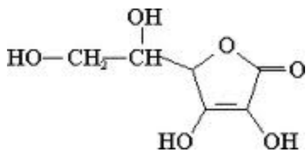
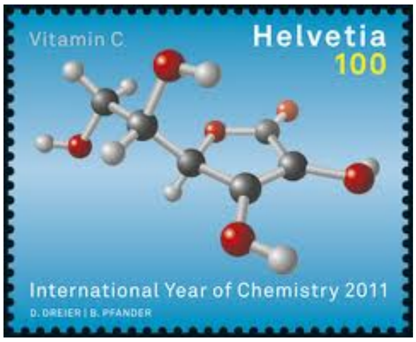
APPLIED CHEMISTRY



$C_6\,H_7\,O_6$

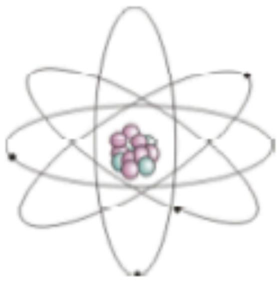


2012, 2nd edition
Heinz Beat Winzeler

„Today, science means a valid method of explaining the observed reality. The well-founded disciplines of modern science are in a way related to Buddhism since Buddhist philosophy also searches and establishes truth through rational analysis, similar to that of science.“

H.H. The Dalai Lama, 2002

Science meets Dharma: Introduction



How does Science work?

1. Model of reality /observation
⇓
2. Hypothesis (to explain observation)
⇓
3. Control experiment
⇓
4. Results
⇓
5. New model of reality

It is important to document so other people can follow and repeat the experiment!

ཚན་རིག་ག་འདྲ་ལས་ཀ་བྱེད་ཀྱི་ཡོད་དམ།

༡༽ དངོས་དོན་དང་མཐུན་པའི་དཔེ་གཟུགས་སམ་དཔྱད་ཞིབ།
⇓
༢༽ རགས་པའི་གྲུབ་དོན། （དཔྱད་ཞིབ་བྱས་པ་དེ་འགྲེལ་བརྗོད་ཆེད།）
⇓
༣༽ ཚོད་འཛིན་བྱེད་པའི་བརྟག་དཔྱད།
⇓
༤༽ གྲུབ་འབྲས།
⇓
༥༽ དངོས་དོན་དང་མཐུན་པའི་དཔེ་གཟུགས་གསར་པ།

གལ་ཆེ་བ་ཞིག་ལ་མི་གཞན་གྱི་བརྟག་ཞིབ་དེ་རྟོགས་ཐུབ་དང་རྒྱུད་འཛིན་བྱེད་ཐུབ་དགོས།

1 What is Chemistry རྫས་འགྱུར་ཚན་རིག།

Definition

Chemistry is the study of **matter** with its **properties** and **transformation** of materials (chemical reactions).

All known matter – gas, liquid and solid – is composed of chemical elements or of compounds made from those elements.

All living processes are controlled by chemical reactions.

Chemistry is sometimes called „the central science“ because it *connects physics with other natural sciences such as astronomy, geology and biology*.

2 Historical Abstract

Early chemical abilities:

Ancient civilizations were able to make pottery and glazes, to ferment beer and wine, to prepare pigments for cosmetics and painting, to extract metals from ores, to extract chemicals from plants for medicine and perfume. But also cheese making, dying cloth, tanning leather, rendering fat into soap, making glass, and making alloys like bronze.

Alchemy - precursor of modern Chemistry

Alchemists discovered pure metals such as gold, silver, copper, iron, lead, mercury and developed separation and purification methods. They searched for the *Philosopher's Stone* which was believed to transform cheap metals into gold by mere touch. The separation processes were not understood as such, but seen as a transformation.

Questions:

- ❖ how can chemistry be defined?
- ❖ Compare the definition of Chemistry with the definition of Physics [1]

3. Properties of Matter

Ancient elements system - ***earth, water, air and fire***
Early Buddhism differentiated physical things into four elements, which are sensed in terms of *solidity or inertia (earth), cohesion (water), expansion or vibration (air) and heat or energy content (fire)*.

The Buddha's teaching on the four elements is to be understood as the base of all observation of real sensations. A derivative group of the four are color, smell, taste, and nutriment.

[1] Physics is a branch of science concerned with the properties of matter and energy and the relationships between them. It

Can the western scientific view seen as an analogy to this?

- **The states of aggregation – a physical view**
  - solid state
  - liquid state
  - gaseous state and a 4th state: plasma (electrically charged gas)

Properties of a substance (matter)

We examine different substances systematically: How do they react? What do we observe?

རྒྱུ་རྫས་ཀྱི་ཁྱད་ཆོས་ཁག། (འབེམ་གཟུགས།)

ང་ཚོས་རྒྱུ་རྫས་འདྲ་མིན་གོ་རིམ་ལྡན་པའི་སྒོ་ནས་བརྟག་ཞིབ་ནན་པོ་བྱེད།
རྒྱུ་རྫས་འདི་རྣམས་ཇི་ལྟར་འགྱུར་གྱི་འདུག་གམ།
ང་ཚོའི་ག་རེ་མཐོང་གི་འདུག་གམ།

Properties ཁྱད་ཆོས་རྣམས།	Salt ཚྭ། (Sodium Chloride)	Alcohol ཆང་རག།	Iron ལྕགས།
Color/ smell ཚོན་མདོག་དང་དྲི་མ།			
State of matter (solid, liquid, gaseous) (སྲ་གཟུགས། གཤེར་གཟུགས། རླུང་གཟུགས།)			
Flammability མེ་སོགས་འབར་སླ་བའི་རང་བཞིན།			
Conductor of heat and electricity དྲོད་འགྲུད་གློག་འགྲུད་ཀྱི་དང་བཞིན།			
Boiling point ཁོལ་ཚད།			
Melting point བཞུར་ཚད།			
Magnetism ཁབ་ལེན་རྡོའི་རང་བཞིན།			

4. Types of Mixtures

- A mixture is a combination of pure substances.
- Each substance remains in its original pure form. But each of it is not always easy to see distinctly once the mixture is made.

Main component Side component	**Solid**	**Liquid**	**gas**
Solid	Mixture, alloys	Suspension e.g. sand in water, gel	Aerosol, moke, dust,
Liquid	e.g. dough, soil,	emulsion	Aerosol fog, mist, vapor, cloud
gas	foam, e.g. whipped cream	suspension	Gas mixture

4.1 Homogeneous mixtures

Individual components are **not visible** in the mixture, the matter is **uniform**

a) solid homogeneous mixtures

examples:
- brass is a yellow metal containing copper and zinc
- bronze is an alloy of copper and up to one third of tin
- stainless steel is an alloy containing iron and chromium

b) Liquid homogeneous mixtures

examples:
- Homogenized millk is a mixture of water, fat and proteins.
- sea water is water containing salt,
- sugar water, syrup, filtered apple juice

1. gaseous homogeneous mixtures

examples:
- air is an (invisible) mixture of nitrogen (78%) and oxygen (21 %). plus 0.9 % Argon, 0.04 % CO2
- Halogen bulbs contain a mixture of iodine and argon
- Exhaust gas of an engine or heating oven contains nitrogen, CO2, and water vapour
- Brass, salt water, diluted alcohol, soda water under pressure, explosive gas

4.2 Heterogeneous Mixtures

individual substances **are visible** in the mixture. Suspensions with particles less than 0.5 µm is a colloid, otherwise it is heterogeneous.
Suspension (visible particles) – colloid (microscopic droplets) - solution
- Examples: Gravel and sand, sand in water, oil in water/water in oil, foam, smoke in air

4.3 Separation of mixtures

Mixtures can be separated into two or more substances by mechanical or physical means. Heterogeneous substances are always mixtures. Homogeneous mixtures are not easy to detect as such.

- **Pure or chemical substance**

  is a form of matter that has constant chemical composition and characteristic properties. It cannot be separated into components by physical separation methods, i.e. without breaking chemical bonds. They can be solids, liquids or gases.

e.g. table salt, sugar, ice, acetone, carbon dioxide, ..

→ distinguish in above terms: coffee, steam, salad sauce, methane gas, tea, sugar,

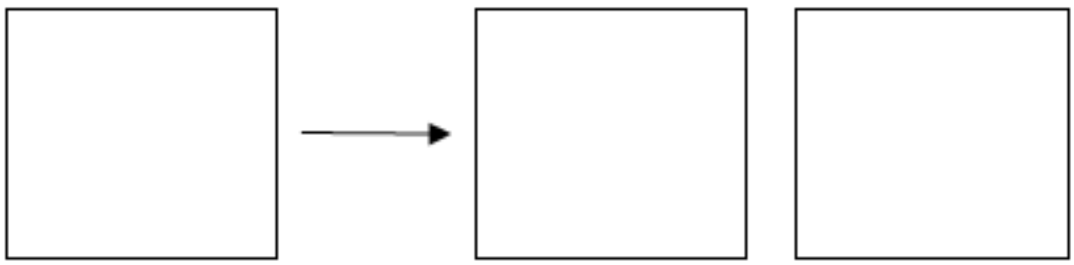
Pure Substances ལྷད་མེད་རྒྱུ་རྫས་ཁག།

Different meanings of “pure” or Purity ལྷད་མེད་ཀྱི་གོ་དོན་འདྲ་མིན།

Everyday life དུས་རྒྱུན་མི་ཚེའི་ནང་།	Dharma ནང་ཆོས་ནང་།	Science ཚན་རིག་ནང་།

Pure substance in Chemistry means: རྫས་འགྱུར་ཚན་རིག་ནང་ལྷད་མེད་རྒྱུ་རྫས་ཀྱི་གོ་དོན།

Model:



Source: Sybille Menet, translated by Tenzin Choekyi, Jangchub Choeling Nunnery

5. Obtaining pure Substances: Separation of Mixtures

Isolating and purification of pure substances are very important processes in chemistry.

Basic Techniques for Separating Mixtures
གཞི་རྩའི་ཐུན་མོང་མ་ཡིན་པའི་འདྲེས་མ་དབྱེ་འབྱེད་ཐབས་རྩལ།

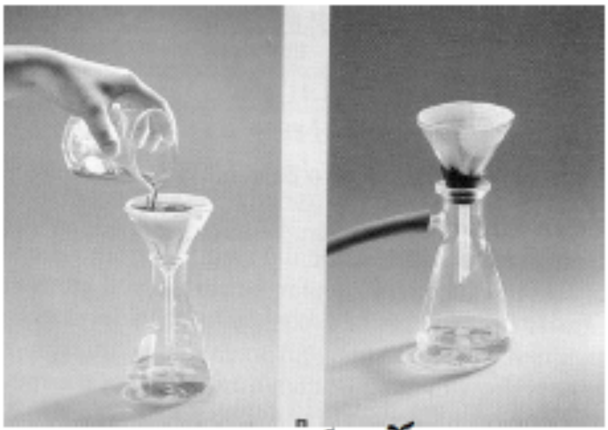


Fig. 1: Filtration འཚག་སྦྱོར།

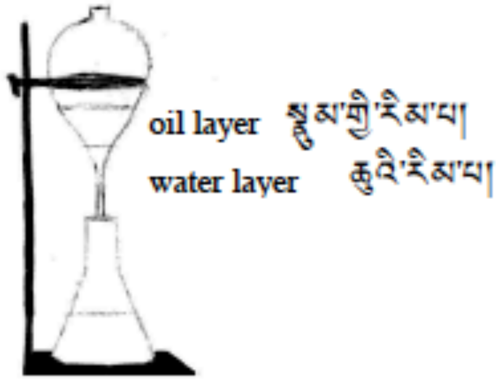


Fig. 2: Extraction འཐེན་སྦྱོར།

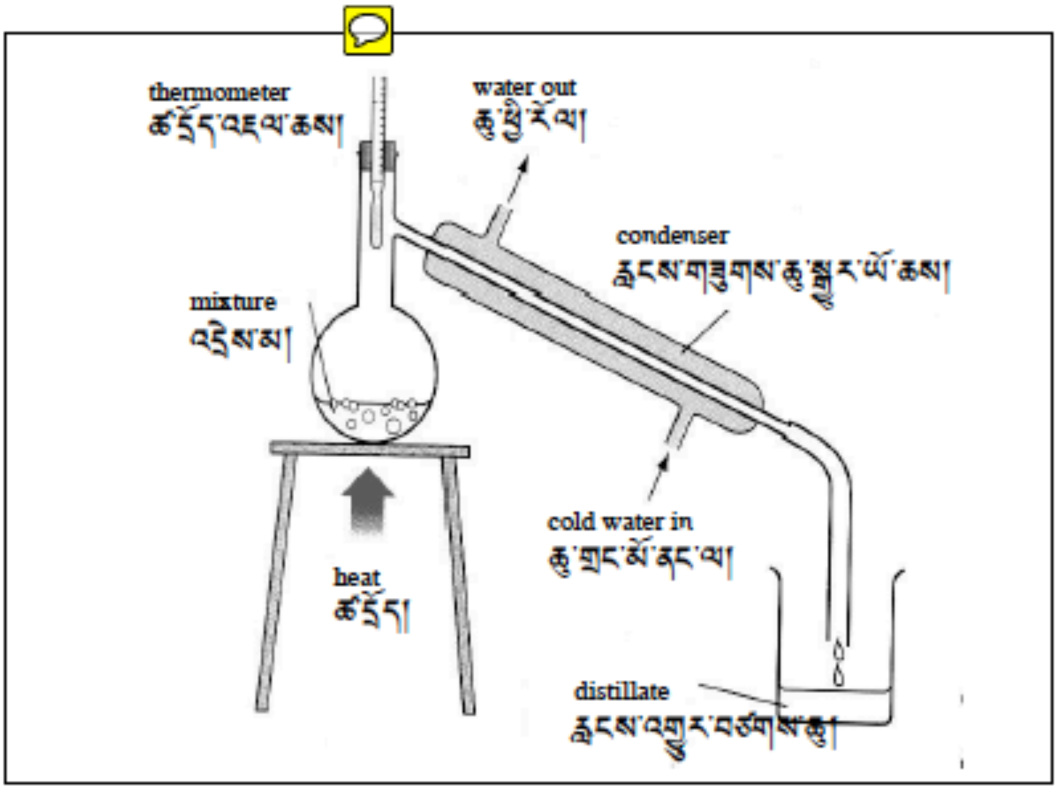


Fig.3: Distillation རླངས་འགྱུར་བཙགས་ཆུ།

6. Chemical Elements

6.1 Elements and compounds

Elements and compounds

Using chemical methods, a pure substance can still be further dissected. The smallest particles that can't be further dissected are called atoms (simplification!). A substance made out of the same kind of atoms is called an **element.**

ཁམས་རྫས་དང་བསྡེབས་རྫས

ལྷད་མེད་རྫས་རྣམས་རྫས་འགྱུར་གྱི་ཐབས་ལམ་བེད་སྤྱོད་བཏང་སྟེ་ད་དུང་ཆུང་ངོར་དབྱེ་ཐུབ། མཐའ་མའི་དབྱེ་ཕྱེད་མི་ཐུབ་པའི་ཕྲ་རབ་དེ་ཚོ་ལ་ཨེ་ཊོམ་ ཡང་ན་ **རྡུལ་ཕྲན་**ཟེར་གྱི་ཡོད། རྫས་གང་ཞིག་རྡུལ་ཕྲན་གྱི་རིགས་གཅིག་གི་བཟོས་པ་ན་**ཁམས་རྫས་**ཞེས་ཟེར།

Model:
དཔེ་གཟུགས།

In science, is water considered an element?
⇒ water electrolysis

ཚན་རིག་ནང་ཆུ་དེ་ཁམས་རྫས་ཀྱི་ཁྲོངས་སུ་གཏོགས་སམ།
⇒ ཆུའི་གློག་བགོ་ལ་དབྱེ་ཕྱེད།

6.2 The discovery of elements

An element is a chemical substance that is made up of a particular kind of atoms and hence cannot be broken down or transformed by a chemical reaction into a different element.

~1670 dicovery of **phosphorus -** the chemical element with symbol **P** (this happened upon a trial to transfer urine to gold). It took 200 years until P is industrially used e.g. for matches.

1770 Carl Scheele discovered 8 further elements: chlorine Cl, fluorine F, manganese Mn, barium Ba, molybdenum Mb, tungsten (wolfram) W, nitrogen N, oxygen O and many useful compounds, such as ammonia, glycerol, tannic acid, chlorine as bleaching agent, etc.

He demonstrated the role of oxygen in the rusting of metals or in respiration and explained combustion (before a „phlogiston theory“ postulated that materials released a substance called phlogiston when burned).

1789 *Antoine Lavoisier* discovered that sulfur S is an element, which before was assumed to be a compound. Thorough weighing with all experiments he found, that although matter can change its state in a chemical reaction, the total mass of matter remains constant despite chemical change. Lavoisier formulated

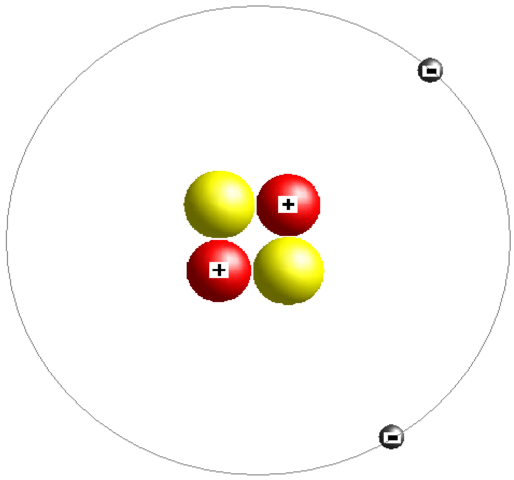
- **the law of conservation of mass.**

Lavoisier investigated the composition of water and air:

- **water** is a *compound* of two elements (oxygen and hydrogen)
- **air** was a *mixture* of gases (primarily nitrogen and oxygen).

