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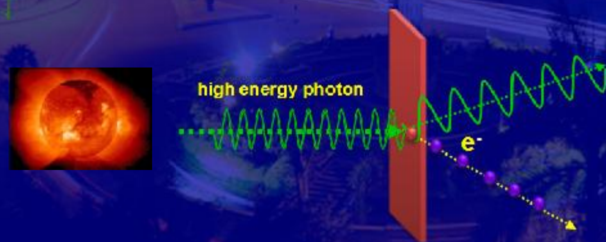
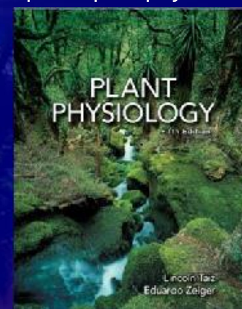
LECTURE 1: INTROPDUCTION & ENERGY

http://5e.plantphys.net/





An important part of understanding life is understanding how energy is stored and moved from molecule to molecule

COMPETENCY

Students, after mastering the materials of Plant Physiology course, should be able to:

1. Explain what plant physiology is
2. To understand and uncover the law of life activity of plant
3. To protect and utilize plant in the agricultural and industrial practice according to the law
4. Access pertinent literature of plant physiology
5. Identify some career options for the plant physiologist

LECTURE OUTLINE

1. INTRODUCTION

1. Definition
2. History of Plant Physiology
3. How Plants Work
4. Syllabus
5. References

2. ENERGY

1. Definition
2. Energy Of Organisms
3. Law of Conservation of Energy
4. State and Form of Energy
5. Electron Energy
6. Free Energy

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STRUCTURED TASK

1. My Dictionary

Buy a writing book (150 pages, hard cover), and write every English word that you do not understand in my lectures

4. Paper

- *Write a paper about Plant Physiology (you can find materials from internet)*
- *Max. 3 pages (single space)*
- *Format*
  - *Title*
  - *Name*
  - *Abstract*
  - *Introduction*
  - *Subject*
  - *Conclusion*
  - *References*

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EXAMPLE

THE RATE OF PHOTOSTYNHESIS OF SOYBEAN

Romeo

Abstract

1. Introduction
   General aspect (ï 2 paragraphs)
   - what is it (General description; 3-5 sentences)
   - what is its importance (3-5 sentences)
2. The Rate of Photosynthesis of Soybean
   - The description of Photosynthesis (3-5 paragraphs):Function and location in plants
   - The rate of soybean photosynthesis
   - Factors influencing the rate of soybean photosynthesis
3. Conclusion
4. References

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1. INTRODUCTION

What is Plant Physiology?

1.1 Definition

a) Plant physiology is the study of
   - plant processes-how plants function as they interact with their physical (abiotic) and living (biotic) environment (Taiz and Zeiger, 2010).

b) Plant physiology is the study of
   - the functions and processes occurring in plants
   - the vital processes occurring in plants
   - how plants work (Saupe) http://employees.csbsju.edu/ssaupe/biol327/Lecture/intro-lec.htm)

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c) Plant physiology is a study of the plant way of life, which include various aspects of the plant lifestyle and survival including:

- metabolism,
- water relations,
- mineral nutrition,
- development,
- movement,
- irritability (response to the environment),
- organization,
- growth, and
- transport processes

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INTRODUCTION

What is Plant Physiology about ?

d) Plant physiology is about

- how plants use the energy of sun to assimilate carbon,
- how they convert that carbon to stuff of which they are made,
- how plants obtain and distribute nutrients and water,
- how they grow and develop,
- how they respond to their environment,
- how they react to stress,
- how they reproduce

In short, plant physiology is about **HOW PLANTS WORK**

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1.2 History of Plant Physiology

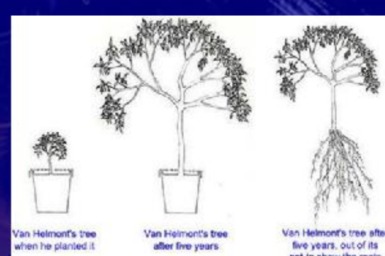
1. Sir Francis Bacon (1561 –1626), an English philosopher, published one of the first plant physiology experiments in 1627 in the book, *Sylva Sylvarum.*

Bacon grew several terrestrial plants, including a rose, in water and concluded that soil was only needed to keep the plant upright

2. Jan van Helmont

began the research of the process in the mid-1600s when he carefully measured the mass of the soil used by a plant and the mass of the plant as it grew.

After noticing that the soil mass changed very little, he hypothesized that the mass of the growing plant must come from the water, the only substance he added to the potted plant. .



