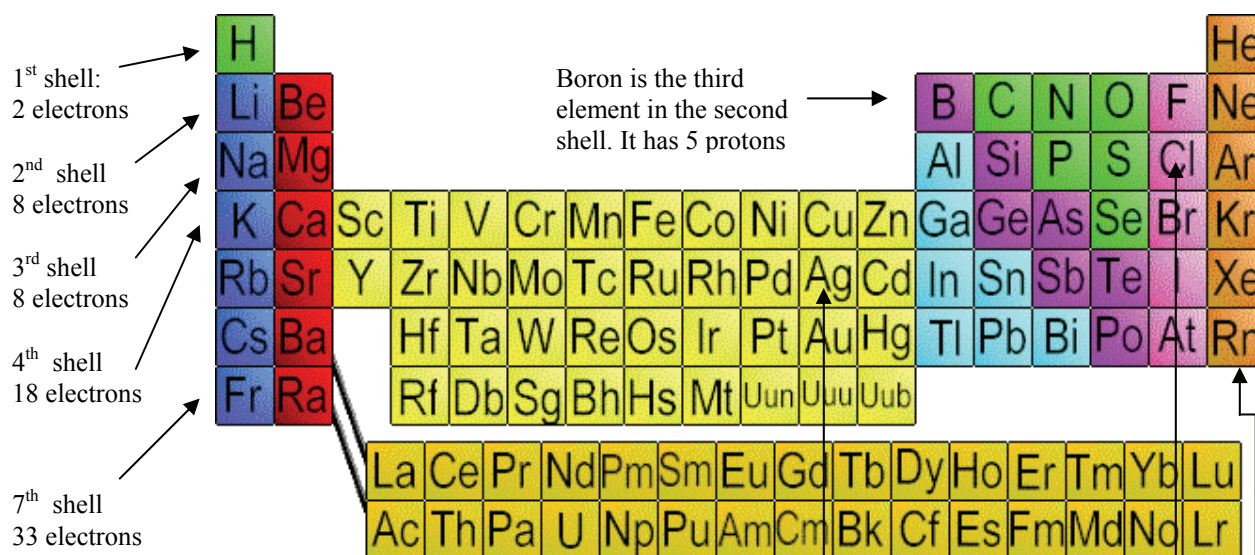
Below are some guidelines that may help you understand the periodic table. The elements are all arranged in a particular fashion, so that regularities can be seen. Once arranged this way, the properties of each elements can be predicted. In fact, this table helped chemists discover any missing elements. Study the Periodic Table.

Number of electrons per shell:

In the first shell there is space for two electrons. Hydrogen has one electron in its first shell, Helium has two electrons. The maximum number of electrons in the first shell is two.

Number of protons in the nucleus:

Hydrogen has one proton, Helium has two, Lithium has three, Beryllium has four, Boron, five, carbon six, etc. The number of protons increases from left to right, and from the first to the second to the third row.



2nd and 3rd shell elements:

The maximum number of electrons in the first shell is two, the maximum number of electrons in the 2nd and 3rd shell is eight electrons.

(Actually, the second can have a maximum of eight electrons of which two electrons are in the “s”-shell, and six in the “p” shell. The third shell also has s, and p shells.)

4th and 5th shell elements:

The maximum number of electrons in the fourth and fifth shell is 18. (In that shell there are three sub-shells, the s-level, the p-level and the d-level. The s-level can harbor two electrons, the p-shell six, and the d-shell 10, giving a total of 28 electrons.)

