



Tananyag fejlesztés idegen nyelven

Prevention of the atmosphere

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Calculation of greenhouse effect. The carbon cycle

Lecture 11
Lessons 31-33



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Lesson 31

Calculation of the size of greenhouse effect



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Temperature definitions

Black body temperature

Black body: theoretical object, the full radiator. It absorbs all the incoming radiation and it emits on maximum level at a given temperature.

This temperature dependent emitted thermal radiation from the black body is called as black body radiation.

Effective temperature of a planet is equating the power received by the planet with the power emitted by a blackbody of temperature T (K). The Stefan-Boltzmann law expresses the power radiated by the planet.





Average air temperature (normal) – what we measure for a longer time period. This is a balanced or equilibrium temperature. We have very precise satellite radiation measurements for more than 3 decades. We apply them in our calculation.

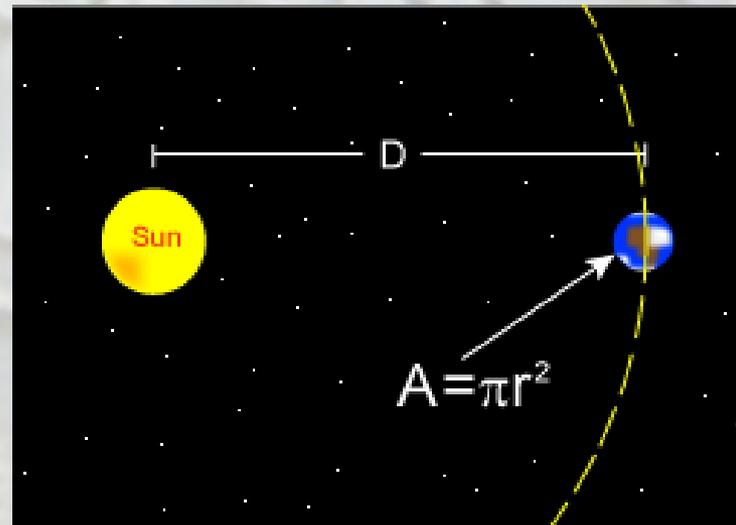
In the planets, the incident and emitted radiation have the most significant impact on their temperature.

The energy is only a small proportion of the total one coming from the Sun, and strikes the top of the Earth's atmosphere.





Fig. 86 Sun's emitted radiation on the surface of the Earth



http://en.wikipedia.org/wiki/Black_body#Temperature_relation_between_a_planet_and_its_star



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Exercise

Let's calculate the size of the greenhouse effect for the Earth!

During the past few decades the mean air temperature close to the surface remained almost constant. It has of meaning that the incoming (E_{in}) and outgoing (E_{out}) radiations are balanced:

$$E_{in} = E_{out}$$

The Earth only has an absorbing area equal to a two dimensional circle, rather than the surface of a sphere; see Fig. 86!





The power absorbed by the Earth and its atmosphere is then:

$$r^2 \pi (1 - \alpha) I_0 = E_{in}$$

where r is the Earth radicle

I_0 is the solar constant

α is the planetary albedo

The emitted radiation for the Earth:

$$E_{out} = 4 \pi r^2 \sigma \cdot T_k^4$$

T_k : surface temperature in Kelvin



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- Do not forget that the whole sphere emits the power oppositely to the received solar radiation.

Assuming the equilibrium state the two sides are equal:

$$r^2 \pi (1 - \alpha) I_0 = 4 r^2 \pi \sigma \cdot T_k^4$$

Arrange the equation!

At first let's divide with $r^2 \pi$ both of equation sides:

$$\frac{(1 - \alpha) I_0}{4 \sigma} = T_k^4 \quad : 4 \sigma$$



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$$\frac{(1 - \alpha) I_0}{4\sigma} = T_k^4$$

Arrange further the equation sides:

$$\sqrt[4]{\frac{(1 - \alpha) I_0}{4\sigma}} = T_k$$

And now substitute the known values needed to solve the equation!