6.3 *Atoms, elements, ions, isotopes*

Atoms



Helium atom

Nucleus:

protons (positively charged particle) and neutrons

e.g. hydrogen H 1 proton + 1 neutron

helium He 2 protons +2 neutrons

Shell:

electron (negatively charged)

e.g. hydrogen H1 electron

Helium He 2 electrons

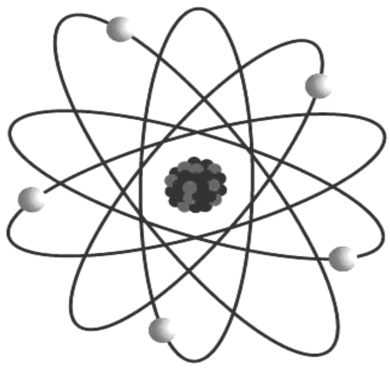
Diameter of an atom ~ 1 Ångström (Å) = 10^{-10} m

diameter of a nucleus ~1 fm (femtometer) = 10^{-15} m

(a grain of dust of 10 µm in a ball of 1 m diameter)

Materia consists of atoms, the mass is concentrated on extremely small points

→ As a matter of fact this is an other case of *emptiness and interdependence* !



→ Which type of atom / element is this?

Ions

Some elements and molecules can collect or release electrons to another element or molecule. Then these particles become negatively or positively charged. Charged atoms or molecules are called an ***ion***

e.g.	H	– 1 electron	=	H^{+},
	O	+ 2 electrons	=	O^{2-}

Isotopes

There exist variants of certain atoms with different atomic weights, while they have the same atomic number.

6.4 *The Periodic Table of Chemical Elements*

Notation of chemical elements

In 1828 *Berzelius*, a Swedish chemist compiled a table of relative atomic weights.

He developed the **Notation of chemical elements,** a system in which the elements were given simple written labels—such as O for oxygen, or Fe (Latin ferrum) for iron.

The most important Symbols are: གལ་ཆེ་ཤོས་མཚོན་རྟགས་རྣམས་ནི།

H	K	Zn
C	Ca	Sn
N	Cl	F
Na	Ag	Cu
O	Au	Fe
S	Hg	

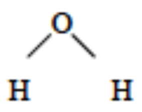
The proportion of an element in a compound is noted in subscript numbers.

Formulas show information about the molecules or compounds: Which elements are involved, how many atoms of each element and how the atoms are bonded with each other.

སྦྱོར་ཐབས་རྣམས་ཀྱི་བསྡུས་རྡུལ་ལམ་བསྲེ་བས་རྫས་ཀྱི་གནས་ཚུལ་སྟོན་གྱི་ཡོད། ཁམས་རྫས་ག་རེ་འཚུད་ཀྱི་ཡོད་མེད། ཁམས་རྫས་རེ་རེའི་རྡུལ་ཕྲན་ག་ཚོད་དང་རྡུལ་ཕྲན་ཕན་ཚུན་ག་འདྲ་མཐུད་ཡོད་མེད་བཅས་སྟོན་གྱི་ཡོད།

Example of formulas: སྦྱོར་ཐབས་ཁ་ཤས་ཀྱི་དཔེ་མཚོན།

Water: H_2O



ཆུ།

Salt: NaCl

ཚྭ།

རྡུལ་ཕྲན་གྱི་ལྗིད་ཚད་ (ལྗི་ཚད་གྲངས) རྣམས་ གཡས་ཕྱོགས་སྣང་གི་སྡེ་ར་བྲིས། ཁམས་རྫས་ཀྱི་ རྡུ་ཁག་རྣམས་ལ་ཚོན་འདྲ་མིན་བེད་སྤྱོད་བྱེད།

Periodic Table

Mendelejew (St. Petersburg, 1860) classified the elements according to their

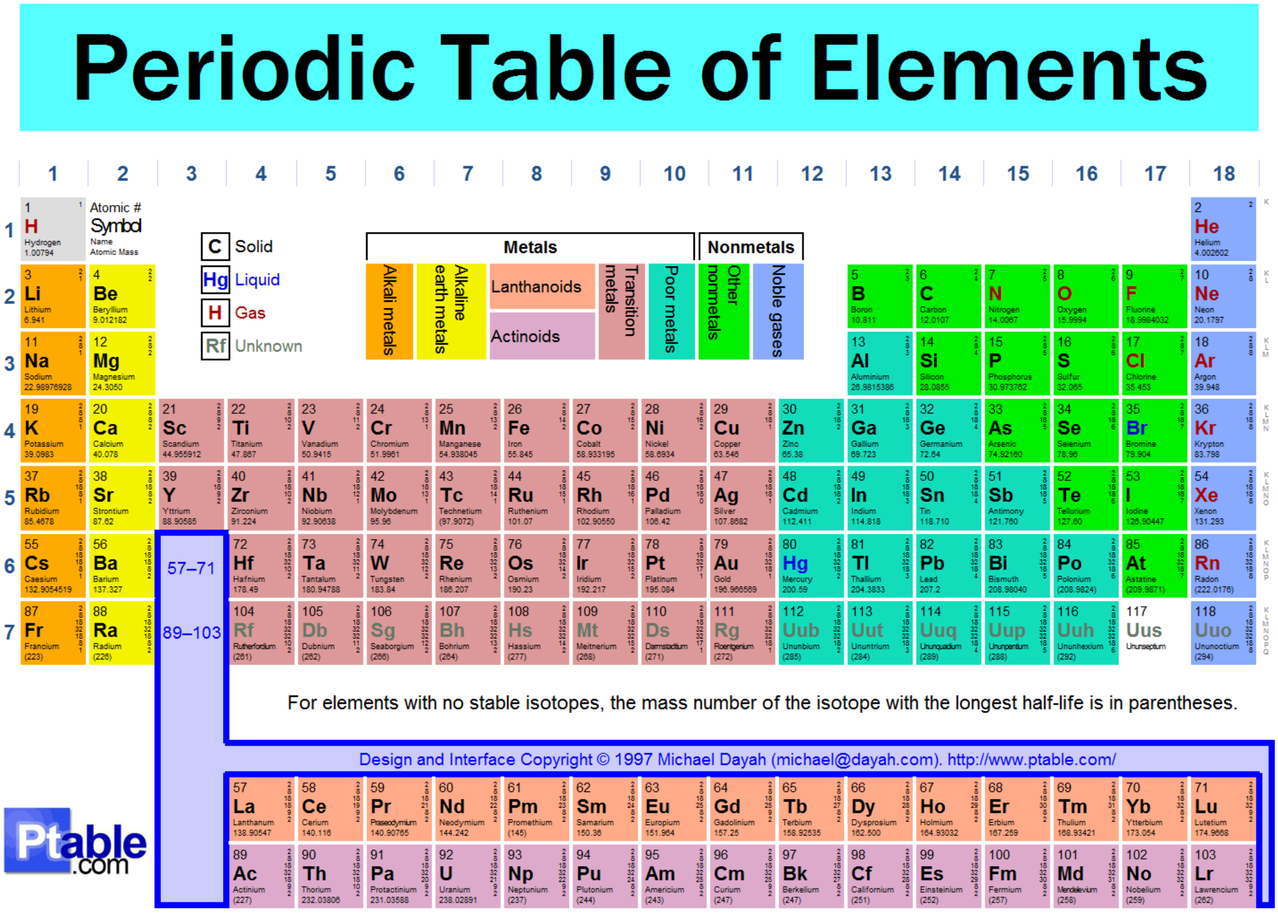
- atomic weight and
- chemical properties.

He observed a certain periodicity, repeating properties in every 8th position.

Assembling in periods of 7 and groups he presented the *periodic system of elements*

a) atoms are arranged by increasing weight of atoms in horizontal arrays

b) common properties are grouped vertically.



All elements up to Uranium No 92 are anaturally occuring. Those beyond are artificially composed.

Atomic number

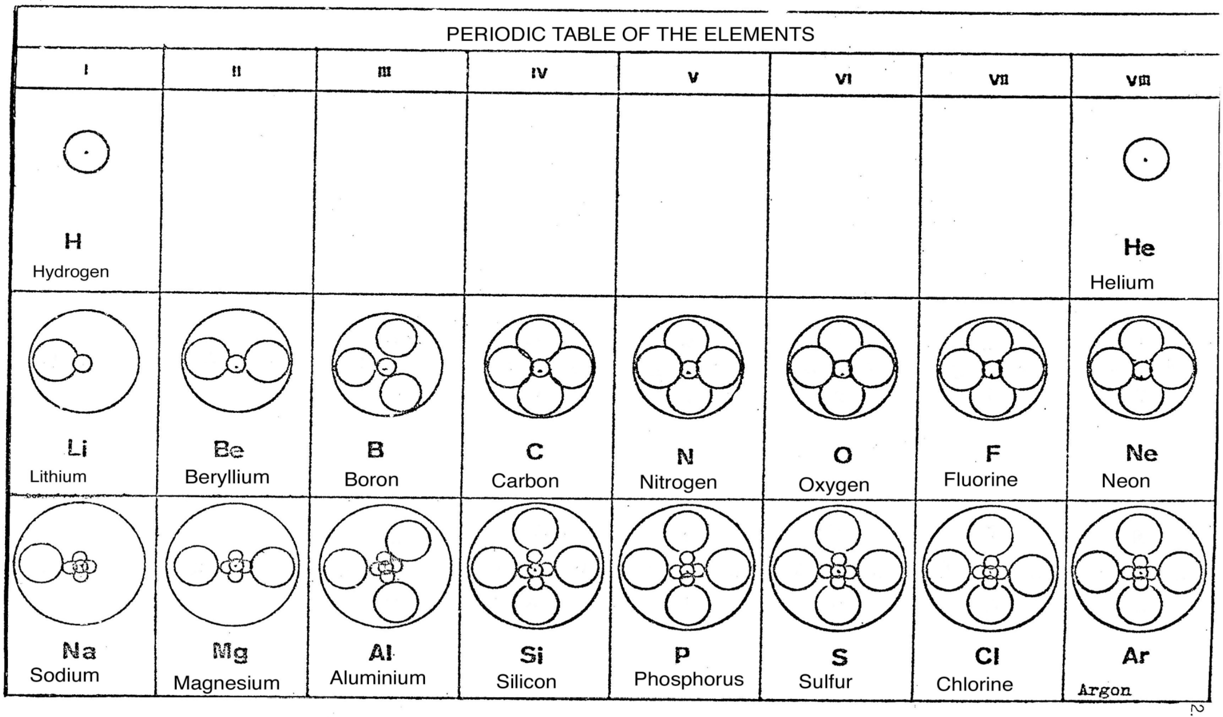
Atomic number stands for the number of protons in an element atom, e.g. Hdrogen (H): 1 proton, Helium (He) 2 protons, Beryllium (Be) contains 3 protons, iron (Fe) with 26 protoons etc

QUESTIONS: Which atomic number has nitrogen N?

How many of the elements are metals, nobel gases, non-metals?

Which elements are liquid and which ones in gaseous state ?

Please fill in the number of electrons. One electron cloud can hold only two electrons. In order to reach the noble gas state, atoms can share electrons with other atoms and form molecules. མོ་རྡུལ་གྱི་གྲངས་ཁ་སྐོང་བྱེད། མོ་རྡུལ་སྤྲིན་གཅིག་གི་མོ་རྡུལ་གཉིས་རེ་འཛིན་ཐུབ། བཟང་རླུང་གནས་སྟངས་སླེབ་པས་རྒྱུར། རྡུལ་ཕྲན་དབར་མོ་རྡུལ་ནམས་མཉམ་སྤྱོད་བྱེད་དེ་བསྡུས་རྡུལ་བཟོས།



2.10 GM

6.5 Abundance of elements on earth and in the universe

The **Earth** is composed mostly of

iron	32.1	%
oxygen	30.1	%
silicon	15.1	%
magnesium	13.9	%
sulfur	2.9	%
nickel	1.8	%
calcium	1.5	%
aluminium	1.4	%

The remaining 1.2% consist of trace amounts of other elements.
The core region is believed to be primarily composed of iron (88.8%),

Ten most common elements in the Milky Way Galaxy estimated spectroscopically[1]

Z	Element	Mass fraction in parts per million	
1	Hydrogen	739,000	71 × mass of Oxygen (red bar)
2	Helium	240,000	23 × mass of Oxygen (red bar)
8	Oxygen	10,400	
6	Carbon	4,600	
10	Neon	1,340	
26	Iron	1,090	
7	Nitrogen	960	
14	Silicon	650	
12	Magnesium	580	
16	Sulfur	440	

98 % of material space consist of H and He

6.6 Isotopes, radioacitivity

Isotopes *(from Greek isos =* equal *and topos =* place*)* are variants of chemical elements with a given number of protons (atomic number) but different number of neutrons. Different isotopes of a single element occupy the same position on the periodic table. Each isotope of a given element has a different mass number.

Hydrogen for example exists in three isotopes of the element hydrogen H: hydrogen-1 (99.98 %), hydrogen-2 (deuterium) and hydrogen-3 (tritium).
Water formed of H-2 (D or deuterium, D_2O) instead of H is called *heavy water*.

Carbon-12, carbon-13 and carbon-14 have the same atomic number 6, which means that every carbon atom has 6 protons, but the number of neutrons of these isotopes are 6, 7 and 8 respectively.

Oxygen exists in isotopes O-16 and O-18, nitrogen as N-14 and 15.
Uranium: naturally occurring isotopes are U-238 (99.3 %) and U-235 (0.7%)

Many isotopes are not stable, they decay into lighter elements. Such elements exhibit radioactivity (continuous disintegration).

Radioacivity is exhibited by several naturally occurring elements, including radium and uranium. Some isotopes of lighter elements, such as carbon-14 are used in radioactive dating. Radioactivity may also be induced, or created artificially, by bombarding the nuclei of normally stable elements in a particle accelerator. **Radioacitve decay** shows three types of rays: alpha, beta, and gamma rays.

Alpha rays are nuclei of ordinary helium atoms. Alpha decay reduces the atomic weight, or mass number.

For example, decay of uranium-238 is followed by loss of alpha particles. This produces radioactive thorium. The alpha decay reduces the atomic number of the nucleus by 2 and the mass number by 4

Beta rays are high-speed electrons. In beta decay a neutron within the nucleus changes to a proton. The electron is immediately ejected from the nucleus, and the net result is an increase of 1 in the atomic number of the nucleus but no change in the mass number. The thorium-234 produced above experiences two successive beta decays.

Gamma rays have very great penetrating power and are not affected at all by a magnetic field. They move at the speed of light and have a very short wavelength (or high frequency); thus they are a type of electromagnetic radiation accompanies alpha or beta decay and affects neither the atomic number nor the mass number of the nucleus.

7 Chemical bonds

Most atoms can join with other atoms through chemical bonds to form molecules. Chemical reactions can change molecules to form new bounds and molecules.

e.g. $H+H = H_2$ $C + O_2 = CO_2$

7.1 Covalent bonds

Atoms feel more comfortable when their outer shell (Orbit) is full.
The state with a full outer shell is called *noble gas configuration.*
Noble gases are very stable elements and they don't react with other elements. In other words, atoms share electrons in order to achieve a stable electron structure.

མཉམ་སྤྱོད་ཉུས་ཅན་གྱི་འབྲེལ་

རྡུལ་ཕྲན་ཕྱིའི་འཁོར་ལམ་རྣམས་ཆ་ཚང་གང་བ་ཡིན་ན་བདེ་པོ་ཡོད། ཕྱིའི་འཁོར་ལམ་ཆ་ཚང་གང་བའི་གནས་སྟངས་དེ་ལ་**བཟང་རླུང་གི་ཆགས་དབྱིབས་**ཟེར། བཟང་རླུང་རྣམས་ནི་ཧ་ཅང་བརྟན་པོ་ཡོད་པའི་ཁམས་རྫས་ཡིན་པར་བརྟེན་དེ་ཚོ་ཁམས་རྫས་གཞན་དང་འདྲེས་ཀྱི་མེད། དེ་ཡང་། རྡུལ་ཕྲན་ཚོས་མོ་རྡུལ་མཉམ་སྤྱོད་བྱེད་དེ་མོ་རྡུལ་གྱི་གཟུགས་དབྱིབས་བརྟན་པོ་ཞིག་འགྲུབ་ཐབས་བྱེད་ཀྱི་ཡོད།

A covalent bond is formed when two atoms share pairs of electrons. If the atoms share more than two electrons, double and triple bonds are formed H-O-H, O=C=O, $N\equiv N$, O=N-O

By sharing their electrons, both atoms achieve a highly stable electron configuration corresponding to that of a noble gas. For example, in methane (CH_4), carbon shares an electron pair with each hydrogen atom; the total number of electrons shared by carbon is eight. This corresponds to the number of electrons in the outer shell of neon; each hydrogen atom shares two electrons with the carbon atom. This corresponds to the configuration of *helium* He.

