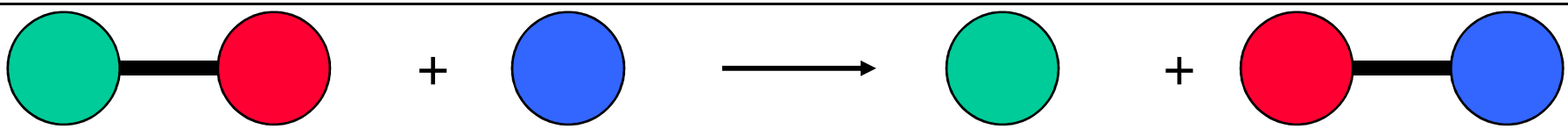
chemical reactions



Every process that is connected to the reorganization of chemical bonds is called a chemical reaction.

Chemical reactions are often named according to the predominant changes that are induced, e.g. oxidation, reduction, addition etc.

examples for chemical reactions

Common representation:

$$2H_2 + O_2 \longrightarrow 2H_2O$$
$$2Na + 2H_2O \longrightarrow 2NaOH + H_2$$
$$H_2O + CO_2 \longrightarrow H_2CO_3$$

Most chemical reactions are reversible and therefore lead to a chemical equilibrium (symbolized by double arrows):

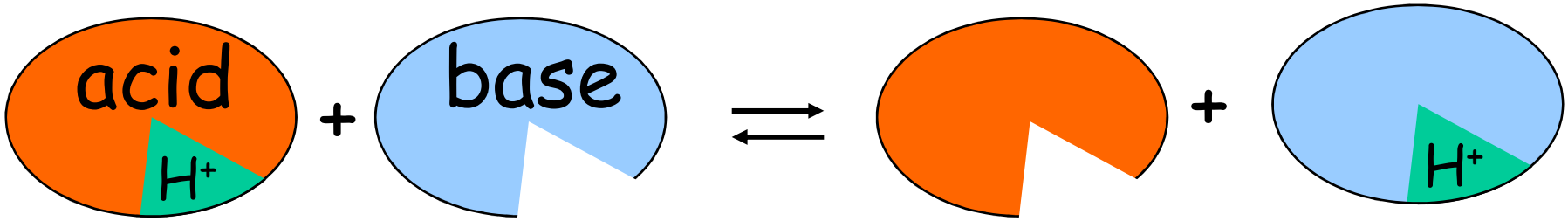
$$H_2O + CO_2 \rightleftharpoons H_2CO_3$$

important types of chemical reactions

Acid-base-reaction:	a reaction where a H^+-ion is exchanged between two partners
Oxidation:	one or several electrons are removed from an element
Reduction:	one or several electrons are added to an element
Redox-reaction:	oxidation of one element together with a reduction of another

Acid-base-reaction:

a reaction where a H^+-ion is exchanged between two partners



examples:

$$HCl + OH^- \rightleftharpoons Cl^- + H_2O$$

$$2\ CH_3\text{-}COOH + CO_3^{2-} \rightleftharpoons 2\ CH_3\text{-}COO^- + H_2CO_3$$

$$HCl + NH_3 \rightleftharpoons Cl^- + NH_4^+$$

Acid-base-reaction:

The acidity of an aqueous solution of an acid is measured by the pH-value:

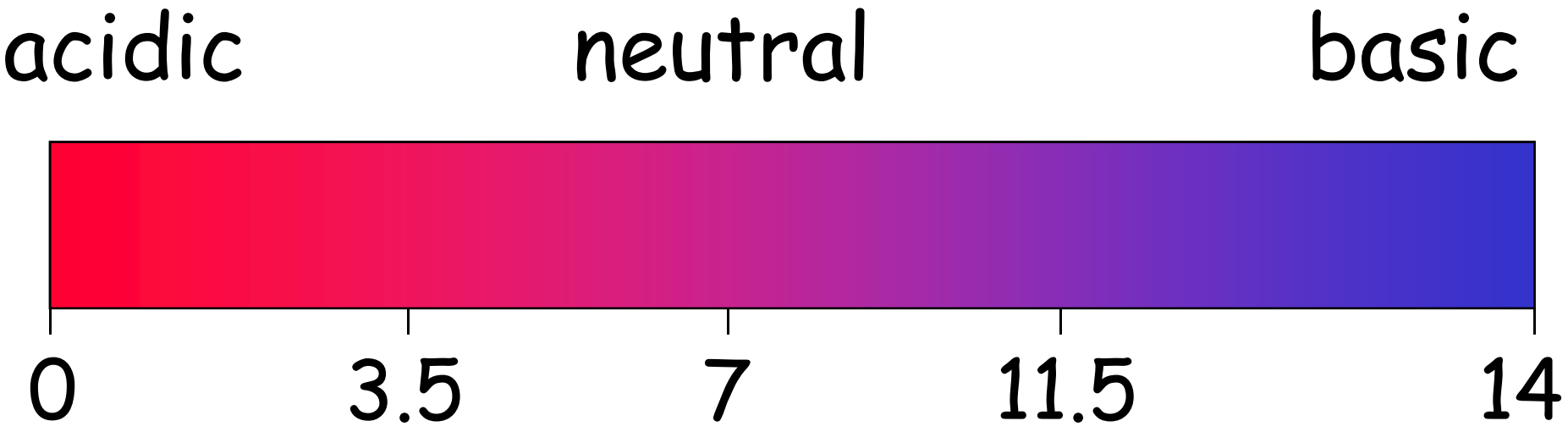
$$HX + H_2O \rightleftharpoons X^- + H_3O^+$$

$$pH = - \lg c(H_3O^+)$$

in words: the pH-value is the negative decadic logarithm of the concentration of H_3O^+-ions in water.

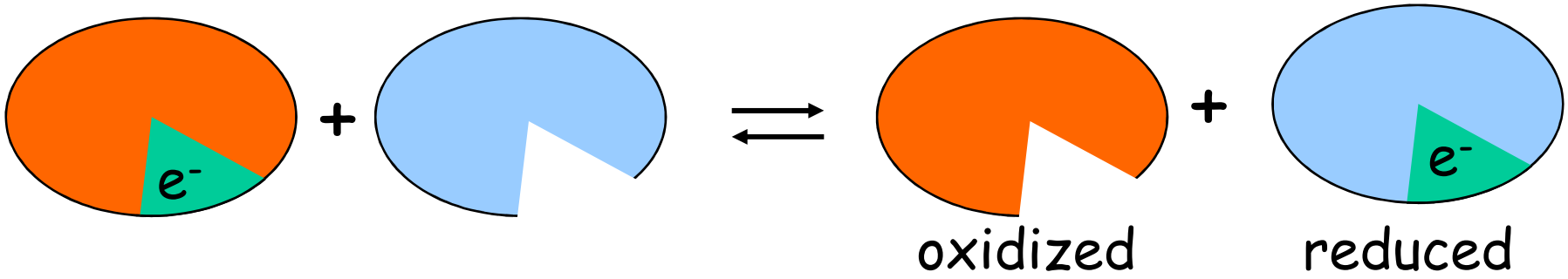
Acid-base-reaction:

The pH-value usually varies on a scale between 0 and 14, with pH = 7 being neutral:



Redox-reaction:

a reaction where an electron is exchanged between two partners



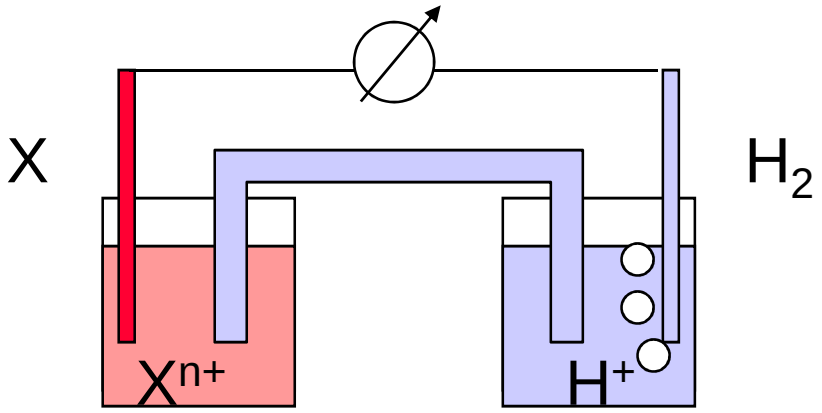
examples:

$$Zn + Cu^{2+} \rightleftharpoons Zn^{2+} + Cu$$

$$2Cu + O_2 \rightleftharpoons 2CuO$$

$$2H_2 + O_2 \rightleftharpoons 2H_2O$$

The tendency of elements to deliver an electron can be measured by their voltage against a hydrogen electrode:



high tendency

(all values in V against H_2)

Li	lithium	- 2.96
K	potassium	- 2.92
Ca	calcium	- 2.76
Na	sodium	- 2.71
Mg	magnesium	- 2.34
Al	aluminum	- 1.33
Mn	manganese	- 1.10
Zn	zinc	- 0.76
Cr	cromium	- 0.51
Fe	iron	- 0.44

low tendency

Cd	cadmium	- 0.40
Co	cobalt	- 0.28
Ni	nickel	- 0.23
Sn	tin	- 0.16
Pb	lead	- 0.12
H_2	hydrogen	0
Cu	copper	0.34
Ag	silver	0.79
Hg	mercury	0.85
Au	gold	1.36
Pt	platinum	1.60