α stands for planetary albedo=0.3

I_0 is the solar constant= 1367 W/m²

σ is Stefan-Boltzmann constant = 5,67x10⁻⁸ Wm⁻²K⁻⁴



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Steps of calculation are as follows:

$$\sqrt[4]{\frac{(1 - 0,3) \cdot 1367 \left[\frac{W}{m^2} \right]}{4 \cdot 5,67 \cdot 10^{-8} \left[\frac{W}{m^2 K^4} \right]}} = T_k$$

$$\sqrt[4]{\frac{0,7 \cdot 1367}{23 \cdot 10^{-8}} [K^4]} = T_k$$

$$\sqrt[4]{\frac{957}{23} \cdot 10^8 [K]} = T_k$$



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$$\sqrt[4]{42} \cdot 10^2 [K] = T_k$$

$$2,5457 \cdot 10^2 [K] = T_k$$

$$\underline{\underline{254,57 [K] = T_k}}$$

- Convert the K into °C!

$$254K = ?^\circ C$$

$$254 = t_k + 273$$

$$t_k = -19^\circ C$$





The effective temperature of the Earth is -19°C . This is the temperature that the Earth would be at if it radiated as a perfect black body in the infrared, ignoring greenhouse effects, and assuming an unchanging albedo.

Finally the greenhouse effect is the difference between the balanced temperature and effective temperature:

$$15 - (-19) \text{ }^{\circ}\text{C} = 34^{\circ}\text{C}$$

The presence of special gases in the atmosphere is heating the lower part of the air, our living place.

(The above calculation may differ when the evaluated albedo and solar constant values change)



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Lesson 32

The carbon cycle. Global carbon budget and its members



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The global carbon cycle

This carbon cycle has of primary importance because two of the greenhouse gases, the CO_2 and methane are included. The carbon cycle is more sophisticated than that of the water cycle, due to the presence of chemical transformation. It means that not only the path of gases from sources to sinks has to be accounted, but chemical reactions also.

There are two categories of carbon cycle. The geological one operates over large time scales (millions of years). The second is the biological, which operates at shorter time scales (days to thousands of years).





The global carbon cycle expresses the movements of carbon, during the exchanges between reservoirs (sinks), and occurs due to chemical, physical, geological, and biological processes.

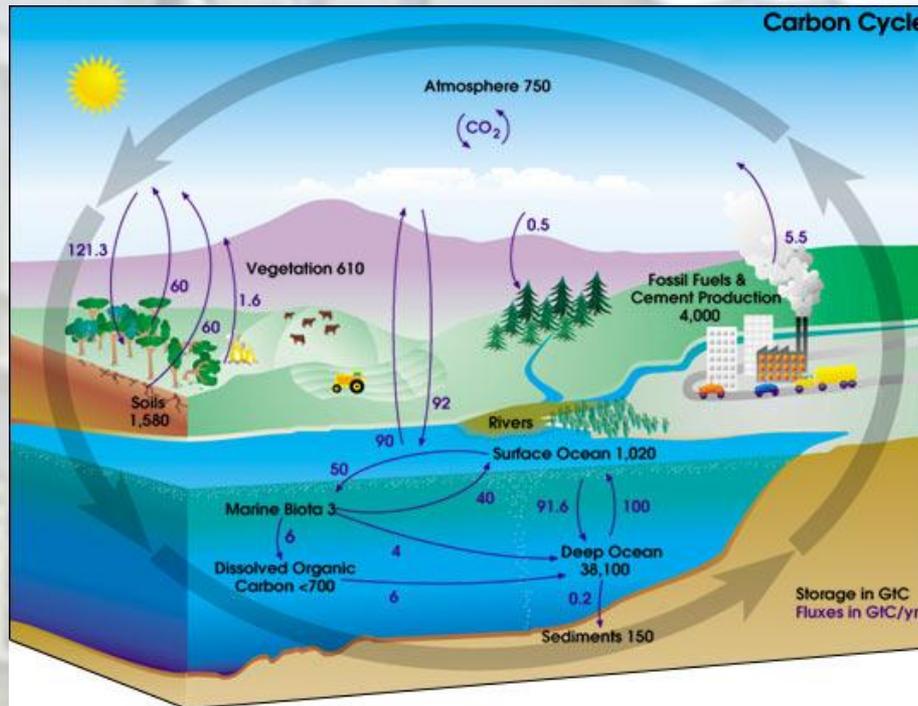
The global carbon cycle comprises carbon reservoirs interconnected by pathways of exchange. These are;

- The atmosphere
- The terrestrial biosphere (non-living organic materials)
- The oceans (dissolved carbon and marine biota)
- The sediments including fossil fuels.
- volcanoes and geothermal systems (Earth interior)





Fig. 87 The carbon cycle diagram. Values are in Gt.



http://earthobservatory.nasa.gov/Library/CarbonCycle/carbon_cycle4.html



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- The carbon cycle diagram presents the carbon storage and annual exchange of carbon between the different reservoirs, see earlier . The cycle demonstrates how carbon is to be recycled and is reused through the organismus of the biosphere
- The dimension is expressed in gigatons - or billions of tons - of Carbon (GtC).

Analyzing the diagram's figures the burning of fossil fuels by human activity adds at about 5.5 GtC of carbon per year into the atmosphere.





The **global carbon budget** is calculated for the globe as a whole, where the other spheres are included (hydrosphere, atmosphere, pedosphere and biosphere).

The budget expresses the state of the system after different exchange processes (incomes and losses) of carbon between the reservoirs (sinks) or between specific ways of the system members (e.g., atmosphere ↔ biosphere) of the cycle.

Studying the branches of the carbon budget of a reservoir give information about whether the pool is functioning as a source or sink for carbon dioxide. This is important in global warming process.





- The atmospheric reservoir is in medium size, somewhere between the largest Earth crust and the smallest biosphere. The exchange processes are in close connection to the size of the pool; the less in size of the pool the faster is the CO_2 exchange time of the reservoir. Earth crust has orders of magnitude longer residence time than that of the atmosphere.
- The longer residence time also shows much slower exchange processes when compounds of the system are attenuated from one reservoir to the other.
- Table 12 sums the most important features of the carbon pools.





Table 12 C-reservoirs and their most important features

Reservoir	Capacity	Residence time
Atmospheric CO ₂	1.6	10 years
Atmospheric CH ₄	0.02	9 years
Green part of the biosphere	0.2	Days to seasons
Tree trunks and roots	1.2	Up to centuries
Soils and sediments	3	Decades to millennia
Fossil fuels	10	—
Organic C in sedimentary rocks	20,000	2 × 10 ⁸ years
Ocean: dissolved CO ₂	1.5	12 years
Ocean CO ₃ ²⁻	2.5	6,500 years
Ocean HCO ⁻	70	200,000 years
Inorganic C in sedimentary rocks	80,000	10 ⁸ years

(After Wallace and Hobbs)



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- In case of capacity the unit is in kg m^{-2} averaged over the Earth surface
- The reservoirs in the *Table 12* contains sub-parts as well.
- In the atmosphere two greenhouse gases are parts of the carbon cycle: methane and CO_2 .
- The fossil fuels comprise a separate line in the table
- Organic- and inorganic C in the sediments are also separately present
- The residence time is from days (crops) up to millenia (soil sediments)