PERIODIC TABLE OF THE ELEMENTS

<http://www.ktf-split.hr/periodni/en/>

PERIOD	GROUP	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18															
		IA	IIA	IIIB	IVB	VB	VIB	VIB	VIB	VIB	VIB	VIB	VIB	IIIA	IVA	VA	VIA	VIA	VIIA	VIIIA														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18															
1	1	1.0079 H HYDROGEN	4 9.0122 Be BERYLLIUM	13 10.811 B BORON	21 44.956 Sc SCANDIUM	22 47.867 Ti TITANIUM	23 50.942 V VANADIUM	24 51.996 Cr CHROMIUM	25 54.938 Mn MANGANESE	26 55.845 Fe IRON	27 58.933 Co COBALT	28 58.993 Ni NICKEL	29 63.546 Cu COPPER	30 65.39 Zn ZINC	5 10.811 B BORON	6 12.011 C CARBON	7 14.007 N NITROGEN	8 15.999 O OXYGEN	9 18.998 F FLUORINE	10 20.180 Ne NEON														
2	2	6.941 Li LITHIUM	12 24.305 Mg MAGNESIUM	19 39.098 K POTASSIUM	37 85.468 Rb RUBIDIUM	38 87.62 Sr STRONTIUM	56 137.33 Ba CAESIUM	88 (226) Ra RADIUM	111 (272) Au GOLD	112 (285) Hg MERCURY	81 204.38 Tl THALLIUM	82 207.2 Pb LEAD	83 208.98 Bi BISMUTH	84 (209) Po POLONIUM	85 (210) At ASTATINE	86 (222) Rn RADON	13 26.982 Al ALUMINIUM	14 28.086 Si SILICON	15 30.974 P PHOSPHORUS	16 32.065 S SULPHUR	17 35.453 Cl CHLORINE	18 39.948 Ar ARGON	31 69.723 Ga GALLIUM	32 72.64 Ge GERMANIUM	33 74.922 As ARSENIC	34 78.96 Se SELENIUM	35 79.904 Br BROMINE	36 83.80 Kr KRYPTON	49 114.82 In INDIUM	50 118.71 Sn TIN	51 121.76 Sb ANTIMONY	52 127.60 Te TELLURIUM	53 126.90 I IODINE	54 131.29 Xe XENON
3	3	23 50.942 V VANADIUM	41 92.906 Nb NIOBIUM	73 180.95 Ta TANTALUM	106 (266) W TUNGSTEN	107 (264) Re RHENIUM	108 (277) Os OSMIUM	109 (268) Ir IRIDIUM	110 (281) Pt PLATINUM	111 (272) Au GOLD	112 (285) Hg MERCURY	113 (284) Tl THALLIUM	114 (289) Pb LEAD	115 (288) Bi BISMUTH	116 (285) Po POLONIUM	117 (283) At ASTATINE	118 (286) Rn RADON	119 (286) Fr FRANCIUM	120 (285) Ra RADIUM	121 (284) Ac ACTINIDE	122 (283) Th THORIUM	123 (281) Pa PROTACTINIUM	124 (277) U URANIUM	125 (270) Np NEPTUNIUM	126 (269) Pu PLUTONIUM	127 (268) Am AMERICIUM	128 (267) Cm CURIUM	129 (265) Bk BERKELIUM	130 (264) Cf CALIFORNIUM	131 (262) Es EINSTEINIUM	132 (261) Fm FERMIUM	133 (260) Md MENDELEVIUM	134 (259) No NOBELIUM	135 (258) Lr LAWRENCIUM

Legend:

- Metal
- Semimetal
- Nonmetal
- Alkali metal
- Alkaline earth metal
- Transition metals
- Lanthanide
- Actinide
- Chalcogens element
- Halogens element
- Noble gas

STANDARD STATE (25 °C; 101 kPa)

- Ne - gas
- Fe - solid
- Ga - liquid
- Tc - synthetic

GROUP IUPAC

RELATIVE ATOMIC MASS (1)

GROUP CAS

ELEMENT NAME

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(1) Pure Appl. Chem., 73, No. 4, 667-683 (2001)
Relative atomic mass is shown with five significant figures. For elements with no stable nuclides, the value enclosed in brackets indicates the mass number of the longest-lived isotope of the element.

However three such elements (Th, Pa, and U) do have a characteristic terrestrial isotopic composition, and for these an atomic weight is tabulated.

Editor: Aditya Vardhan (adv@netlinx.com)

From http://geology.isu.edu/geosciences/periodic_table.gif

name

Complete the Table

Hand in this page only; keep the periodic table for the main laboratory

Consult the periodic table on the next page. How many proton, neutrons, and electrons does each element have? How many electrons are in the outermost shell? What is the most common isotope of each element? What are the melting and boiling points of these elements? Which of the elements below are gases, liquids or solids at room temperature (~300K).

	Symbol	# protons	# neutrons	Mass relative to the mass of a Carbon atom	most common isotope	# electrons in outer shell	Boiling Point	Melting Point	State (gas, solid, liquid)
Hydrogen									
Helium									
Oxygen									
Carbon									
Iron									
Mercury									
Silicon									
Gold									
Technicium									
Uranium									