CE421/521

Energy and Metabolism

Bioenergetics

- Thermodynamic considerations
  - Thermodynamic relationships govern whether a reaction can occur
  - Simply because a relationship is thermodynamically possible still may not occur
    - Could be activation energy required
    - Biochemical reactions require specific enzymes
    - Genetic potential required for production of specific enzymes

Gibbs Free Energy

$$\Delta G = \Delta H - T\Delta S$$

Where ΔG is the change in Gibbs free energy
ΔH is the change in enthalpy and
ΔS is the change in entropy
for a closed system at constant pressure

For a reaction to proceed, the entropy of the system must increase, i.e., ΔG must be negative

Gibbs Free Energy (cont'd)

Gibbs Free Energy (cont’d)

Gibbs Free Energy (cont'd)

Gibbs Free Energy (cont’d)

- $\Delta G°$ for elements is zero
- Just because $\Delta G°$ is negative does not necessarily mean the reaction will proceed
- Relationship of $\Delta G°$ is valid for equilibrium conditions (says nothing about whether reaction will proceed)
- Thermodynamic equilibrium (nothing to say about rate of reaction – kinetics)

Oxidation Reduction

- Another measure of the energy contained in a compound is its oxidation state
  - Oxidation is the loss of electrons (often associated with dehydrogenation)
  - Reduction is the gain of electrons (often associated with hydrogenation)
- The carbon in CH_4 is completely reduced and has an oxidation state of -4
- The carbon in CO_2 is completely oxidized

Oxidation reduction reactions

- In biochemical reactions there are electron d__________ and electron a_____________
- In general the electron donor is the energy source
- The electron acceptor is the last step in the electron transport system (ETS) the terminal electron acceptor

ThOD, COD, and BOD

Microbial Metabolism

- **Enzymes**
  - p_______ – specific for a particular m_________________ (substrate)
  - c________________ of biochemical reactions, but do not get consumed in the reaction
  - c_____________________ applications exist:

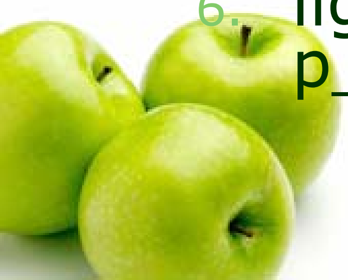
Enzymes Cont'd

- some non-p________________ molecules may be involved in enzyme catalyzed reactions:
  - co-factors or co-enzymes (e.g., nicotinamide adenine dinucleotide, NAD, NADH, also FAD, FADH)
  - may also act as e_____________ carriers

Enzymes

- Six categories of enzymes:

1. oxidoreductases: involved in o_______________ reduction reactions
2. transferases: transfer of constituents from one c____________________ to another
3. hydrolases: responsible for h______________ of carbohydrates, proteins, and lipids
4. lyases: catalyze the a_______________ or removal of constituents
5. isomerases: i_______________ formation
6. ligases: join m__________________, p_______________ formation



Kinetics

- **<u>Enzyme Kinetics</u>** enzymes are "catalysts" in biodegradation and metabolism

- $S + E \rightarrow ES \rightarrow P + E$
  - S = substrate
  - E = enzyme
  - ES = enzyme substrate complex

Michaelis - Menton

Michaelis - Menton

Michaelis-Menton vs Monod

Lineaweaver-Burke Example

Calculate v_{max} and K_m for the following data:

