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Lecture 8

ENERGETICS

How do microbes generate energy to live?

For example: we talked about methanogens and why they do not burn the methane they produce Why?

One of the foremost questions in the environment is what supports life processes? We said that life is the conversion of energy.

What is energy?

The ability to do work. What kind of work? Synthesis of molecules, movement, replication of DNA etc.

Why do we breathe oxygen?

chemical reactions are accompanied by changes in energy

free energy – available to do useful work

A+B ---> C+D

$\Delta G0'$ (if negative, work can be done, if positive, work needs to be done for a reaction to proceed)

(the apostrophe means that this is calculated under standard conditions – the concentration of all reactants is 1M, pH is 7 and T is 25 degC)

by convention, the free energy to form pure substances is 0

the change in free energy for a reaction is the sum of free energies of products minus the sum of the free energies of the reactants

(chemical balancing of the reactions)

a free energy does not tell us how fast the reaction proceeds – we need to break the initial bonds first – catalysts

Fig. 4.3

most living organisms use oxidation-reduction reactions to generate energy (so if we can track the electrons, we can understand how they generate energy)

reduced substance (more negative) donates electrons, more positive couple is the one accepting electrons

H_2 -> 2e- + 2H+ (hydrogen is oxidized)

half reaction (these electrons go somewhere) – they reduce something

oxidation, reduction, oxidized, reduced, electron donor, electron acceptor

oxidation state as a measure of electronegativity of a compound in a substance (pure substance is 0, oxygen is usually -2, hydrogen is + 1 unless next to an alkali metal, carbon can be various things, methane, CO_2, sulfur – from -2 to + 6, ion is equal to the charge, the sum iin a neutral molecule is 0, in an ion, equal to the charge of the ion, CH_4)

IN OXIDATION-REDUCTION REACTIONS – balance of the electrons, charges and the total number of atoms on the left and right side (of all species)

REDUCTION POTENTIAL

E0' of a substance: the measure for the tendency of a substance to accept electrons

measured in reference to H_2

oxidized + ne- --> reduced

n is the number of electrons transferred

$DG^{0\prime} = -nF\Delta E_0'$ (difference between the electron accepting and the electron donating couple)

equilibrium constant: aA + bB <=> cC +dD

$k= [C]^c[D]^d/[A]^a[B]^b$ IN EQUILIBRIUM, Q when it's not in equilibrium

$DG= DG^0 + RT\ln Q$ (this describes how much energy can be gained when the system is not in equilibrium)

½ O_2 + 2H+ + 2e- ----> H_2O

2H+ + 2e- ---> H_2

the oxidized form is always on the left

$\Delta G0$ – standard free energy at 1atm pressure and 1M concentrations

$\Delta G0'$ – standard conditions and pH 7 = $\Delta G0 + m\ \Delta G'f(H+)$

WHEN SUBSTRATES ARE SOLUBLE

the changes in the concentration usually don't change the energy yield by much, except when H2 is a player

m is the net number of protons in the reaction and the last part is the std. energy of the formation of protons at pH 7 at 25 degC

more notes from Aquatic Chemistry

example:

methane production from hydrogen and CO2

$H_2 \text{ -> } 2H^+ + 2e^- /4\ (+0.42)$

$CO_2 + 8H^+ \text{ ---> } CH_4 + 2H_2O + 8e\text{-}\ (-0.24)$

CO2 + 4H2 -> CH4 + 2H20

activity of gases – how to put that into the equation

$DG = DG0 + RTln\ P(CH4)/p(CO2)\ p(H2)^4$

$= -8F\Delta E_0' + RTln$

(0.18)

look at the electron tower and tell me why we breathe oxygen

could something breathe iron?

ATP-ase needs to pump three/four protons out of the cell to generate one ATP

phospholipid bilayer: proteins can span it – access to the inside and the outside

Gram-positive and Gram-negative microbes: protons extruded to the outside or to the periplasm

the extrusion of protons is usually linked to the passage of electrons through an electron transport chain because there is no free leakage (they all can be spatially separated and transported through specific transporters)

there are electron carriers and proton carriers

NADH hydrogenase can take hydrogen atoms and pass them to flavoproteins, quinones – accept H and donate electrons (two electron carriers)

flavoproteins: accept H atoms, extrude H+ and pass on the electrons

electron carriers: cytochromes, iron-sulfur proteins

organic molecules: electrons and protons are transferred to carrying molecules, they pass on the electrons down the electron tower (NAD+/NADH) to FAD to iron-sulfur (two protons out), two protons taken up from the cytoplasm and coenzyme Q (quinone), q one electron at a time to cytochrome bc1, this is present in most respiring organisms

bc1 transfers electrons to cytochrome c and protons are translocated (OH- accumulates in the cytoplasm)

proteins take up electrons and bind protons (and discharge protons) – that’s how charge is moved

Q-cycle : for every two molecules of QH. one is reduced to QH2 and the other is oxidized to Q.