3. **John Woodward**

(1 May 1665 – 25 April 1728), an English naturalist, antiquarian and geologist, published experiments in 1699 on growth of spearmint (***Mentha spicata***) in different sources of water.

He found that plants grew much better in water with soil added than in distilled water.

4. **Stephen Hales, FRS** (17 September 1677 – 4 January 1761), an English physiologist, chemist and inventor

He is considered the Father of Plant Physiology for the many experiments in the 1727.

Hales studied the role of air and water in the maintenance of both plant and animal life.

5. Joseph Priestley→plants produce O_2
a chemist and minister, discovered that when he isolated a volume of air under an inverted jar, and burned a candle in it, the candle would burn out very quickly, much before it ran out of wax. He further discovered that a mouse could similarly "injure" air. He then showed that the air that had been "injured" by the candle and the mouse could be restored by a plant.

6. Jan Ingenhousz →O_2 produced by plants +light
a court physician to the Austrian Empress, repeated Priestley's experiments in 1778, . He discovered that it was the influence of sun and light on the plant that could cause it to rescue a mouse in a matter of hours.

7. Jean Senebier →CO_2 taken up by plants
a French pastor, showed in 1796, that CO_2 was the "fixed" or "injured" air and that it was taken up by plants in photosynthesis.

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8. **Nicolas-Théodore de Saussure →CO_2 +H_2O**
soon afterwards, showed that the increase in mass of the plant as it grows could not be due only to uptake of CO_2, but also to the incorporation of water. Thus the basic reaction by which photosynthesis is used to produce food (such as glucose) was outlined.

Modern scientists built on the foundation of knowledge from those scientists centuries ago and were able to discover many things

9. **Cornelius Van Niel** → Chemistry of photosynthesis
made key discoveries explaining the chemistry of photosynthesis. By studying purple sulfur bacteria and green bacteria, he was the first scientist to demonstrate that photosynthesis is a light-dependent redox reaction, in which hydrogen reduces carbon dioxide.

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10. Robert Hill →O_2 (photosynthesis)← H_2O

He in 1937 and 1939 performed further experiments to prove that the oxygen developed during the photosynthesis of green plants came from water

He showed that isolated chloroplasts give off oxygen in the presence of unnatural reducing agents like iron oxalate, ferricyanide or benzoquinone after exposure to light.

The Hill reaction is as follows:

$$2\ H_2O + 2\ A + (\text{light, chloroplasts}) \rightarrow 2\ AH_2 + O_2$$

where A is the electron acceptor. Therefore, in light the electron acceptor is reduced and oxygen is evolved.

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11. Samuel Ruben and Martin Camen →O_2 (phot)← H_2O
    They used radioactive isotopes to determine that the oxygen liberated in photosynthesis came from the water.
11. Melvin Calvin and his partner Benson were able to puzzle out each stage in the dark or light-independent phase of photosynthesis, known as the Calvin Cycle → Calvin –Benson Cycle
12. Rudolph A. Marcus, a Nobel Prize winning scientist, was able to discover the function and significance of the electron transport chain.

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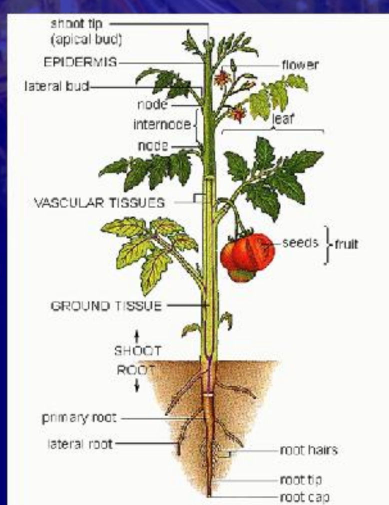
1.3 How Plants Work

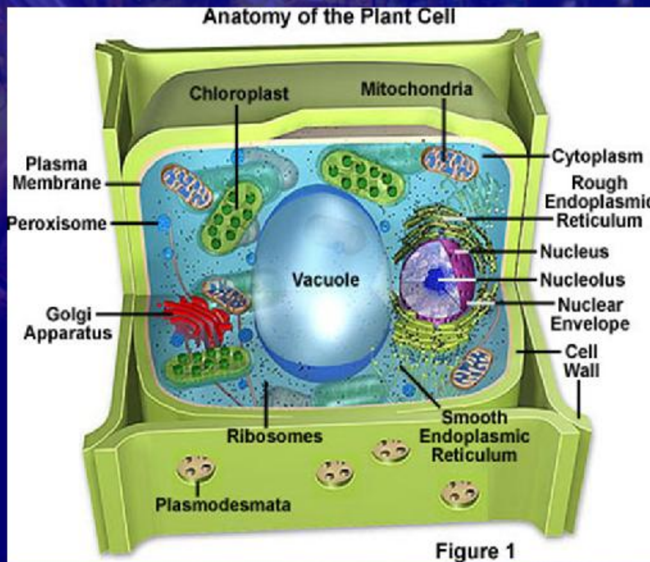
- Plant Level
  - Shoot
    - Leaves
    - Stem
    - Reproductive Organ
  - Root
- Cellular Level
  1. Cell wall
  2. Cell membrane
  3. Cytoplasm
  4. Vacuole
  5. Mitochondrion
  6. Christae
  7. Nucleus
  8. Nuclear membrane
  9. Nucleolus
  10. Centrosome
  11. Ribosome
  12. Chloroplast
  13. Chlorophyll
  14. Stroma
  15. Thylakoid disk
  16. Granum
  17. Amyloplast
  18. Golgi body
  19. Peroxisomes
  20. Microfilaments
  21. Microtubules
  22. Plasmodesmata
  23. Rough endoplasmic reticulum
  24. Smooth endoplasmic reticulum

Plant Level



- The Shoot System
  - Above ground (usually)
  - Elevates the plant above the soil
  - Many functions including:
    - photosynthesis
    - reproduction & dispersal
    - food and water conduction
- The Root System
  - Underground (usually)
  - Anchor the plant in the soil
  - Absorb water and nutrients
  - Conduct water and nutrients
  - Food Storage

Cellular Level



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1. **Cell wall** - a thick, rigid membrane that surrounds a plant cell. This layer of cellulose fiber gives the cell most of its support and structure. The cell wall also bonds with other cell walls to form the structure of the plant.
2. **Cell membrane** - the thin layer of protein and fat that surrounds the cell, but is inside the cell wall. The cell membrane is semipermeable, allowing some substances to pass into the cell and blocking others.
3. **Cytoplasm** - the jellylike material outside the cell nucleus in which the organelles are located.
4. **Vacuole** - a large, membrane-bound space within a plant cell that is filled with fluid. Most plant cells have a single vacuole that takes up much of the cell. It helps maintain the shape of the cell.
5. **Mitochondrion** - spherical to rod-shaped organelles with a double membrane. The inner membrane is infolded many times, forming a series of projections (called cristae). The mitochondrion converts the energy stored in glucose into ATP (adenosine triphosphate) for the cell.

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6. Christae - (singular crista) the multiply-folded inner membrane of a cell's mitochondrion that are finger-like projections. The walls of the cristae are the site of the cell's energy production (it is where ATP is generated).
7. Nucleus - spherical body containing many organelles, including the nucleolus. The nucleus controls many of the functions of the cell (by controlling protein synthesis) and contains DNA (in chromosomes). The nucleus is surrounded by the nuclear membrane
8. Nuclear membrane - the membrane that surrounds the nucleus.
9. Nucleolus - an organelle within the nucleus - it is where ribosomal RNA is produced.
10. Centrosome - (also called the "microtubule organizing center") a small body located near the nucleus - it has a dense center and radiating tubules. The centrosomes is where microtubules are made. During cell division (mitosis), the centrosome divides and the two parts move to opposite sides of the dividing cell. Unlike the centrosomes in animal cells, plant cell centrosomes do not have centrioles.

11. Ribosome - small organelles composed of RNA-rich cytoplasmic granules , approximately 60 percent RNA and 40 percent protein , that are sites of protein synthesis. In eukaryotes, ribosomes are made of four strands of RNA. In prokaryotes, they consist of three strands of RNA.
12. Chloroplast - an elongated or disc-shaped organelle containing chlorophyll. Photosynthesis (in which energy from sunlight is converted into chemical energy - food) takes place in the chloroplasts.
13. Chlorophyll - chlorophyll is a molecule that can use light energy from sunlight to turn water and carbon dioxide gas into sugar and oxygen (this process is called photosynthesis). Chlorophyll is magnesium based and is usually green.
14. Stroma - part of the chloroplasts in plant cells, located within the inner membrane of chloroplasts, between the grana.
15. Thylakoid disk - thylakoid disks are disk-shaped membrane structures in chloroplasts that contain chlorophyll. Chloroplasts are made up of stacks of thylakoid disks; a stack of thylakoid disks is called a granum. Photosynthesis (the production of ATP molecules from sunlight) takes place on thylakoid disks.

16. Granum - (plural grana) A stack of thylakoid disks within the chloroplast is called a granum.
17. Amyloplast - an organelle in some plant cells that stores starch. Amyloplasts are found in starchy plants like tubers and fruits.
18. Golgi body - (also called the golgi apparatus or golgi complex) a flattened, layered, sac-like organelle that looks like a stack of pancakes and is located near the nucleus. The golgi body packages proteins and carbohydrates into membrane-bound vesicles for "export" from the cell.
19. Peroxisomes - Microbodies are a diverse group of organelles that are found in the cytoplasm, roughly spherical and bound by a single membrane. There are several types of microbodies but peroxisomes are the most common. These are involved in metabolic processes including biosynthesis of plant hormones
20. Microfilaments - Microfilaments are solid rods made of globular proteins called actin. These filaments are primarily structural in function and are an important component of the cytoskeleton.
21. Microtubules - These straight, hollow cylinders are found throughout the cytoplasm of all eukaryotic cells (prokaryotes don't have them) and carry out a variety of functions, ranging from transport to structural support.

22. Plasmodesmata - Plasmodesmata are small tubes that connect plant cells to each other, providing living bridges between cells.
23. Rough endoplasmic reticulum - (rough ER) a vast system of interconnected, membranous, infolded and convoluted sacks that are located in the cell's cytoplasm (the ER is continuous with the outer nuclear membrane). Rough ER is covered with ribosomes that give it a rough appearance. Rough ER transport materials through the cell and produces proteins in sacks called cisternae (which are sent to the Golgi body, or inserted into the cell membrane).
24. Smooth endoplasmic reticulum - (smooth ER) a vast system of interconnected, membranous, infolded and convoluted tubes that are located in the cell's cytoplasm (the ER is continuous with the outer nuclear membrane). The space within the ER is called the ER lumen. Smooth ER transport materials through the cell. It contains enzymes and produces and digests lipids (fats) and membrane proteins; smooth ER buds off from rough ER, moving the newly-made proteins and lipids to the Golgi body and membranes

1.4 SYLLABUS

LECTURE TOPICS	CONTENTS
1. ENERGY	Introduction Energy
2. PHOTOSYNTESIS I	Light Reaction: Synthesis of NADPH
3. PHOTOSYNTESIS II	Light Reaction: Synthesis of ATP
4. PHOTOSYNTESIS III	Dark Reaction: C3 Plants
5. PHOTOSYNTESIS IV	Dark Reaction: C4 & CAM Plants
6. RESPIRATION	Glycolysis, TCA Cycle & Terminal Oxidation
7. SUGAR TRANSPORT	Phloem and Xylem Transport
MID SMESTER EXAM	Multiple Choice in English

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2. ENERGY

What is the importance of studying Energy in plant physiology?

- As plant physiology is about **HOW PLANTS WORK** or the **PLANT WAY OF LIFE** then sufficient understanding of energy is important in the study of plant physiology as

  Energy is the ability to do work

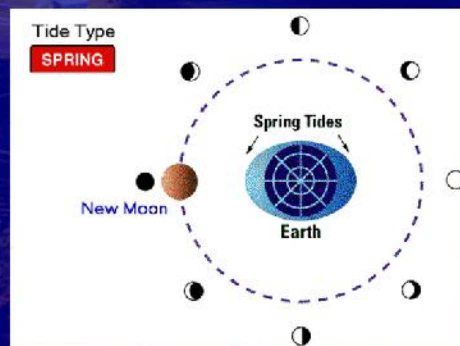
2.1 Definition

Energy is the ability to do work

- Living organisms need energy for growth and movement.
- Energy is the basic requirement of plant to function
- Energy sustains the work of biosynthesis of cellular and extracellular components, the transport of ions and organic chemicals etc.
- Sunlight is the ultimate source of energy for life.

Tides

- Primarily caused by the pull of the Moon on Earth
  - Not exactly 24 hours apart
  - Causes two tidal bulges



- Sun also causes tides
  - Can work with or against the Moon's force

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2.2 Energy of Organisms

- Organisms are divided into two groups based on the principal carbon source (Staniewr *et al*, 1977).
  - **Autotrophic:** Organisms use inorganic carbon (plants)
  - **Heterotrophic:** Organisms use organic carbon (animals)
- Another division of organisms is based on energy sources
  - **Phototrophic** (or photosynthetic) Organisms use the radiant (solar) energy
  - **Chemotropic** Organisms use the energy released during chemical oxidations

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- Combining these two basic criteria leads to the recognition of four major nutritional categories :

1. **Photoautotrophs**, utilizing light as an energy source and $C0_2$ as the principal source of carbon (e.g. higher plants, algae, cyanobacteria and the purple and green sulphur bacteria).
2. **Photoheterotrophs**, dependent on light as a source of energy and deriving much of their carbon from organic compounds. This category is represented by a specialized group of photosynthetic bacteria known as non-sulphur purple bacteria.

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3. Chemoautotrophs, deriving energy from the oxidation of inorganic compounds and using $C0_2$ as the principal carbon source. This category comprises several groups of specialized bacteria, including the nitrifying bacteria and thiobacilli.
4. Chemoheterotrophs, utilizing organic compounds as both energy and carbon sources (e.g. animals, protozoa, fungi and most bacteria).

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2.3 Law of Conservation of Energy

1. Energy can neither be created nor destroyed
2. Energy is always changing from one kind to another.
3. The total energy of an object never changes. The amount of energy in the Universe is constant!!

- Potential energy + Kinetic energy = Total energy, Total energy – Kinetic energy = Potential energy and Total energy - Potential energy = Kinetic energy

Conservation of Energy is different from Energy Conservation, the latter being about using energy wisely

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2.4 State and Form of Energy

- **State of Energy**
  1. Kinetic Energy
  2. Potential Energy
- **Form of Energy**
  1. Chemical Energy
  2. Mass Energy
  3. Radiant Energy
  4. Electrical Energy
  5. Nuclear Energy
  6. Thermal Energy
  7. Sound Energy
  8. Mechanical Energy
  9. Magnetic Energy

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State of Energy

- **Kinetic Energy**
  - Kinetic energy exists whenever an object which has mass is in motion with some velocity. Everything you see moving about has kinetic energy. The kinetic energy of an object in this case is given by the relation:

$$KE = (1/2)mv^2$$

m = mass of the object

V = velocity of the object

  - The greater the mass or velocity of a moving object, the more kinetic energy it has.

Kinetic Energy

- The energy of motion.
- The faster the object moves – the more kinetic energy.
- Kinetic energy depends on both mass and velocity.

  KE = ½(<u>mass x velocity^2)</u>
- Kg m^2/s^2 =Newton*meter= Joules

The greater the mass or velocity of a moving object, the more kinetic energy it has.

- Potential Energy
  - Potential energy exists whenever an object which has mass has a position within a force field. The most everyday example of this is the position of objects in the earth's gravitational field. The potential energy of an object in this case is given by the relation:

$$PE = mgh$$

PE = Energy (J = Joules)
m = mass (kg)
g = gravitational acceleration of the earth (9.8 m/s^2)
h = height above earth's surface (m)

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1 W = 1 J/s

Example of Power from Niagara Falls

- Each kg of water gets kinetic energy of
  $KE = mg\Delta h$
  $= 1 \text{ kg} \times 9{,}8 \text{ m/s}^2 \times 58 \text{ m} = 568 \text{ J}$

H = 58 m
Flow = $7.6.10^6$ kg/s

- Each second, 7.6 million kg of water fall, or
  $P = 7.6 \times 10^6 \text{ kg/s} \times 586 \text{ J/kg}$
  $= 4.3.10^9 \text{ J/s} = 4.310^9 \text{ W}$

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Form of Energy

1. Chemical Energy
   - Chemical Energy is required to bond atoms together, and when bonds are broken, energy is released.
   - Burning
     - a wooden match (0.3 grams) releases about
       - 1055 Joules >3,000 J/g, nearly 1 Cal/g
     - gasoline yields about
       - 39 kJ per gram, or just over 9 Cal/g
   - A 2000 Calorie per day diet means 2000×4184 J = 8,368,000 J per day→8.37 MJ in (24 hr/day) ×(60 min/hr)×(60 sec/min) = 86,400 sec → corresponds to 97 Watts of power

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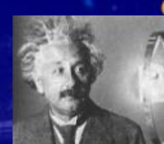
2. Mass Energy



In the special theory of relativity Einstein demonstrated that mass and energy could be traded one for the other.

The relationship between the mass and the energy is contained in what is probably the most famous equation in science,

$$E = mc^2$$

- The energy equivalent of one gram of material (*any composition!!*) is

  $(0.001 \text{ kg})\times(3.0\times10^8 \text{ m/s})^2 = 9.0\times10^{13} \text{ J} = 90 \text{ TJ}$

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- If one gram of material undergoes a *chemical* reaction, losing about 9,000 J of energy, how much *mass* does it lose?

  $9{,}000\ \text{J} = \text{a}mc^2$,

  So

  $\text{a}m = 9{,}000/c^2 = 9\times10^3/9\times10^{16} = 10^{-13}$ kg

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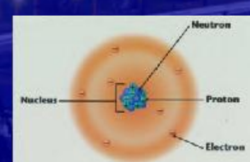
2.5 Electron Energy

- Atoms are not indivisible
  - Made up of protons, neutrons, and electrons
- The nucleus contains protons and neutrons



- Subatomic particles have charge (sometimes)
  - Protons have positive charge (H^+)
  - Electrons have negative charge (e^-)
  - Neutrons have no charge

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Terminology

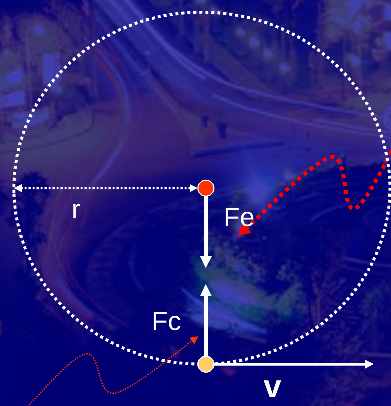
- *Atomic Number* (Z) is how many protons an atom (X) has
- *Atomic Mass Number* (A) is how many protons and neutrons an atom has

$^{A}_{Z}X$

- Elements are defined by atomic number
  - Different AMUs result in different *isotopes*
  - ^{12}C is "carbon 12", ^{14}C is "carbon 14" etc
- *Mass of particles*
  - *Electron = 0,00055 amu*
  - *Proton = 1,00728 amu*
  - *Neutron = 1,00866 amu*
  - *Positron = 0.00055 amu*
  - *Deutron = 2,01355 amu*

1 AMU = $1.66053892 \times 10^{-24}$ grams

- Niel Bohr pada tahun 1913 menyajikan gambaran novel atom yang terdiri dari elektron yang mengorbit inti
- Elektron dapat mengorbit pada jarak yang dekat dengan atau jauh dari inti, dan tempat orbit ini tertentu



Centripetal force
$Fc = mv^2/r$

Centrifugal force = electrical attraction between the proton and the electron

$Fe = kZe^2/r^2$

$k = 9.10^9 \ N.m^2/C^2$

e = muatan elektron $= 1.60219.10^{-19}C$

Z = jlh proton dalam inti
r = jari-2 orbit
v = kecepatan elektron

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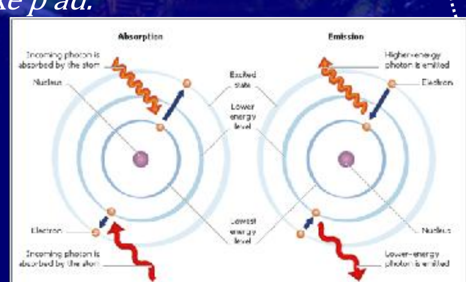
- Bohr kemudian mengasumsikan bahwa ada orbit tertentu dimana elektron stabil
- Elektron yang jauh dari inti dapat jatuh ke orbit yang mendekati inti karena gaya centripetal diikuti dengan kehilangan energi potensial (PE)

Mis. Energi total elektron pada orbit n = En dan pada orbit p = Ep

Kehilangan energi dengan elektron jatuh dari orbit n ke p ad.

En – Ep



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- Energi elelektron pada orbit tertentu (n) dapat diestimasi dengan persamaan berikut

$En = -(kZe^2/2)(kZe^2 4\pi^2 m/n^2h^2)$

$\underline{En = -2\pi^2k^2e^4Z^2m/n^2h^2}$ ....(9)

$\pi = 22/7$

$k = 9.10^9\ N.m^2/C^2$

$e = 1.60219.10^{-19}\ C$

$m = 9.1095.10^{-31}\ kg$

$h = 6.6262.10^{-34}\ Js$

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- Untuk atom yang mempunyai nomor atom Z (proton + neutron) = 1, persamaan diatas dapat disederhanakan menjadi

$En = -13{,}6/n^2\ eV$ ....(10)

$1\ J = 6{,}25.10^{18}\ eV$

Illustration

Singly ionized helium atom which has lost one of its two electrons. Draw the energy-level diagram for this ion

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Reasoning

The singly ionized helium atom will be much like hydrogen atom except that the change on nucleus is +2e, and so Z = 2. From equation, it is found

$E_n = -54{,}4/n^2$ eV

Sehingga

$E_1 = -54.4$ eV

$E_2 = -13{,}6$ eV

$E_3 = -6{,}04$ eV

$E_4 = -3{,}42$ eV

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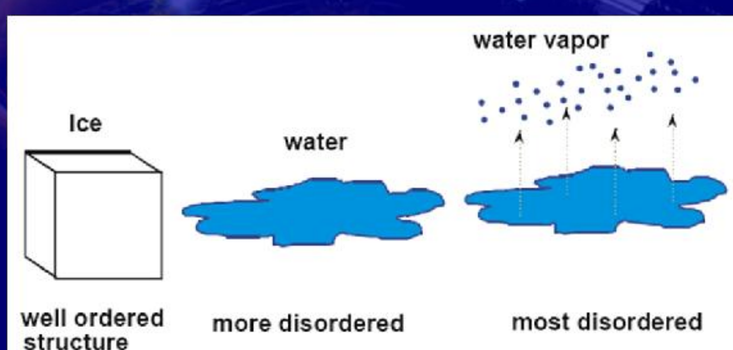
2.6 Free Energy

- Second Law of Thermodynamics: In any spontaneous process the entropy of the *universe* increases
- Entropy (S) is a measure of the disorder in a system.
  - Molecules distributed randomly have high entropy (large S) while ordered molecules have low entropy (small S).