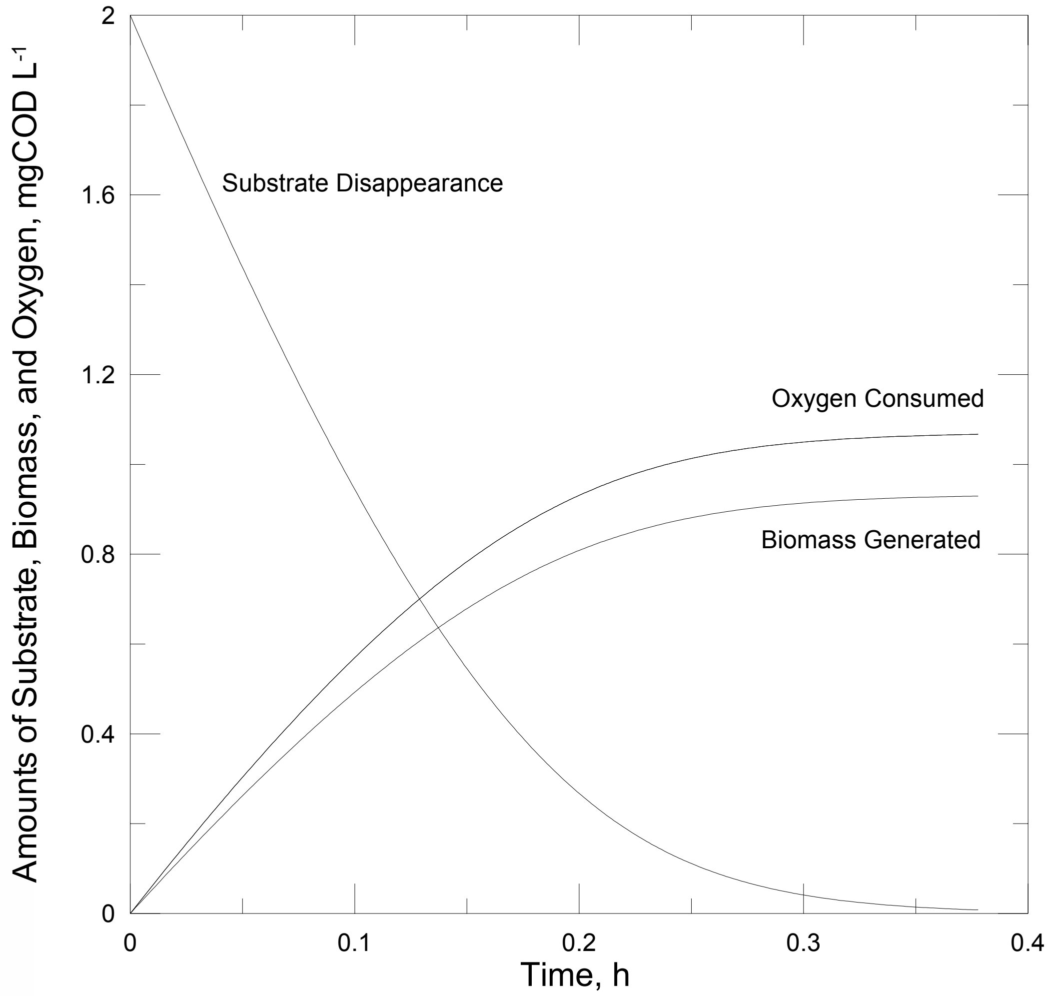
V, mol/L min	S, mol/L
0.00064	0.01
0.00058	0.008
0.000479	0.006
0.00038	0.004
0.000219	0.002

Lineaweaver-Burke Example

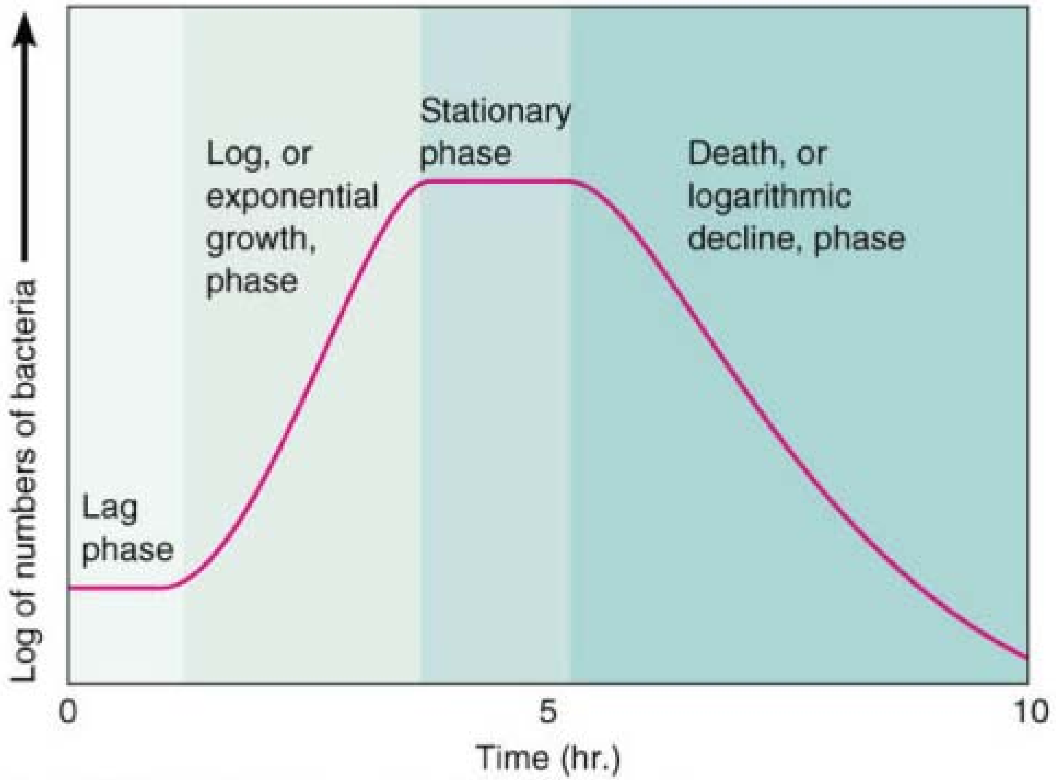
Microbial Growth Kinetics

- Procaryotic cells divide by b__________ fission: simple c___________ of DNA and cell division
- growth rate = increase in n____________ of microorganisms or increase in microbial m____
- time required for microbial population to d____________ = generation time (doubling time) during unlimited growth conditions
- b_______________ versus continuous culture
- growth curve:

Growth Curve



Growth Curve (log scale)



- stationary phase, g__________ = decay
- death phase – how to distinguish bacterial d______________ versus bacterial d___________?

Continuous Culture

- m__________ b________________ on substrate: