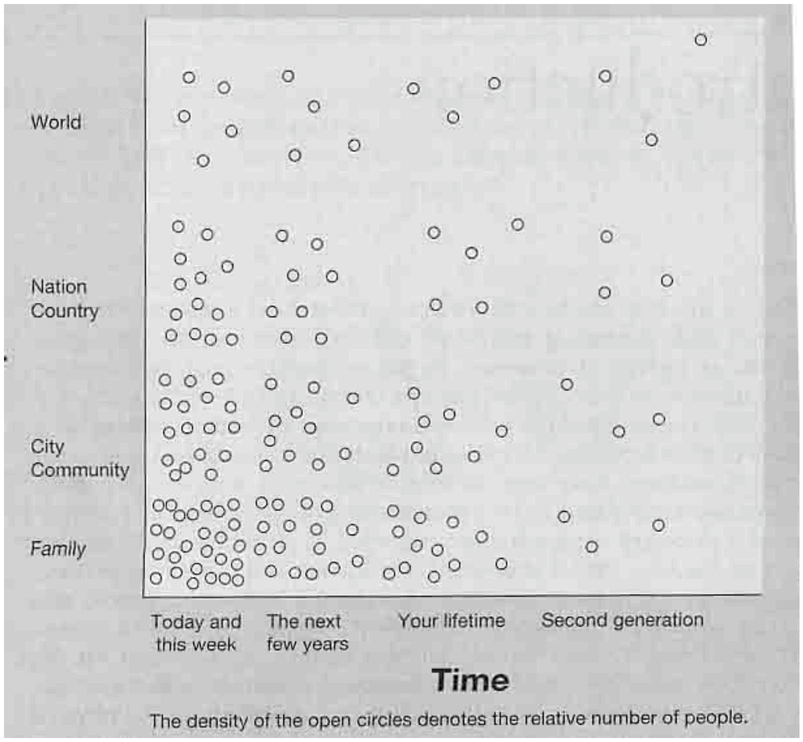
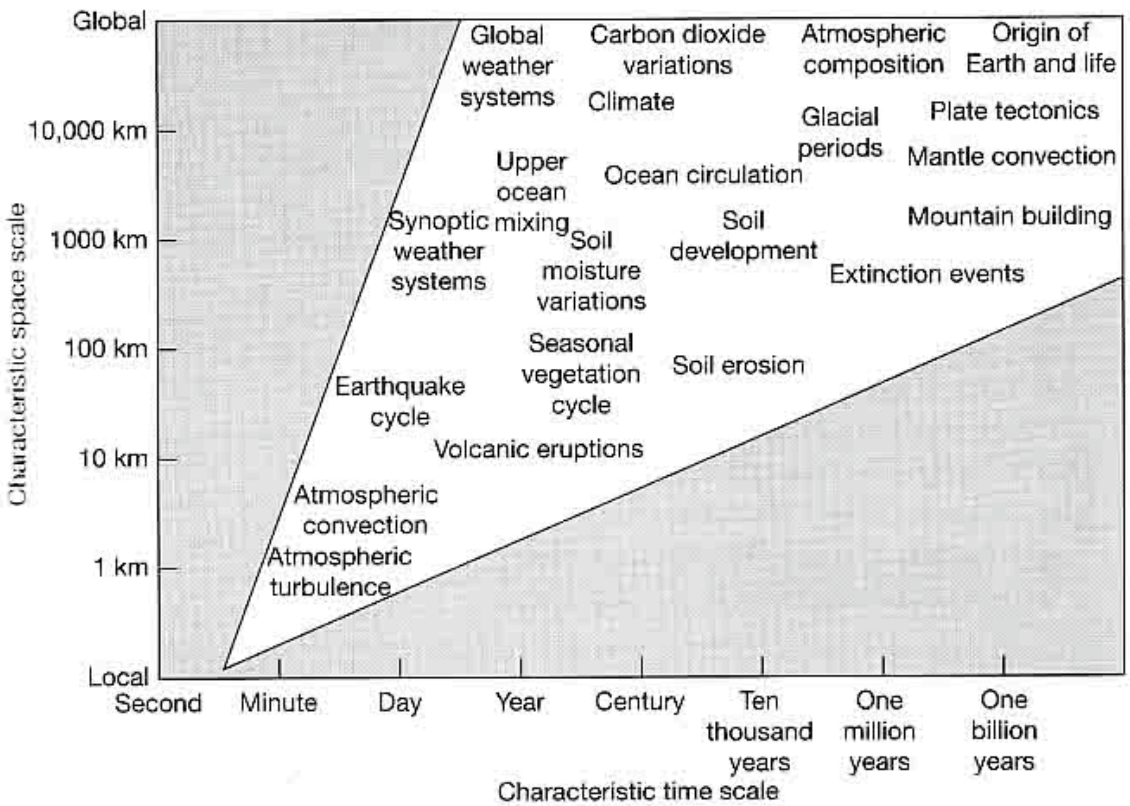

World
Nation
Country
City
Community
Family
Today and this week
The next few years
Your lifetime
Second generation
Time
The density of the open circles denotes the relative number of people.