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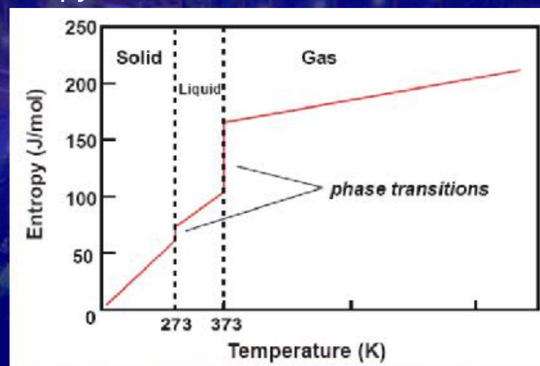
- The functions performed in plants are associated with a reduction in the entropy



Substance (form)	Enthalpy $\Delta_f H$ (kJ)	Gibbs $\Delta_f G$ (kJ)	Entropy (J/K)	Specific heatC_P(J/K)
CO_2 (g)	-393.51	-394.36	**213.74**	37.11
$C_6H_{12}O_6$ (glucose)	-1268	-910	**212**	115

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- The combination of entropy (S), temperature (T) and enthalpy (H) explains whether a reaction is going to be spontaneous or not.
- Gibbs free energy is defined in 1876 by Josiah Willard Gibbs to predict **whether a process will occur** spontaneously at constant temperature and pressure. Gibbs free energy, also indicating how much work is attainable for any given process, is defined as

aG = aH – aTS

where
G is the Gibbs free energy (J)
H is the enthalpy (J)
T is the temperature (^{0}K)
S is the entropy (J/ ^{0}K)

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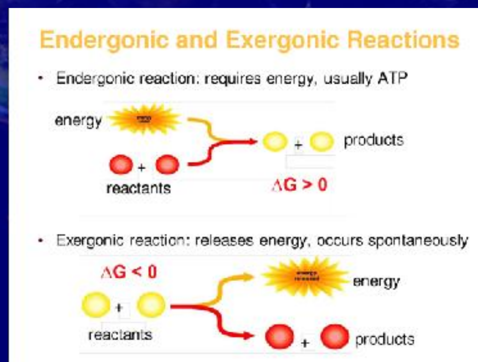
- When
  - ΔG = *negative*, →a *spontaneous* reaction or process
  - ΔG = *positive*, → a *non-spontaneous* reaction.

  - Spontaneous = exergonic (energy releasing)
  - Non-spontaneous = endergonic (energy releasing)



- When the concentrations of reactants and products are variable for the following reaction

  A ì B

  we can determine ΔG as

$$\Delta \mathbf{G} = \Delta \mathbf{G}^{0'} + \mathbf{R} + \mathbf{T}.\ln \frac{[\mathbf{B}]}{[\mathbf{A}]}$$

where R is the universal gas constant, T is temperature, and [B] & [A] are the initial concentrations of the products and reactants.

- We can plot ΔG as a function of [B]/[A] to see how the free energy of the reaction changes as reactants are converted to product ([B]/[A] increases).

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Process	Chemical Reaction	$aG^{o'}$ (kcal/mol)
photosynthesis	$6CO_2 + 6H_2O$ ì glucose + $6O_2$	+686
hydrolysis of sucrose	Sucrose + H_2O ì glucose + fructose	-7.0
conversion of ATP to ADP	ATP + H_2O ì ADP + phophate	-7.3
esterification	glucose + phosphate ì glucose 6-phosphate + H_2O	+3.3

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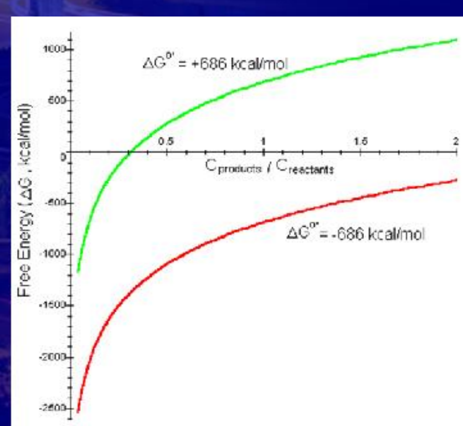
- As an example, the chemical reaction of photosynthesis has a standard free energy
  $aG^{o'}$ = +686 kcal/mol
  The reverse reaction has
  $aG^{o'}$ = -686 kcal/mol