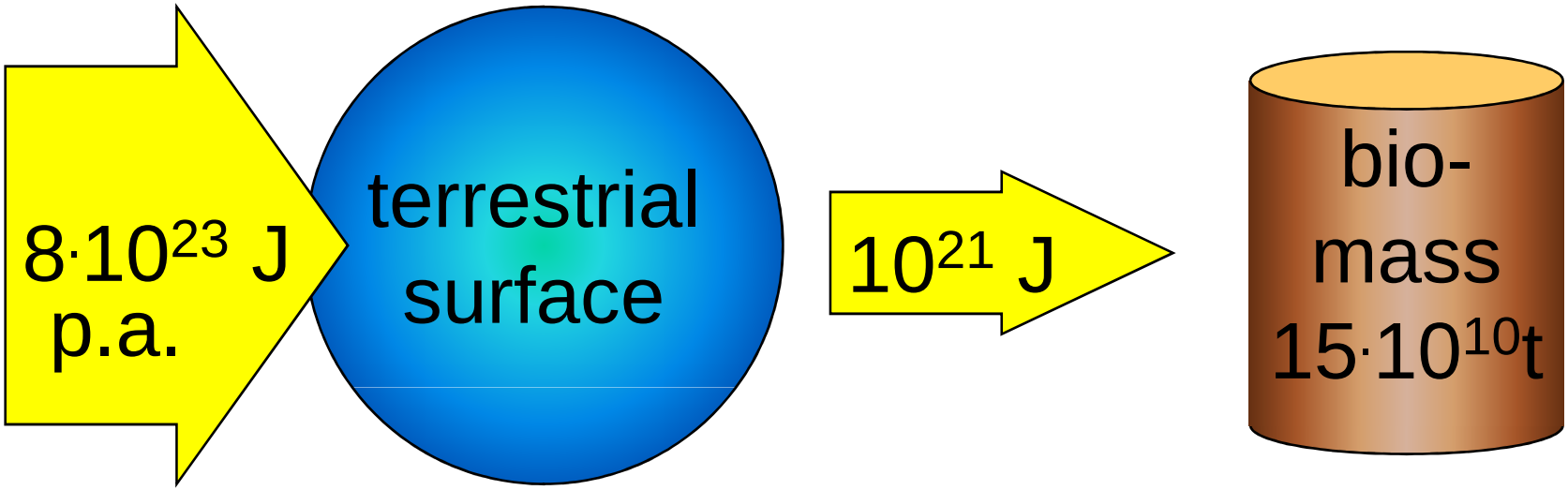
chemical reactions for energy storage

Chemical reactions can be used to store and to supply energy.

The amount of energy is determined by the enthalpy change ΔH (in kJ/mol)

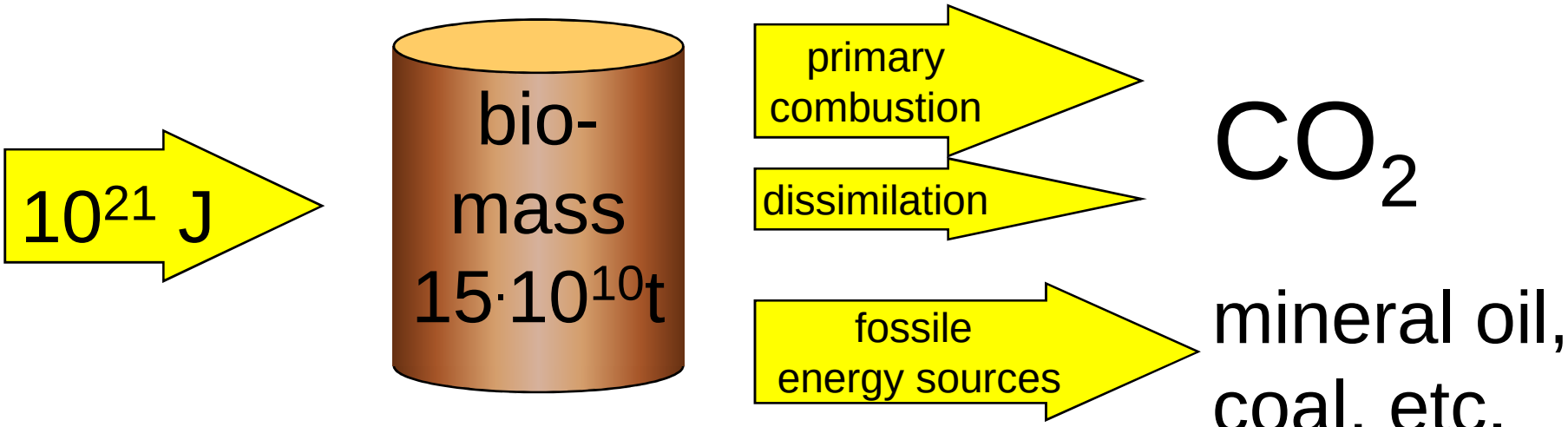
negative ΔH: energy is supplied
positive ΔH: energy is stored