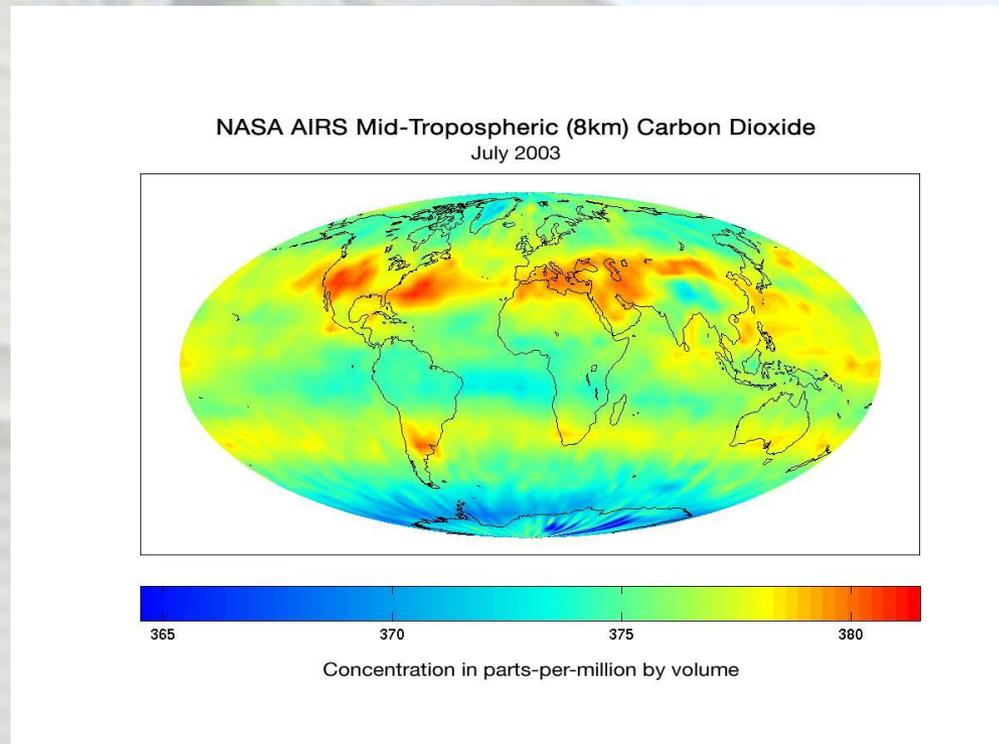


Reservoirs 1. Atmosphere

- Although the carbon dioxide occupies only a very small percentage of the atmosphere (385 ppmv; approximately 0.04 vol %), it's role to keep our life (biosphere) steady. The gas is irreplaceable.
- Two other atmospheric gases also belong to this cycle; the methane and the chlorofluorocarbons (freons). The freons contain more than 100 separate members. They are entirely antropogenic origin.
- Most of the atmospheric carbon is in form of CO_2 . The variability of gas is low due to its chemical inertness. The change in CO_2 concentration over the surface is only 1%.



Fig. 88 The global distribution of CO₂



ppj-web-3.jpl.nasa.gov/target/Earth?order=Ins...



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Lesson 33

Reservoirs and their role in the Earth atmosphere system (carbon cycle). Air – see also the earlier lesson. Biosphere. Oceans. Earth crust