Global
10,000 km
1000 km
100 km
10 km
1 km
Local
Characteristic space scale
Global weather systems
Carbon dioxide variations
Atmospheric composition
Origin of Earth and life
Climate
Glacial periods
Plate tectonics
Upper ocean mixing
Ocean circulation
Mantle convection
Synoptic weather systems
Soil moisture variations
Soil development
Mountain building
Extinction events
Seasonal vegetation cycle
Soil erosion
Earthquake cycle
Volcanic eruptions
Atmospheric convection
Atmospheric turbulence
Second
Minute
Day
Year
Century
Ten thousand years
One million years
One billion years
Characteristic time scale

Earth's building blocks: Atoms, gases, liquids, and solids (minerals, biota, rocks…)

Relative atomic mass: Defined by carbon (C) given atomic mass of 12.0000

Isotope: Defined as atoms of same number of protons but different number of neutrons.

$$^{\text{Mass}}_{\text{Protons}}\text{Element}_{\text{neutrons}}$$

Examples of Isotopes and their natural abundances (biased by where sample is from….)

$^{1}_{1}H_{0}$ Hydrogen. 99.9885%

$^{2}_{1}H_{1}$ Deuterium. 0.0115%

$^{3}_{1}H_{2}$ Tritium. Radioactive 1/2 life = 12.3 years

Relative Atom Mass (RAM) of naturally occurring hydrogen is 1.008

$^{16}_{8}O_{8}$ 99.757%

$^{17}_{8}O_{9}$ 0.038%

$^{18}_{8}O_{10}$ 0.205%

Relative Atom Mass (RAM) of naturally occurring oxygen is 15.9994

Relative Molecular Mass (RMM) is calculated by adding elements that make a compound.

Example: Water - H_20 1.008 + 1.008 + 16.000 = 18.016

Mole: Number of atoms in 12 grams of ^{12}C. This is Avogadro's number 6.023×10^{23} at/mol

Therefore, 1 mole of H has a mass of 1.008 grams.

Examples: 1 mole of water H_20 1.008 + 1.008 + 16.000 = 18.016 grams

Moles: This is a helpful concept for understanding relative number of atoms or unit formulae involved in a chemical reaction.

For example: let's react calcite with sulfuric acid (i.e., acid rain).

$$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + CO_2 + H_2O$$

For every mole of calcite and sulfuric acid, we produce one mole of anhydrite, one mole of carbon dioxide, and one mole of water.

Chemical reactions must conserve both mass and electric balance. The check of equalizing mass and electric charge on both the left and right hand sides is called the process of **balancing a chemical reaction**.

Equivalents: One equivalent is the weight of a substance that will react completely with an equivalent weight of another substance. Typically it is equal to or less than the molecular weight (RMM).

In the example above, the sulfuric acid has two replaceable hydrogen ions (protons).

If the reaction involves hydrochloric acid, then,

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$$
(1 Eq) (1Eq)
(.5 mole) (1 mole)

Equivalent weights are reacted. Two moles of HCl are required to react with one mole of calcite. For each mole of HCl reacted, we only need 50 gram-equivalent weight of calcite. A practical aspect of this understanding involves the measurement of alkalinity in natural waters.

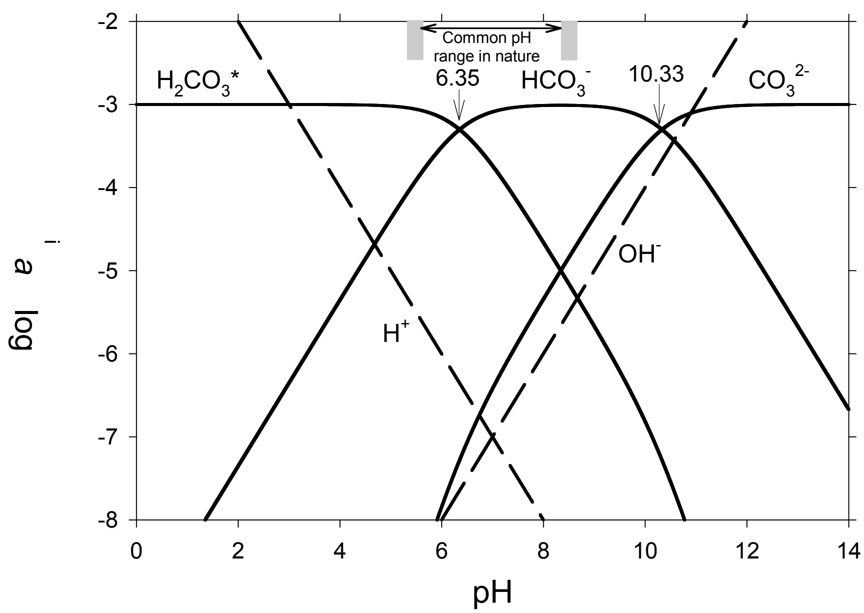
Total alkalinity is formally defined as the sum of all bases in solution that are titratable by a strong acid (i.e., their ability to accept protons). In practice, field measurement of alkalinity is made by a titration reaction using sulfuric acid and pH-sensitive color indicating compounds (phenolphthalein and bromo-creosol green methyl red). Since most water's ability to accept protons comes from carbonate anions, we often only consider carbonate alkalinity ($CA = HCO_3^- + 2CO_3^=$). Just remember that at high pH's (>10) hydroxyls become important proton acceptors.