In most covalent bonds, each atom contributes one electron to the shared pair (H-H)

Examples [2]:

Chlorine *Cl_2*: This element is a gas composed of two chlorine atoms. Both atoms share one pair of electrons (one electron cloud).
རྡུལ་ཕྲན་གཉིས་ཀས་མོ་རྡུལ་ཆ་གཅིག་མཉམ་སྤྱོད་བྱེད་ཀྱི་ཡོད། （མོ་རྡུལ་གྱི་སྤྲིན་གཅིག།）

Oxygen gas molecule *O_2*: Two pairs of electrons are shared. This bond is called *double bond*.
མོ་རྡུལ་ཆ་གཉིས་མཉམ་སྤྱོད་བྱེད་པ་ན། དེ་ལ་**ཉིས་ལྡབ་འཆིང་ཐིག་**ཟེར།

Nitrogen gas molecule *N_2*: Three pairs of electrons are shared. This therefore is called a triple bond.
མོ་རྡུལ་ཆ་གསུམ་མཉམ་སྤྱོད་བྱེད་པ་ན། དེ་ལ་**སུམ་ལྡབ་འཆིང་ཐིག་**ཟེར།

[2] original Adrian Wirth, translation Lhundup Dorjee, adapted by Heinz Winzeler (please check the Tibetan translation)

7.2 *The Ionic Bond*

The ionic bond results from the attraction of oppositely charged ions.

Metals (e.g. sodium Na) lose their outer electrons easily, while the atoms of non-metals (e.g. chlorine Cl), tend to take up electrons. In an ionic crystal like sodium chloride (NaCl), no molecules exist: Sodium chloride is composed of Na^{+} and Cl^{-} ions. Each Ion is attracted to neighboring ions of the opposite charge. Together they form a crystal. [3]

Ionic compounds

Some atoms tend to gain or lose electrons to achieve a full outer Orbit. The result is either a positive or negative charged atom. We call them ions. Positive and negative Ions are strongly attracted to each other

རྫས་འགྱུར་འགྲོ་ལྡོག།

རྫས་འགྱུར་འགྲོ་ལྡོག་རྣམས་ནི་གཟུགས་དབྱིབས་ཀྱི་སྒྱུར་བ་ཞིག་རེད། གནས་སྟངས་འདི་ནང་འཚུད་པའི་རྫས་རྣམས་ཀྱི་གཟུགས་དབྱིབས་ལ་འགྱུར་བ་ཕྱིན་ཏེ་རྫས་གསར་པ་ཞིག་ཏུ་འགྱུར་གྱི་ཡོད། བསྡུས་རྫུལ་རྣམས་ལོགས་སུ་ཆག་སྟེ་ཐབས་ལམ་གཞན་གྱི་སྒོ་ནས་སྦྱོགས་བསྡུས་བྱེད་ཀྱི་ཡོད།

Example:

Sodium Na has two full Orbits (shells) and one single electron in the outer shell. This is a very unstable electron arrangement. When the sodium atom loses its outer electron, it becomes a positive Ion:

དཔེ་མཚོན། ཟེ་ལྷུང་ལ་འཁོར་ལམ་གང་མ་གཉིས་དང་ཕྱིའི་འཁོར་ལམ་ལ་མོ་རྡུལ་གཅིག་བཅས་ཡོད། དེ་ཧ་ཅང་བརྟན་པོ་མེད་པའི་སྒྲིག་སྟངས་ཞིག་རེད།

ཟེ་ལྷུང་རྡུལ་ཕྲན་གྱི་ཕྱིའི་མོ་རྡུལ་ཀླག་པ་ན་དེ་ཕོའི་གློག་ལྡན་རྡུལ་ཕྲན་དུ་འགྱུར་གྱི་ཡོད།

Because the sodium chloride compound NaCl is made out of ions, it is called an ionic compound. ཟེ་ལྷུང་ཚྭ་ཀླངས་ཀྱི་སྡེབ་རྫས་དེ་ལ་གློག་རྡུལ་གྱི་བཟོས་པར་བརྟེན། དེ་ལ་གློག་རྡུལ་གྱི་སྡེབ་རྫས་ཞེས་ཟེར།

7.3 *Metallic and Hydrogen Bonds*

In metals all atoms are identical. Bonds therefore are not ionic. They form a lattice in which electrons behave like a free gas moving within the matrix (framework) of metal atoms.

This explains the good conductivity of heat and electricity.

[3] source: http://www.infoplease.com/ce6/sci/A0857263.html - ixzz1bLlYnkdj

8 Chemical reactions

8.1 Chemical change

Nuclear and chemical reactions: Which elementary parts of an atom are involved in a nuclear and a chemical reaction respectively?

Chemical reactions are transformations:
The involved substances are transformed into new substances which have other properties.
The molecules decompose and the parts are reassembled in a new configuration. [4]

རྫས་འགྱུར་འཕྲོ་ཕྲོག་རྣམས་ནི་གཟུགས་དབྱིབས་ཀྱི་སྒྱུར་བ་ཞིག་རེད། གནས་སྟངས་འདི་ནང་འཚུད་པའི་རྫས་རྣམས་ཀྱི་གཟུགས་དབྱིབས་ལ་འགྱུར་བ་ཕྱིན་ཏེ་རྫས་གསར་པ་ཞིག་ཏུ་འགྱུར་གྱི་ཡོད། བསྡུས་རྡུལ་རྣམས་ལོགས་སུ་ཆག་སྟེ་ཐབས་ལམ་གཞན་གྱི་སྒྲོ་ནས་ཕྱོགས་བསྡུས་བྱེད་ཀྱི་ཡོད།

8.2 Experiments:

a) Mixture of iron and sulphur - mixing and separation
see video: - chemical reaction

བརྟག་དཔྱད། ལྕགས་དང་མུ་ཟི་འདྲེས་མ།
ཞིབ་རྟོགས།

Observation and conclusion?

b) Steel wool on a balance
- observation? Make a sketch:
- explanations? འགྲེལ་བཤད།

བརྟག་དཔྱད། དྲངས་ལྕགས་བལ་ཉ་གའི་སྟེང་།
ཞིབ་རྟོགས། སྒྲི་རིས་བཟོས།

c) Remember the candle experiment?
We already know that it is not the solid or liquid which is burning, but the gas of the wax.
What exactly is happening in this burning process?
Write down all observations and make a sketch!

ཡང་སྐྱར། ཡང་ལ་ཡི་བརྟག་དཔྱད

ང་ཚོས་ཡང་ལ་ཡི་རླུང་གཟུགས་ཆ་ཤས་དེ་འབར་གྱི་ཡོད་པ་སྔོན་ནས་ཤེས་ཀྱི་ཡོད། དངོས་ཡོད་ཀྱི་འབར་བའི་རྒྱུད་རིམ་འདིའི་སྐབས་ག་རི་བྱེད་ཀྱི་ཡོད། ཞིབ་རྟོགས་ཀྱི་གཟིགས་ཚུལ་རྣམས་བྲིས་པའི་ཐོག་སྒྲི་རིས་སོགས་དགོས་ཚེ་བཟོ་དགོས

4 Source: Adrian Wirth, translation Lhundup Dorjee, adapted by HW

8.3 Chemical Equations [5]

During a chemical reaction atoms are not created or destroyed. i.e. the number of atoms of each element must be the same in the *reactants* as in the *products*. The equation of elements is *balanced*. Balanced symbol and formula equations show how many molecules of reactants and products are formed.

The physical state of substances is indicated by symbols (s) for solid, (l) for liquid and (g) for gaseous state. Substances dissolved in water are indicated with (aq) for aqueous solutions.

Examples of chemical reactions are

- carbon burning in oxygen (O_2 in air) to form carbon dioxide
- decomposition of calcium carbonate to calcium oxide and carbon dioxide on heating
- silver nitrate solution and sodium chloride solution into silver chloride and sodium nitrate.