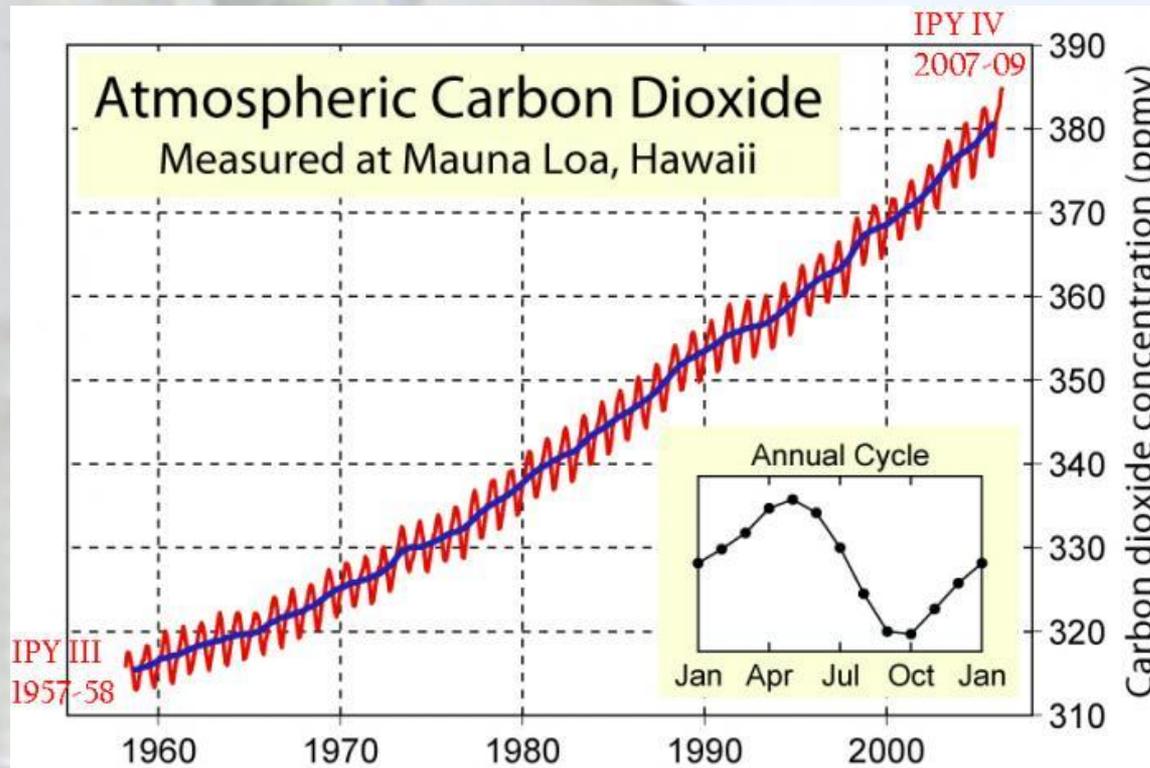
The Keeling curve

The consumers of the CO_2 are the crops in the process of photosynthesis, which enters oxygen to the air. The intensity of the process is variable; with the strongest one during the vegetation period (use of CO_2 and producing O_2).

The highest oxygen emission belongs to deciduous trees (forests). Sharp temporal variation in carbon dioxide concentration causes the „sawtooth” form of the curve of CO_2 gas concentrations. This diagram became famous as the so called Keeling curve.



Fig. 89 The Keeling curve



http://icestories.exploratorium.edu/dispatches/wp-content/uploads/2008/05/keeling_graph.jpg



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Sources of CO₂

- Forests store 86% of the planet's above-ground carbon and 73% of the planet's soil carbon
- The cooler the water, the higher the carbon concentration of it. The marine organism binds the carbon and as a hard matter e.g. shell it falls down to the bottom of the ocean (downward carbon flux – carbon pump). It will be the entry in biological pump.
- Bicarbonate from weathering of rocks is not carried the carbon to reservoirs, and they are ready to return to the atmosphere.
- Respiration of humans and animals produces CO₂.





- Microbes break down the carbon compounds in dead animals and crops converting their carbon content to carbon dioxide if oxygen is present, or methane if not.
- Every burning produces CO_2 .
- Cement production releases the CO_2 gas when limestone is heated
- The warmer the surface water temperature is, the more CO_2 is released back to the atmosphere.

Exercise

Following the above list find the relationship with source intensity and process of global warming!



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CH₄

- The methane, one of the greenhouse gases can be found in the atmosphere in trace concentration. In spite of low concentration the methane is chemically active gas.
- The mining operations enter the gas into the air as antropogen source. The agriculture is also a large producer through rice production and breeding ruminants.
- In the nature and also in human activity anaerob decay of organic matter emits methane to the surroundings.



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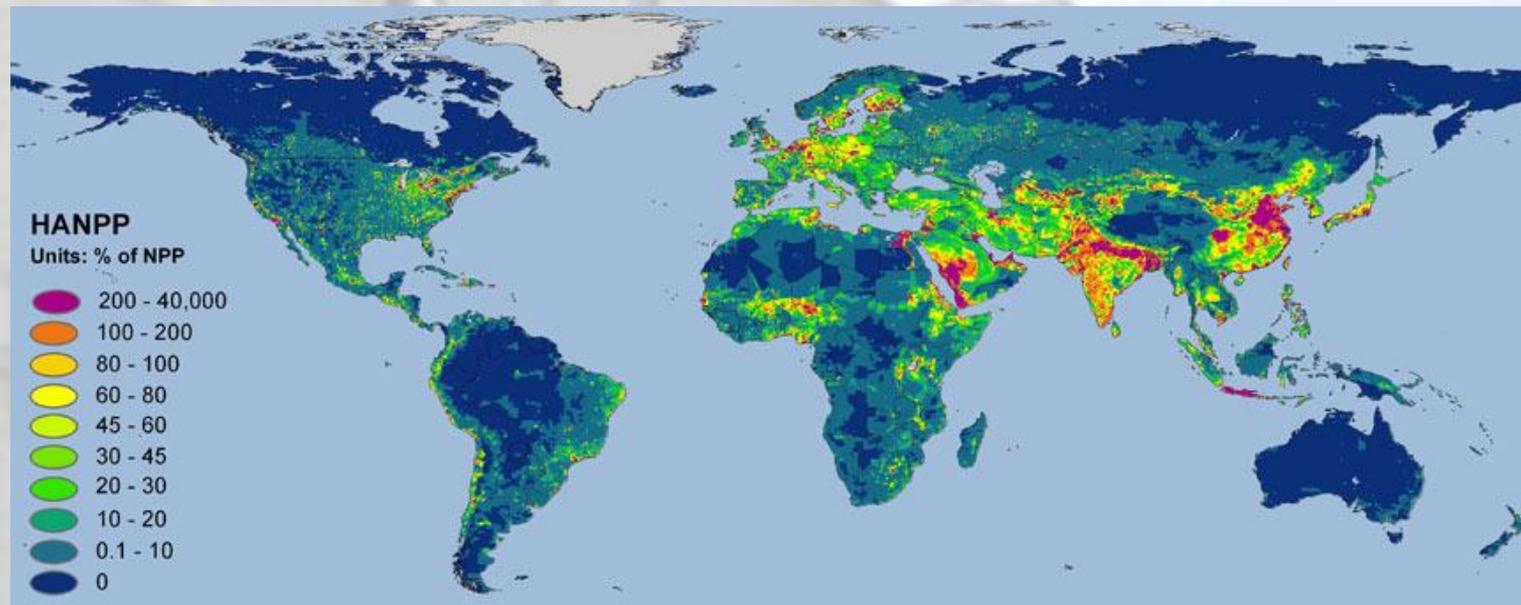


