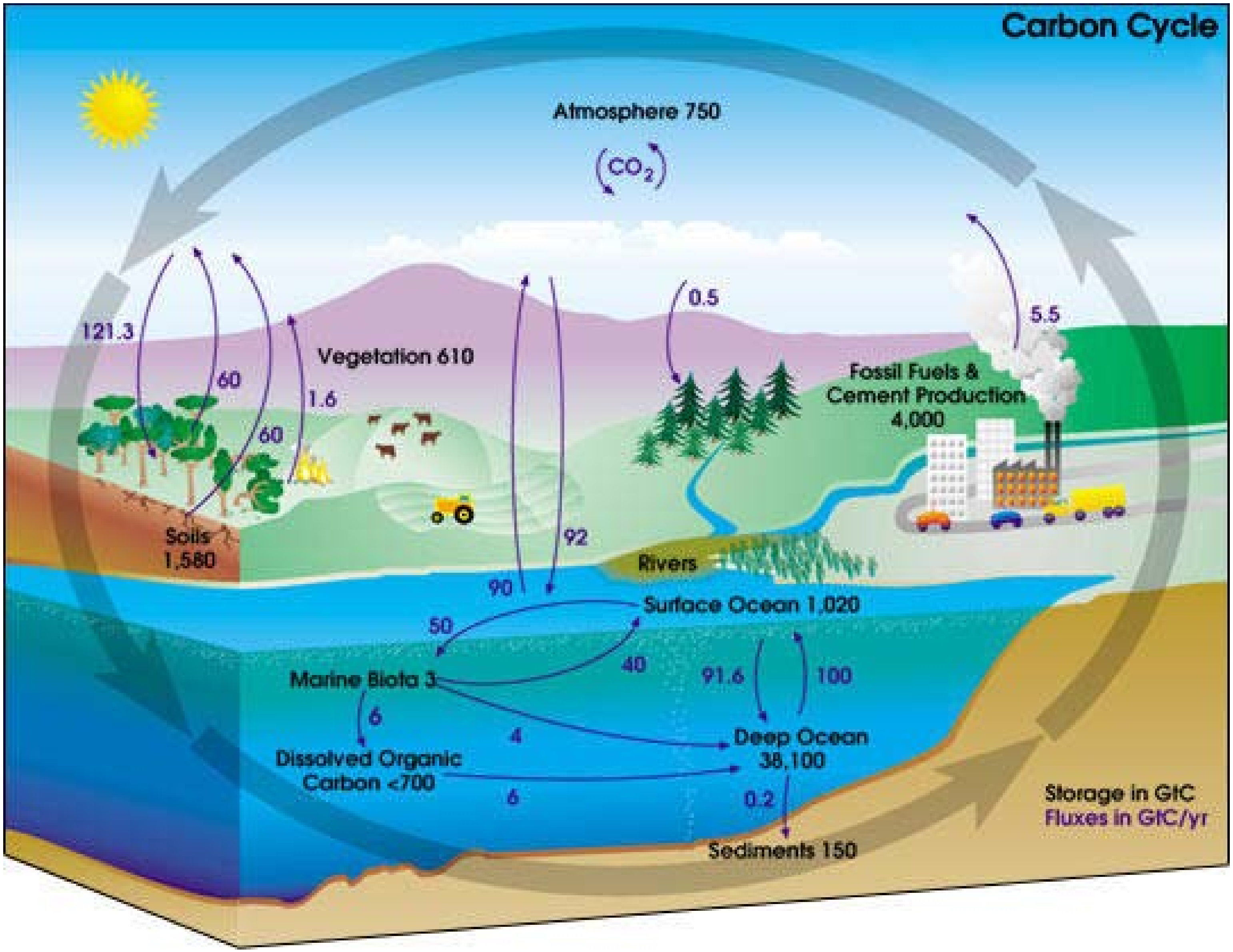
Carbon cycle



Scientists now think that the early atmosphere was nearly 100% CO_2. The majority of the CO_2 is "sequestered" as limestone, $CaCO_3$ formed by precipitation in the oceans (maybe catalyzed by living creatures). Given this fact, what is the mass of limestone on earth (approximately)?

Solution: The net equilibrium is

$$Ca^{2+} + H_2O + CO_2 = CaCO_3 + 2\ H^+$$

For this problem we see that the mole ratio is 1:1 for $CaCO_3 : CO_2$ and the molar mass of limestone is 100 amu and that of CO_2 is 44 amu. We can Calculate the mass of the atmosphere and then scale it by the ratio of the molar masses to obtain the mass of limestone.

What is the mass of limestone on earth?

How do we calculate the mass of the atmosphere?

$$P = \frac{F}{A} = \frac{mg}{A}$$

Therefore,

$$m = \frac{PA}{g}$$

1 atm is approximately 10^5 Pascals (N/m^2). The surface area of the earth is $A = 4\pi R^2$ so that

$$A = 4\pi(6.37\ 10^6\ m)^2 = 5.1\ x\ 10^{14}\ m^2$$

And g = 9.8 m/s^2. These values are in MKS units so the mass of the atmosphere is:

$$m = \frac{(10^5)(5.1\ x\ 10^{14})}{9.8} = 5.2\ x 10^{18}\ kg$$

What is the mass of limestone on earth?

We know the mass of the atmosphere today is:

$$m_{CO_2} = 5.2\, x10^{18}\ kg$$

and the ratio of the molar masses tells us that this mass of CO_2 would become

$$m_{CaCO_3} = \frac{100}{44} 5.2\, x10^{18}\ kg$$

So the mass of $CaCO_3$ today is 1.1×10^{19} kg from the capture of ancient CO_2 in the atmosphere.

Scientists now think that the early atmosphere was nearly 100% CO_2. The majority of the CO_2 is “sequestered” as limestone, $CaCO_3$ formed by precipitation in the oceans (maybe catalyzed by living creatures). Given this fact, what is the *volume* of limestone on earth (approximately)?

Density units for practical problems

Density is the mass per unit volume.

$$\rho = \frac{m}{V}$$

The units of density can be grams/cm^3.
Note that the value is the same in units of kg/L.

However, we can also use units of kg/m^3. The conversion factor is 1000. Think about water. One cubic meter of water has a mass of 1000 kg.

Using the density of 2500 kg/m^3, calculate the volume of limestone formed by capture of atmospheric CO_2.

Solution: The density equation can be solved for volume.

$$V = \frac{m}{\rho}$$

For $CaCO_3$ we have

$$V = \frac{1.13\ x\ 10^{19} kg}{2500\ kg/m^3}$$

which gives 4.52 x 10^{15} m^3. The surface area of the earth is 5.15 x 10^{14} m^2, so this corresponds to a layer of $CaCO_3$ 9 meters deep over the entire globe.