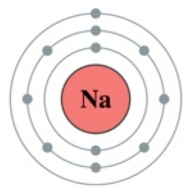
Material World

Module 3 • i2P • La Ruta de Sal

Piles of Salt on the Salar de Uyuni (source: Luca Galuzzi)

"When carbon (C), Oxygen (O) and hydrogen (H) atoms bond in a certain way to form sugar, the resulting compound has a sweet taste. The sweetness resides neither in the C, nor in the O, nor in the H; it resides in the pattern that emerges from their interaction. It is an emergent property. Moreover, strictly speaking, is not a property of the chemical bonds. It is a sensory experience that arises when the sugar molecules interact with the chemistry of our taste buds, which in turns causes a set of neurons to fire in a certain way. The experience of sweetness emerges from that neural activity."

- Fritjof Capra



SALT

The human tongue is capable of five primary tastes: bitter, sour, sweet, savory, and salty. The taste sensation occurs when chemicals in food are dissolved by saliva and come into contact with taste bud receptors on the tongue. The receptors then send signals through nerve cells to the brain. The taste of salt is produced when taste buds detect sodium atoms. Other atoms, like lithium and potassium that are similar to sodium in some properties, can also trigger a salty taste, but to a lesser degree than sodium.

The taste of salt serves a very specific function that we have all experienced. When a human being is low on salt, craving for salty food increases. Salt is lost by human beings during exercise as a byproduct of

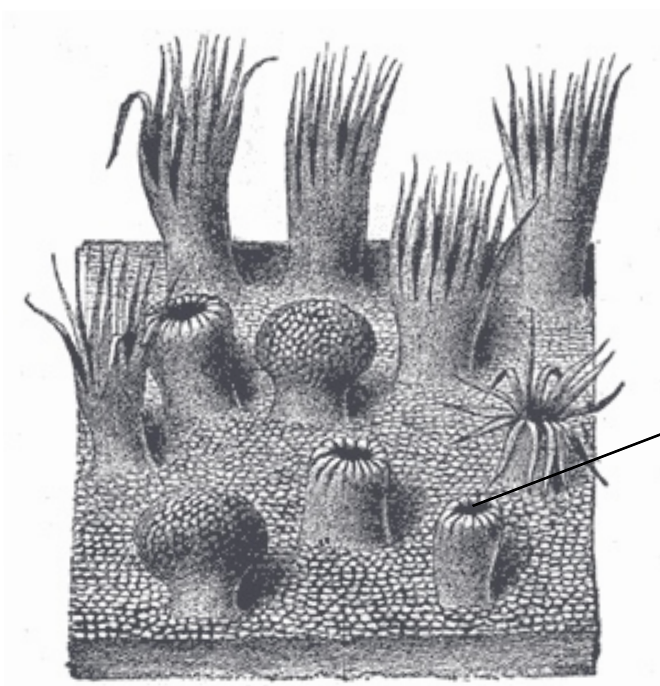
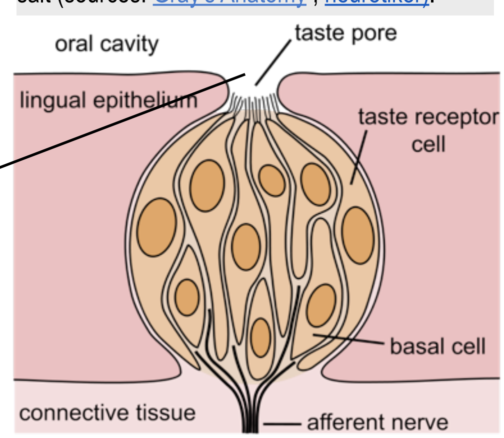


Figure 1: (left) Taste buds on the surface of the tongue come in a variety of forms. Sodium ions enter a taste pore and (right) stimulate a taste receptor cell which causes a signal to pass down a taste nerve to the brain, resulting in the taste of salt (sources: Gray's Anatomy , neurotiker).



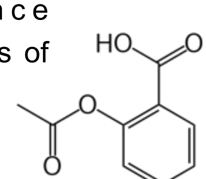
sweating. Runners frequently develop salt cravings, and if they do not pay attention to this sensation they can develop a dangerous salt imbalance (many sports drinks contain salts, also referred to as electrolytes). Sodium is an essential component of body function, and low levels can lead to confusion, seizures, coma and death. Hopefully the ten billion tons of table salt in the Salar de Uyuni will be enough to maintain the sodium balance in the tissue of i2P team members running the flats.

Definition: Element

Each of more than one hundred substances that cannot be chemically interconverted or broken down into simpler substances and are primary constituents of matter. Each element is distinguished by its atomic number, i.e. the number of protons in the nuclei of its atoms.

Figure 2: aspirin was one of the first drugs developed by chemists almost 150 years ago (source: Chaval Brasil)

Understanding the behavior of the sodium atom and how taste is mediated by a chemical reaction is very practical knowledge for a runner. The discipline of modern chemistry provides insight into the composition and behavior of matter, that has not only helped us understand the chemical reactions that govern the function of the human body, but allowed us to create countless new materials that have revolutionized modern life. From modern medicines and vaccines chemically engineered to combat illness, to synthetic materials designed to enhance communication, transportation and energy production, all are built on the principles of chemistry.



Aspirin

It is Elementary

Atoms are a basic unit of matter, and all the materials around us are composed of different arrangements of atoms. Atoms are composed of a nucleus consisting of protons, neutrons, and electrons that form a cloud around the nucleus. Sodium is one of one-hundred and fifteen known types of atoms. Each type of atom has unique properties, such as their physical size, shape, and mass, that distinguish them from one another. An element is a pure chemical substance consisting of one type of atom. Examples of naturally occurring elements are diamonds (which are made of pure carbon atoms), mercury (which is used in thermometers), oxygen and pure gold.

Definition: Matter

Anything that has a mass and occupies space

Atoms are arranged according to their properties in a table called the periodic table. Antoine Lavoisier, the father of modern chemistry, was the first to arrange atoms in a table, but the creation of the periodic table, as we now know it, is ascribed to the Russian chemist Dmitri Mendeleev. Chemistry is the study of how the different atoms interact with each other to form compounds and materials that in turn have different properties.

Did You know?

Glass is considered a liquid

Figure 3: Monument to the periodic table honoring Dmitri Meddeleev, at the Slovak University of Technology in Bratislava, Slovakia (source: mmmdirt)

In 1869 Mendeleev arranged elements according to an atomic number. The atomic number corresponds to the number of protons, and matching electrons in the atom. Hydrogen has an atomic number of one and has one proton and one electron. Carbon is atom number six and has six protons and six electrons. Elements are further sub-grouped according to properties, such as their natural state, (gas, solid or liquid), boiling point and melting points, and freezing and vaporization points. The periodic table is considered the most important tool in chemistry, providing ready information about the fundamental properties of elements.

Period / Group #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1							1 H											2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba		72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra		104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Uub	113 Uut	114 Uuq	115 Uup	116 Uuh	117 Uus	118 Uuo

57 * La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
89 ** Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Figure 4: The periodic Table (source: IUPAC)

Class Exercise

Listen to the famous Element Song by Tom Lehrer!

element song

Each element has *physical* and *chemical properties* that predict how it will behave in different environmental conditions. Physical properties include color, form, melting and boiling points. Chemical properties are the manner in which an element reacts with another element or compound. Iron, for example reacts with oxygen, forming a weak material called rust, which breaks down over time.

Elemental Bolivia

Virtually all the material in our world is composed of atoms, grouped together in a variety of manners. Whether the computer screen you are looking at, a pencil, or a rock, snowflake, or a tree, or the fingers on your hands; all are groups of atoms. The human body is composed of four principle atoms: oxygen, carbon, hydrogen and nitrogen. In contrast, our planet's most abundant elements are oxygen, silicon, aluminum, iron and calcium, and the ocean is largely made of oxygen and hydrogen. The air we breathe is composed principally of nitrogen, oxygen and argon. Most other elements listed on the periodic table are present in the human body but at very low levels. Many of these trace elements perform essential functions in the body.

When atoms group together they assume one of three principle forms: solid, liquid or gas. Most substances have only one naturally occurring form, and can only be changed by introducing external energy to change their physical state (i.e adding heat to solid ice to convert it in to liquid water). Water is very unusual in that is can spontaneously occur as a solid, liquid or gas in nature (ice, water, water vapor).

Figure 5: Water is an unusual compound in its ability to occur as a solid liquid or gas in nature. In this photo of Goldstream Park in British Columbia Canada B.C. water is seen in liquid (stream) and gas forms (clouds and rainbow). Only solid form - snow and ice - is missing from the photo (source: Brandon Godfrey).

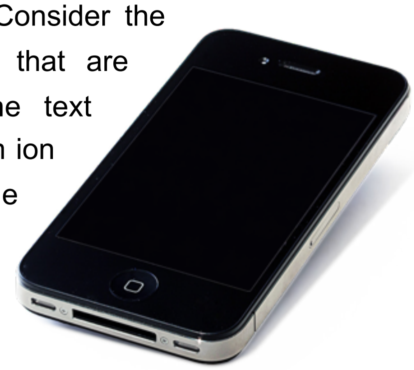
Over the course of the expedition to Bolivia the i2P team will encounter unusual concentrations of elements, some of which are relatively uncommon in nature. For instance, along with the more abundant sodium, chloride and magnesium, the Salar de Uyuni is home to half the world's lithium reserves, an important economic resource for Bolivia (see: lithium). The expedition route will also take the team past lakes rich in copper as well as trace elements such as arsenic, lead, boron, and geysers and volcanoes that bring elements from within the planet's crust to the surface.