energy storage: photosynthesis



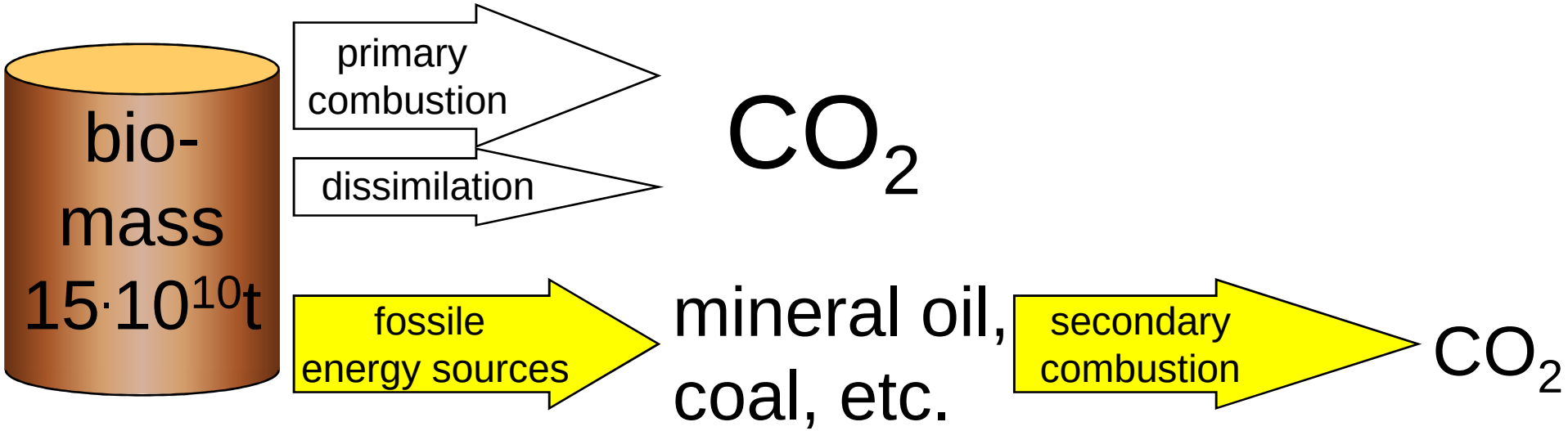
$$6\ CO_2 + 6\ H_2O \xrightarrow{h\nu} C_6H_{12}O_6 + 6\ O_2$$

consumption of chemical energy



$$C_6H_{12}O_6 + 6\ O_2 \longrightarrow 6\ CO_2 + 6\ H_2O$$

combustion of fossile energy sources



$$C_8H_{18} + 25/2\ O_2 \longrightarrow 8\ CO_2 + 9\ H_2O$$

$$C + O_2 \longrightarrow CO_2$$

other sources of chemical energy

$4\ C + S + 20\ KNO_3 \longrightarrow 4\ CO_2 + SO_2 + 20\ NO + 10\ K_2CO_3$

black powder 

$H_2NN(CH_3)_2 + 2\ N_2O_4 \longrightarrow 3\ N_2 + 2\ CO_2 + 4\ H_2O$

self-igniting rocket fuel

$4\ Al + 3\ MnO_2 \longrightarrow 2\ Al_2O_3 + 3\ Mn$

“manganese thermite”

$3\ Mg + KClO_3 \longrightarrow 3\ MgO + KCl$

old-fashioned photographic flash powder

$^{235}_{92}U + {}^{1}_{0}n \longrightarrow X + Y + 2\ {}^{1}_{0}n$

nuclear fission of uranium-235: $\Delta H = -190 \cdot 10^6$ kJ/Mole

mass-reduction connected to chemical reactions

$$\Delta E = \Delta m\, c^2$$

$$\Delta m = \Delta E / c^2$$

example: $2\ H^{\cdot} \rightarrow H_2$

$\Delta G = -406$ kJ/Mol

$\Delta H = -431$ kJ/Mol

$\Delta m = E / c^2 = -4{,}79 \cdot 10^{-9}$ g

(that is: a recombination of 400 t of atomar hydrogen would lead to a loss of 1 g of total mass).