The balanced equations of these reactions are the following:

carbon ( ) + oxygen ( ) $\rightarrow$ carbon dioxide ( )

calcium carbonate (s) $\rightarrow$ calcium oxide (s) + carbon dioxide (g)

silver nitrate (aq) + sodium chloride (s) $\rightarrow$ silver chloride (s) + sodium nitrate (aq)

[5] c.f. Susan Lakin and John Patefield: Essential Science for GCSE, Nelson (1998), topic 21, p.112-113

8.4 Hazard symbols

 (*Explosive*)	 (*Flammable*)	 (*Oxidising*)
 (*Health hazards including carcinogens - see page 3*)	 (*Acutely toxic*)	 (*Corrosive*)
 (*Moderate hazard – see page 3*)	 (*Gas under pressure*)	 (*Hazardous to the aquatic environment*)

Fig. 8.1 Globally Harmonized System (GHS) of classification and labeling

Examples of products:

Explosive: nitroglycerine, dynamite, black powder

Flammable: lamp oil, gasoline, solvents, aerosol can, butane gas

Oxidizer: hydrogen peroxide, bleaching agent

Health hazard: gasoline/benzine, methanol, some etheric oils, lack

Acutely toxic: rat poison, arsenic

Corrosive: baking oven cleaner, strong cleaning agents, softening agent

Moderate hazard: dishwasher tabs, javelle, cleaning material

Gas under pressure: Propane-/ butane gas bottles, CO2-cylinders for soda water

Environmental hazard: mold remover, motor oils, swimmingpool chemicals, insecticide

9 The origin of chemical elements

9.1 The Formation of elementary particles

The most widely accepted theory in cosmology is currently the Big Bang Theory, which was based on Einstein's General Theory of Relativity ($E = mc^2$). According to this, the universe was once concentrated in a small nucleus of extremely high temperature and infinite density.

During the big bang only hydrogen, helium, and trace amounts of lithium and beryllium were formed (out of initially generated protons, neutrons and electrons).

9.2 The formation of further chemical elements

When stars no longer can fuse hydrogen to helium because the hydrogen fuel is exhausted, they expand into a red giant.
Three helium atoms fuse into a carbon atom, four heliums fuse into oxygen. If the core is compressed, heavier elements are formed, when the star collapses into a white dwarf. This goes up to iron (Fe), which is the most dense atoms.

Heavier chemical elements that fill the periodic table are thought to have been produced by various cosmic processes after the appearance of stars. In their depths in the thermonuclear fusion reactions gradually formed nitrogen, oxygen, carbon and heavier elements. But how elements beyond iron emerge, still remain a speculation…

Planetary **nebulae** are containing material enriched with heavy elements.

Fig. 9.1 Cat's eye nebula

The Cat's Eye Nebula was discovered in 1786. This picture was taken by the high-resolution Hubble telescope. In the center of the Cat's Eye there is a bright and hot star, which is10'000 x brighter than our sun. Around 1000 years ago this star lost its outer envelope, producing the nebula.

The distance from earth is 3000 light-years.

Hydrogen is the most abundant element. It looses huge amount of material with solar wind, emitting also traces of other elements in space.

Video clip "Journey in space" authored by A. Zartha: Assembled pictures taken from the Hubble telescope (see further pictures under http://www.hubblesite.org)

10 Carbon

Carbon, symbol C, from latin: carbo = „coal“

Atomic number 6: How many electrons and protons?

There are *three naturally occurring isotopes* 12, 13, 14: how many neurons?

10.1 Different forms of elementary carbon

Carbon exists naturally in 3 forms which have extremely different physical properties:

Black carbon: “coal”, appears naturally as a sedimentary rock, which is easily burning (anthracite coal). Other forms are charcoal, bituminous caol

Graphite: black, soft (pencil), good electrical conductor.

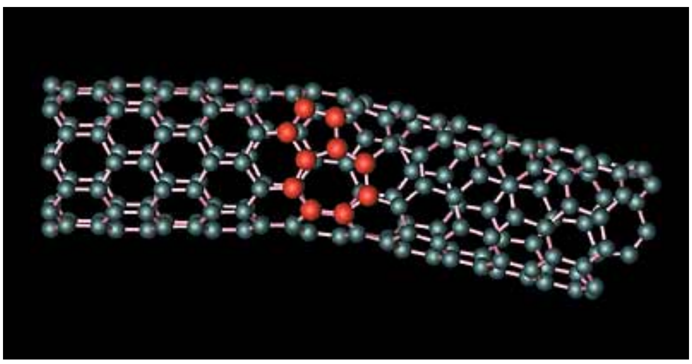
Diamond: highly transparent extremely hard; Diamond conducts no electricity (isolator), but has high conducitivy of heat.

Fig. 10.1 Diamond and anthracite coal (same chemical element C !)

Nanotubes and fullerenes:

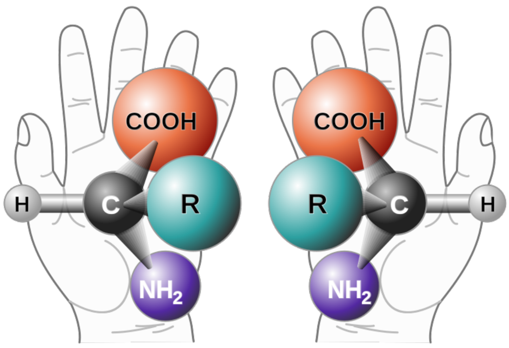
modern working materials which find applications in nanotechnology and -structures, microelectronics, energy storage, biotechnology (biosensors), catalytic chemistry

Fig. 10.2 Nanotube (Model)

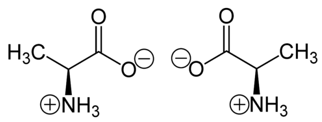


10.2 Tetrahedron form and chiral molecules (mirror symmetry)

- The outer shell has four electrons available to form covalent chemical bonds. Carbon therefore is a very special element because it plays a dominant role in the **chemistry of life**.



Due to the tetrahedron form with 4 electrons in the L-shell carbon is forming more compounds than any other element (almost ten million). Carbon compounds can be asymmetric and form mirror conformation L- or R-forms of molecules (chirality).

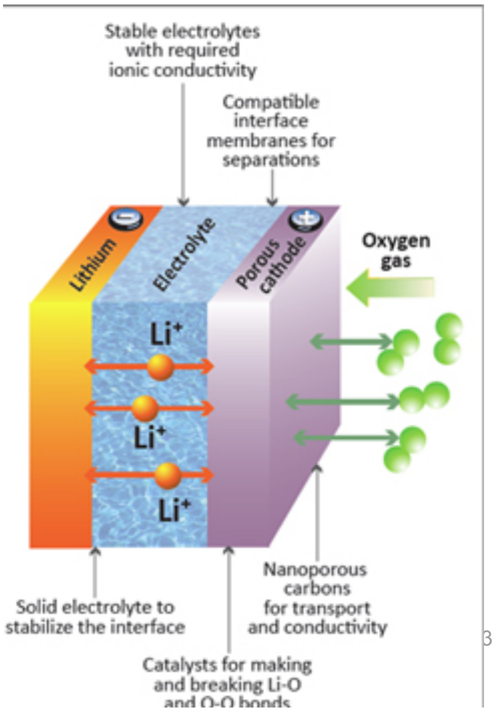


Two molecules (S)-Alanine and (R)-Alanine in ionic form.

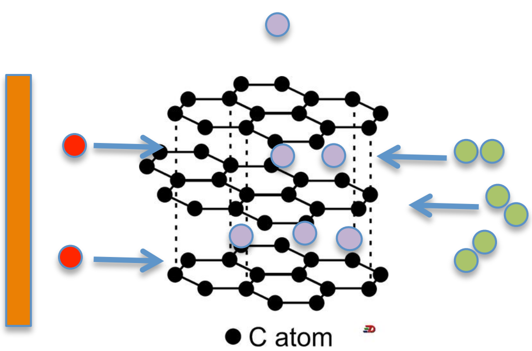
10.3 Applications of carbon nanostructures in Li-Ion batteries

(case study*: problems with Li-Batteies as a reason for the grounding of Boeing 787 "Dreamliner")*

- Working principle of a battery: 2 Redox-reactions, separated by an electrolyte
- The role of an electrolyte: barrier for *electrons* (isolator) but conductivity for *ions*



The **motion of Li-ions** upon *discharging* and *charging*

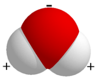


11 The Water molecule

ཆུའི་འདུས་རྡུལ།

Water is an extraordinary substance. It has unusual properties because of the structure of its molecule.
At the same time it is the most common substance on our planet.
Without water, life would not be possible.
Our bodies consist of about 70% of water!
Water is liquid only over a narrow range of temperature – between 0 and 100 deg. Celsius.
If our earth would be a little closer to the sun Most of the water would turn into vapour.
If it would be a little bit further away, most of it would be frozen.

ཆུ་ནི་རྒྱུ་རྫས་ཡ་མཚན་ཅན་ཞིག་ཡིན། དེ་ནི་རང་གི་འདུས་རྡུལ་གྱི་ཆགས་དབྱིབས་མི་འདྲ་བ་ཡོད་པ་ལ་བརྟེན་གྱི་ཡོད། དེ་ཡང་ཆུ་ནི་སའི་གོ་ལའི་སྟེང་གི་རྒྱུ་རྫས་ཁྱབ་མོང་ཅན་ཞིག་ཡིན། ཆུ་མེད་ན། སྲོག་ཡོང་མི་སྲིད། ང་ཚོའི་གཟུགས་པོའི་ནང་གི་བརྒྱ་ཆ་ ༧༠ ཙམ་ཆུ་ཡིན། ཚ་ཚད་ 0° Celsius དང་ 100° C.བར་དུ་ཡིན་སྐབས་ཆུ་གཤེར་གཟུགས་ཀྱི་ངོ་བོར་གནས་ཀྱི་ཡོད། གལ་སྲིད་གོ་ལ་ཉི་མ་དང་ཉེ་རུ་ཕྱིན་པ་ན། ཆུ་མང་ཆེ་བ་རླངས་གཟུགས་སུ་འགྱུར་གྱིས་ཡོད། ཡང་གལ་སྲིད་གོ་ལ་ཉི་མ་དང་ཐག་རིང་དུ་ཕྱིན་པ་ན། དེ་དག་འཁྱགས་པར་འགྱུར་གྱིས་ཡོད།
ང་ཚོས་ཆུའི་འདུས་རྡུལ་ཇི་ལྟར་ཡོད་མེད་ཤེས་ཀྱི་ཡོད།

You know already what a water molecule looks like: 

སྲོག་འཛིན་རླུང་གི་རྡུལ་ཕྲན་གཅིག་དང་ཡང་རླུང་གི་རྡུལ་ཕྲན་གཉིས་མོ་རྡུལ་མཉམ་སྤྱོད་བྱེད་པར་བརྟེན་ནས་པོར་མཉམ་དུ་གནས་ཐུབ་ཀྱི་ཡོད།

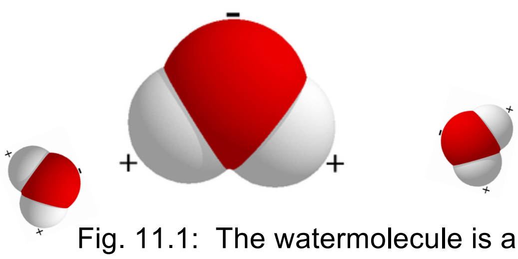


Fig. 11.1: The watermolecule is a dipole

The oxygen atom and the two hydrogen atoms are strongly held together by sharing electrons. But the electrons are not spread evenly around the molecule: Hydrogen atoms have a slightly positive and oxygen atoms a slightly negative charge, This is called a **dipole**. Water molecules have a dipole.
(Remember: The overall charge of the molecule is zero (same amount of electrons and protons, the positive and negative charge are cancelling out each other.)

ཡིན་ན་ཡང་། མོ་རྡུལ་རྣམས་འདུས་རྡུལ་གྱི་གཡས་གཡོན་དུ་སྙོམས་པོར་ཁྱབ་མེད། དེ་དག་སྲོག་འཛིན་རླུང་གི་རྡུལ་ཕྲན་དང་ཉེ་བ་ཡོད། མོ་རྡུལ་རྣམས་མོའི་གློག་ཁུར་ཡོད་པར་བརྟེན། སྲོག་འཛིན་རླུང་གི་རྡུལ་ཕྲན་རྣམས་ཀྱང་མོ་གློག་ཆུང་དུ་ཞིག་དང་ལྡན་པ་དང་། ཡང་རླུང་རྣམས་ལ་ཕོའི་གློག་ཁུར་ཆུང་དུ་ཞིག་ཡོད། དེ་ལ་ **dipole** ཟེར་གྱི་ཡོད། ཆུའི་འདུས་རྡུལ་དག་ལ་ **dipole** ཡོད།
དྲན་པར་བྱེད་དགོས། འདུས་རྡུལ་གྱི་ཁྱོན་སྡོམས་གློག་ཁུར་ནི་ཀླད་ཀོར་ཡིན། (ཕོ་རྡུལ་དང་མོ་རྡུལ་མང་ཉུང་གཅིག་པ་ཡོད། ཕོ་གློག་དང་མོ་གློག་ཕན་ཚུན་མེད་པར་བཟོ་གིས་ཡོད།)

Electrolysis of water

→ Experiment and observations

12 Nitrogen

Case study: The nitrogen cycle – indispensable for our life and food production.

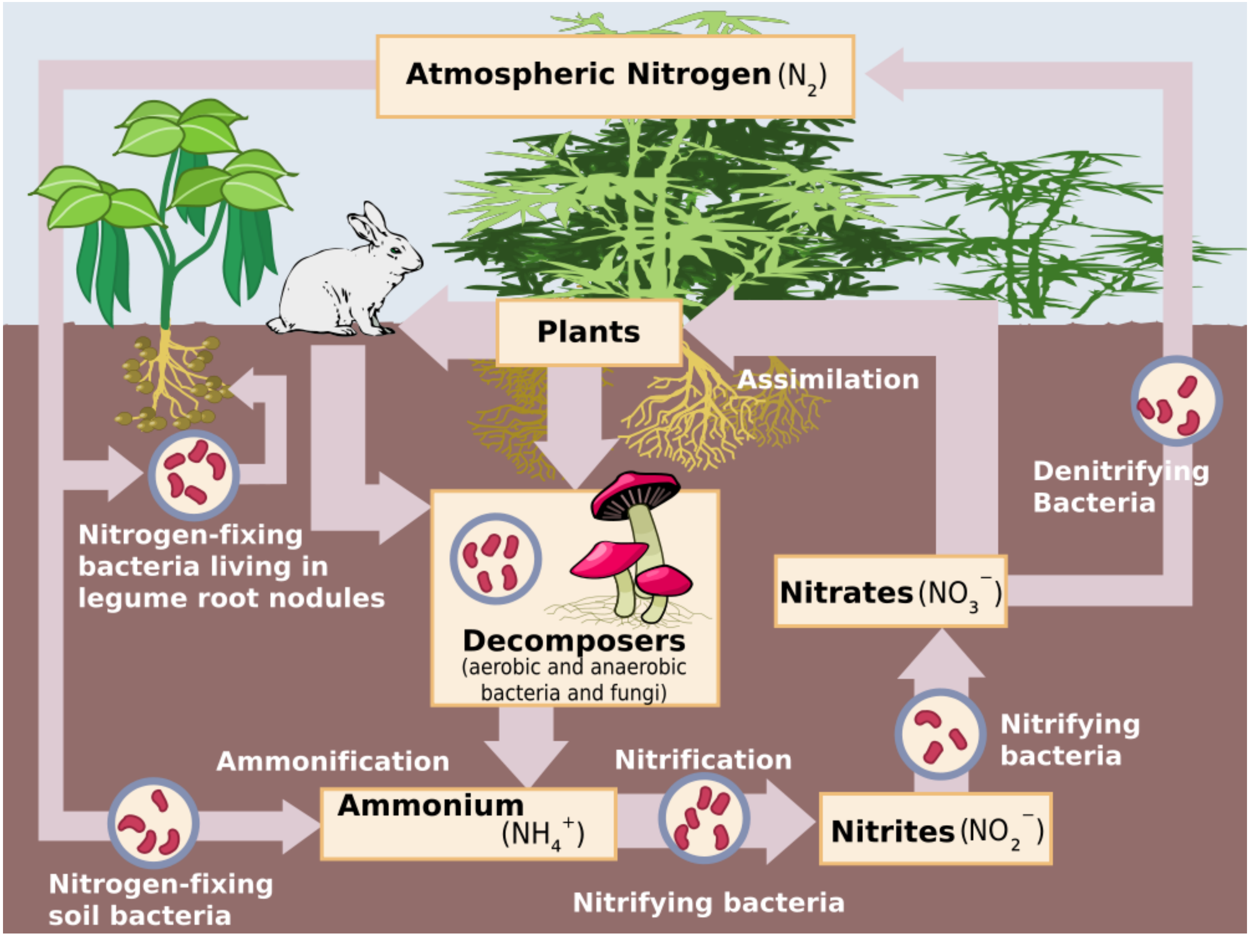


Fig. 11.1: Nitrogen cycle between atmosphere and soil

Plants need nitrogen for the synthesis of **amioacids** and **proteins**. Although air is composed of 4/5th of nitrogen (N_2), plants cannot use atmospheric nitrogen; they must use a combined or fixed form of the element such as nitrates.

Intensive agriculture uses large amounts of industrial nitrogen in the form of ammonia or nitrates (c.f. chapter 9.2)

After photosynthesis, **nitrogen fixation** (or uptake) is the second most important process for the growth and development of plants.

Rhizobium is a soil bacterium which has the ability to fix atmospheric nitrogen and transform it into ammonia (NH_3) or ammonium (NH_4^+). This is a very energy intensive process.

$$N_2 + 8\ H^+ + 8\ e^- \longrightarrow 2\ NH_3 + H_2$$

Symbiosis between plant roots and bacteria

On the roots of **leguminous plants** like peas, beans, lentils and soy, the bacteria reside in nodules. The plant roots are producing amino acids and sugars and make part of it available for the nodule bacteria. This mutual profiting is called **symbiosis**.

Fig. 11.2: Nodules (habitat of nodule bacteria) on lotus trefoil roots

Fig. 11.3: Peas as representative of leguminoses

Explaining the biochemical process:

The rhizobia are chemically attracted and attached to root hairs. The plant then releases flavanoids, which induce the expression of *nod* genes within the bacteria. The expression of these genes results in the production of enzymes called nod factors that initiate root hair curling. During this process, the rhizobia are curled up with the root hair. The rhizobia penetrate the root hair cells with an infection thread that grows through the root hair into the main root. This causes the infected cells to divide and form a **nodule**. The rhizobia can now begin nitrogen fixation.

12 Phhotosynthesis

Photosynthesis is a process used by plants and other organisms to capture the **sun's energy**

- Water is split into hydrogen and oxygen.
- Hydrogen is then combined with carbon dioxide
- Carbon dioxide is absorbed from air or water.

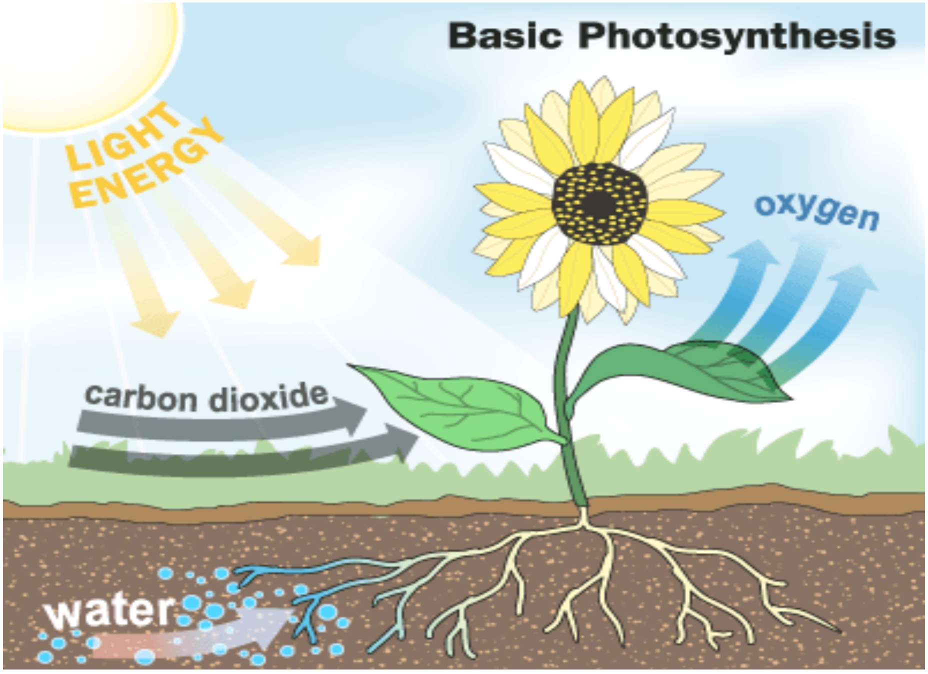


Fig. 12.1 Schematic view of photosyntheic circles

In this process **oxygen** is released and **glucose** is synthesised.

$$6\,CO_2 + 6\,H_2O \underset{\text{respiration}}{\overset{\text{photosynthesis}}{=\!=\!=\!=\!=\!=\!=\!=}} C_6H_{12}O_6 + 6\,O_2$$

Imagine that a 100 years old beech tree holds some 200'000 leaves. They have a total surface of some 1200 m^2! (Compare this area with a football pitch 100 x 70 m. How many trees does this correspond?)

These 200'000 leaves contain 180 g chlorophyll in 10^{14} chloroplasts (Microscope)

On a sunny day such a tree can produce more than 9'000 litres of Oxygen and more than 10 kg of carbohydrates
Calculate: 22,4 litres of oxygen O_2 are 18 grammes =

how many kg of oxygen? *Fig. 12.2 Beach tree in summer time*

The range of light within the spectrum of electromagnetic radiation

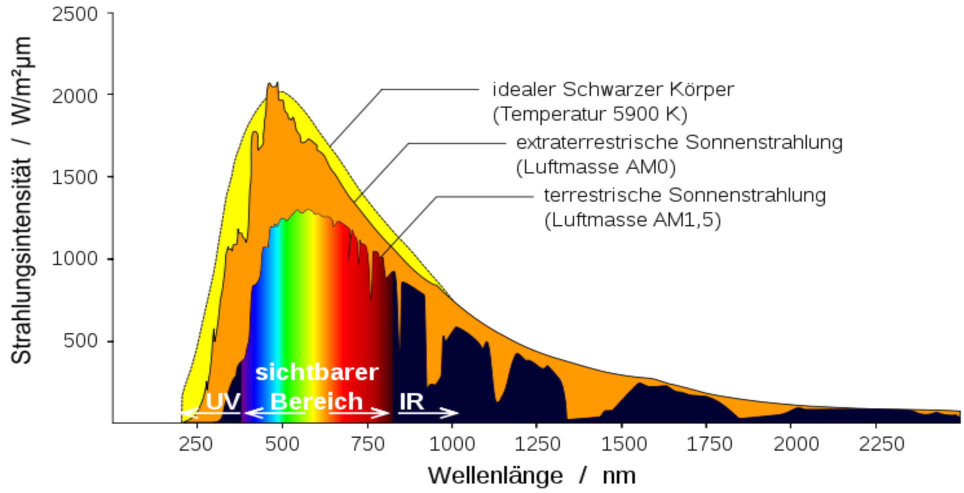


Fig. 121.3 Spectrum of sun light – intensity versus wave length

a) Wave-Particle duality

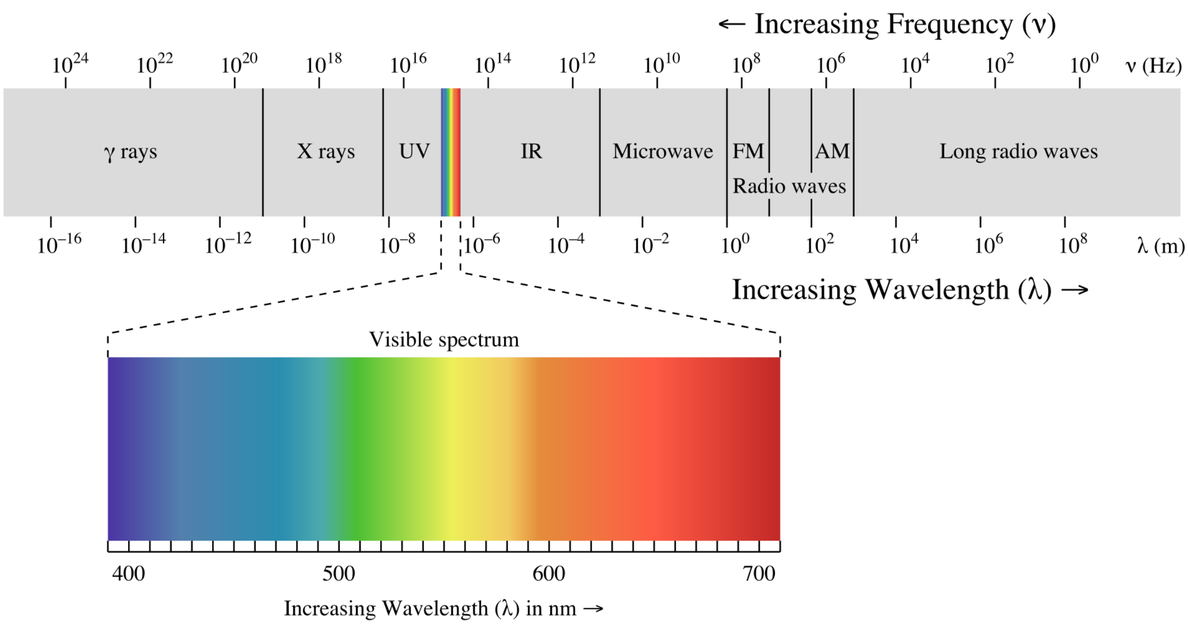
Light exhibits properties of both waves and particles. In common with all types of electromagnetic radiation, visible light is emitted and absorbed in tiny "packets" called *photons*. The study of light is known as *optics.*

Light shows its **wave characteristics** in the refraction of light.
Light shows its **particle nature** e.g. in the photovoltaic effect

b) The speed of light and wavelength

The speed of light (fundamental natural constant) is about 300'000 km/s in *vacuum*.
Visible light has a wave length in the range of 380... 740 nm (between non visible ultra violet and infra red).

c) Electromagnetic Spectrum EMS



Relation between frequency f (Hz) and wavelength l (m): c = f . l