Material World

Despite the relative rarity of some of the elements the i2P team will encounter on the expedition, they all have an important role in material chemistry. Material chemistry is a discipline that applies the principles of matter to science and engineering. By understanding the manner in which different atoms behave scientists have been able to create new materials that serve important functions in science and technology.

Figure 6: Lithium burns with a bright red glow. During the expedition to the Salar de Uyuni the i2P team will be enriching and burning lithium.

Look around your home, virtually everything is chemically engineered; from the metal alloy spoon that you use to scoop up breakfast granola, to the ceramic cereal bowl. Consider the hundreds of thousands of miniature transistors that are switching the flow of electrons transmitting the text messages you send to your friends, and the lithium ion battery that powers the phone. All of these technologies are a product of chemically engineered materials.



source: Daniel Zanetti

Lithium

Lithium is considered a relatively rare element, although it is found widely in low concentrations in seawater (in which it dissolves) and throughout the earth's crust. Considered of little utility by mankind until the last century, today, lithium is an invaluable element. Lithium ion batteries now power most computers and mobile electronic devices because they generate more energy than similar batteries made with lead/acid or zinc/carbon. Lithium's unique physical and chemical properties make it ideally suited for use in batteries. Lithium is also used in fireworks because it burns with an attractive red glow, and is used, among other things, in the manufacture of airplane parts, rocket propellants, and to purify air in submarines and spacecraft. Lithium is even used as a drug. In 1949 an Australian doctor discovered that lithium is useful for the treatment of psychiatric conditions. It remains a mainstay of treatment of bipolar manic depressive disorder to this day.

Although widespread in very low concentrations, there are a number of concentrated lithium reserves in the world, principally in brine pools such as the Salar de Uyuni. The world's largest lithium producers are Argentina, Chile, and China. Bolivia, with the greatest reserves, has yet to produce lithium commercially. If the i2P team runs out of power on the Salar de Uyuni, perhaps they can refurbish the batteries of their mobile devices by dipping into the reserves of lithium in the brine below the crust of salt.

HEAVY METAL

After crossing the Salar de Uyuni the expedition route takes the i2P team south past Laguna Colorado and Laguna Amarilla, to Laguna Verde and Laguna Blanco. All four of these lakes are unique for the high concentrations of elements that they hold.

Figure 7: Laguna Verde, adjacent to the Salar has high concentrations of the elements Copper and Lead, as well as Arsenic is filled with (Source: Ville Miettinen)

Laguna Colorado has islands of Borax; Laguna Amarilla is a lake that is colored yellow by sulfur; Laguna Verde holds high concentrations of the heavy metals Copper and Lead, as well as Arsenic; Laguna Blanca is filled with Boron. Like Lithium, all of these elements occupy a unique position on the periodic table that reflects their specific chemical properties. All of these elements also serve a functional purpose in man made materials. For example, copper when combined with tin, produces the alloy bronze.

Boron is used to make laundry detergent, and arsenic, used to make battery components and treat cancer is perhaps most renowned as the poison that killed Napoleon Bonaparte and Simon Bolivar, after whom Bolivia is named.

Applied Chemistry

Science is driven by curiosity and enabled by observation, measurement, imagination and sometimes, serendipity. From simple observations about the natural world we inhabit, to the a deep understanding of the structure and properties of matter, human beings have been able to identify an element like lithium, determine its properties, and apply this knowledge to technologies that have changed the world.

Figure 8: A 2.5 kg brick is held up by a piece of aerogel weighing only 2.38 grams. Aerogel is a low-density material derived from gel impregnated with gas. The result is an extremely low density solid with several remarkable properties, most notably its effectiveness as a thermal insulator and stregnth. Aerogel is able to hold over 2000 times its own weight (see: NASA).

The gift of chemistry is that on the Salar de Uyuni, the material beneath the feet of the i2P runners is not only terra firma, but is also understood as a crystal composed of two elements: sodium and chlorine. We now understand the atomic structure of sodium, and that this atom is responsible for the taste of salt, and also plays an important role in the function of nerve cells in the human body. Through chemistry we have learned that sodium helps us sense and feel and imagine.

The magic of chemistry is that these very atoms we have discovered, power the nervous impulses and fuel the curiosity and imagination that enabled us to discover them.