2. Biosphere

- Photosynthesis absorbs visible light in form of carbohydrate. The same amount of energy is released in the respiration in form of heat.
- The net primary production (NPP) is the sum of photosynthesis of phytoplanktons and land plants. Altogether about 42,000 Gt of carbon are present in the biosphere. The „green carbon” contains three different carbon pools:
 - living biomass,
 - dead biomass and
 - soil.



Fig. 90 The NPP of the Earth in %



http://earthobservatory.nasa.gov/Newsroom/NasaNews/ReleaseImages/20040623/02_fig2.jpg



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- The rate of carbon exchange is approximated of about $0.1-0.2 \text{ kg C m}^{-2} \text{ year}^{-1}$.

Two groups of living organism acquire the carbon, the most important cell building matter, on a different way. The first group needs external energy to carbon assimilation (photosynthesis); they are the autotrophs. The members of the other group feed the autotrophs using their bound carbon. These are the heterotrophs.

Respiration releases CO_2 into the air. Anaerobic respiration produces methane.

Sedimentation (limestone) is also a circulator for the CO_2 .



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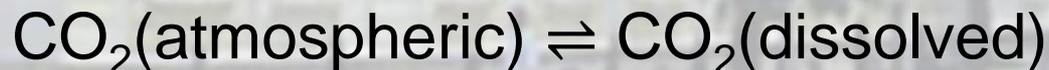


3. The oceans

- There are three forms of CO₂ in the oceans;
 - Carbonic acid (dissolved CO₂) – prevailing form
 - Carbonate ions in paired with calcium or magnesium
 - Bicarbonate ions (-HCO₃)

The carbon exchange is important in controlling water pH and can also vary as a source or sink for carbon. Gas enters into the ocean as follows:

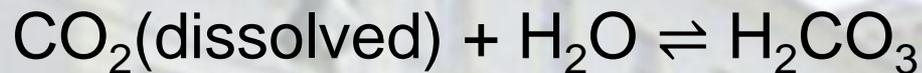
Solution



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Conversion to carbonic acid:



First ionization:



Second ionization:



These reactions determine the inorganic carbon to set of the ocean. The oceanic factor shows 10% increase in atmospheric CO_2 . The element storage in seas (in equilibrium) increases by about 1%, strongly depending on local conditions.



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- The largest reservoirs of carbon cycle in the oceans are the carbonate sediments. They are coming from the limestone of shells of microscopic organisms. After dying of this organisms, their hard crust sinks to the bottom of the ocean.
- **Ocean acidification** means the ongoing decline in the pH of the Earth's oceans. The reason of the phenomenon is the increased atmospheric CO₂ uptake coming from the atmosphere.
- Between 1751 and 1994 surface ocean pH is estimated to have decreased from approximately 8.179 to 8.104.



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4. Earth crust

- The crust is the largest and slowest reservoir of the system (except of the included fossil fuels).
- Carbon enters to the pool through the biosphere. (Deposits of organic carbon are the coal, gas, oil and sedimentary rocks.)
- The largest inorganic carbon reservoir is the product of the marine biosphere.
- Long term inorganic carbon cycle – sedimentary rock oxidizing. Very slow process!!
- The carbon accumulation in fuels is order of magnitude larger than that of the carbon residing in the air.



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Thank you for attention!



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