Commercially available Hach® kits or Lamotte® kits report alkalinity as a concentration of $CaCO_3$ (i.e., mg/L $CaCO_3$) or the amount of $CaCO_3$ needed to neutralize acid. If the analysis reports 100 mg/L $CaCO_3$, then this is the same as 1 mmol/L $CaCO_3$ (recalling there are 100 mg/mmol in $CaCO_3$).

In most natural waters (<pH 10), the common carbonate species is bicarbonate. Carbonate alkalinity is sometimes simplified to be the concentration of bicarbonate (HCO_3^-), which is reported as equivalents HCO_3^- per liter. If the solution contains carbonic acid, then the amount of calcium carbonate needed to neutralize

$$CaCO_3 + H_2CO_3 \rightarrow Ca^{2+} + 2HCO_3^-$$

Note that one mole of calcite produces two moles of bicarbonate.



Other chemical species that contribute to Total Alkalinity include: borate, hydroxide, phosphate, silicate, nitrate, dissolved ammonia, the conjugate bases of some organic acids and sulfide.

Equivalents or milliequivalents (**meq.**) can also be used to describe the reaction of ions in solution.

1 meq. of Na^{1+} = 1.0 mmol of Na^{1+}
1 meq. of Ca^{2+} = 0.5 mmol of Ca^{2+}
1 meq. of Fe^{3+} = 0.33 mmol of Fe^{3+}

Concept is also applied to oxidation and reduction (i.e. redox) reactions

meq. of oxidizing agent = mmol / # electrons gained
meq. of reducing agent = mmol / # electrons lost

Normality: Number of gram-equivalents per liter of solution.

Let's assume that rainwater contains 0.00005 moles per liter H_2SO_4 (where 1 liter = 1000 cm^3).

Summer rainfall in north Georgia is 100 cm. If that amount is distributed over 1 square meter (10000 cm^2) of marble, then that amounts to 10^6 cm^3 or 10^3 liters.

Recall:

$$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + CO_2 + H_2O$$

If the square meter of marble is exposed to 10^6 cm^3 (1000 liters), then 0.00005 mol/l x 1000 liters = 0.05 moles of H_2SO_4 can react with $CaCO_3$.

Therefore, 0.05 moles of calcite are reacted.

Since there are 100 g/mol in $CaCO_3$, then 100 x 0.05 = 5 g of $CaCO_3$ per m^2 per summer are weathered away.

How many grams of $CaSO_4$, CO_2, and H_2O are produced?

$CaSO_4$	[40+32+(4*16)] = 136 g * 0.05 = 6.8 g
CO_2	12+16+16 = 44 g * 0.05 = 2.2 g
H_2O	1+1+16 = 18 g * 0.05 = 0.9 g

What is the volume change?

Measure density = 2.71 g/cm^3

$$5 \text{ g} / 2.71 \text{ g cm}^{-3} = 1.85 \text{ cm}^3$$

What is the height change?

$$1.85 \text{ cm}^3 / 10000 \text{ cm}^2 = 0.000185 \text{ cm} = 1.85 \times 10^{-4} \text{ cm} = 1.85 \times 10^{-6} \text{ m} = 1.85\ \mu\text{m}$$

How does this compare to a standard optical microscope thin-section thickness?

30 μm

How much is this over a 1 million year period?

1.85 meters

If the marble has been exposed since the start of the Mesozoic, how much is lost?

245 x 1.85 = 453 meters ~0.5 km

If a watershed is 100 km^2, then how much calcite is chemically weathered during that summer?

Why don't we see anhydrite forming in the N. Georgia mountains?

How does the amount of Ca^{2+} seen coming down the rivers compare to our estimate of chemical reaction?

Why is there a disparity?

Let's look at some other chemical reactions of interest.

$CO_2 + H_2O \leftrightarrow CH_2O + O_2$

How many moles are you? I weigh 90 kg.

$$1 \text{ mole } CH_2O = 30 \text{ grams} = 0.03 \text{ kg}$$

$$X \text{ moles} / 90 \text{ kg} = 1 \text{ mole} / 0.03 \text{ kg} = 3000 \text{ moles or } 3 \times 10^3 \text{ moles}$$

If I were metamorphosed into a diamond with 100% efficiency, then my mass would be….

$$X \text{ grams} / 3 \times 10^3 \text{ moles} = 12 \text{ grams} / \text{ mole C} = 3.6 \times 10^5 \text{ g or } 36 \text{ kg.}$$

How much is that relative to all the organic carbon in land plants and soils on Earth?

Land Plant carbon = 760×10^{15} g
Soil Carbon = 1500×10^{15} g

Therefore, we individually only represent 4.8×10^{-13} of the Earth's organic carbon.

If we consider the world population (6.4×10^9), then humans constitute 0.3% of world's organic carbon.