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Penentuan ΔG

- Jika suatu reaksi berlangsung, mis. zat A berubah menjadi zat B seperti berikut

$$A \rightleftharpoons B$$

- $G_B > G_A$ = reaksi bersifat eksergonik apabila (energi dibebaskan)
- $G_B < G_A$ = reaksi bersifat endergonik (energi digunakan)

$$A \longrightarrow B$$

$$Keq = \frac{[B]}{[A]}$$

$$\Delta G = \Delta G^0 + RT \ln \frac{[B]}{[A]}$$

aA + bB ⟶ cC + dD + free energy

cC + dD + free energy ⟶ aA + bB

$$Keq = \frac{[C]^c + [D]^d}{[A]^a + [B]^b}$$

$$\Delta G = \Delta G^0 + RT \ln \frac{[C]^c + [D]^d}{[A]^a + [B]^b}$$

Standard

- Kimia fisik :
  - konsentrasi reaktan & produk = 1 M, dan aG & aG^0 dinyatakan pada pH = 0
- Biokimia :
  - konsentrasi reaktan & produk = 1 M kecuali $[H^+] = 10^{-7}$ M, aG' & $aG^{0'}$ dinyatakan pada pH = 7
- *Jadi perubahan energi bebas standar berbeda antara biokimia dan kimia fisik untuk reaksi yang melibatkan ion hidrogen*
- Untuk reaksi yang melibatkan H^+ sebagai produk

$$A + B \longrightarrow C + xH^+$$

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- Pada keadaan standar, [A] = [B] = [C] = 1 M dan $[H^+] = 10^{-7}$ M, sehingga
  $aG^{0'} = aG^0 + RT \ln[H^+]^x = aG^0 + x\,RT \ln 10^{-7}$
- Jika x = 1, maka pada 298^0 K
  $aG^{0'} = aG^0 - 39{,}95$ kJ atau $aG^0 = aG^{0'} + 39{,}95$ kJ
  - *Jadi a G^0 [$G^{0'}$ sebesar 39,95 kJ/mol H^+ yang dibebaskan untuk rekasi yang melibatkan H^+. Ini berarti reaksi akan lebih spontan pada pH = 7*
- Sebaliknya, reaksi yang melibatkan H^+ sebagai reaktan

$$C + xH^+ \longrightarrow A + B$$

$a G^0 = a G^{0'} - 39{,}95$ kJ

- *Sehingga reaksi akan lebih spontan pada pH = 0*

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Ilustrasi 1.

Jika glucose 1-phosphate (G1-P) dikonversi ke G 6-P oleh enzim phosphoglucomutase pada 25^0C dengan [G 1-P) turun dari 0,02 M menjadi 0,001 M bersamaan dengan peningkatan [G 6-P) menjadi 0,019, hitunglah aG^0

Reasoning

Konsentrasi substrat, [G 1-P) = 0,02 dan produk, [G 6-P) = 0,019, sehingga

Keq = 0,019/0,001 = 19

ΔG^0 = -RT ln Keq = -1363 logKeq

= -1363 log 19 = -1745 cal

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Ilustrasi 2.

Apabila a$G^{0'}$ dari hidrolisis ATP ke ADP+Pi = -7,3 kcal.mol^{-1}, hitunglah Keg reaksi tersebut

Reasoning

a$G^{0'}$ = -RT ln Keq'

-7,3 kcal.mol^{-1} = -(1,98.103 kcal.$^0K^{-1}$.mol^{-1})

(2980^0K)(2,303 log Keq')

Log Keq'= 5,35 ; Keq = 2,2.10^5

Ilustrasi 3.

NAD+ dan NADH ad. btk oksidasi dan reduksi nicotinamide adenine dinucleotide. Harga aG^0 untuk oksidasi NADH = -21,83 KJ.mol^{-1} pada 298^0K. Hitunglah aG^0, Keq' dari reaksi tsb. Hitung juga aG dan aG' jika [NADH] = 1,5.10^{-2}, [H^+] = 3.10^{-5}, [NAD+] = 4,6.10^{-3} dan pH_2 = 0,01 atm. *Do it by yourself if you like*

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Tugas

1. How do plants work to live
2. What is the function of cell components
3. What is energy ?
4. Where do plants derive energy from for the first time ?
5. What does it mean by potential energy ?
6. How much is the mass energy of 0,5 kg body ?
7. How much is the free energy of ATP hydrolysis at pH = 7, 25^0C and steady state when the concentration of ATP, ADP dan Pi is 10^{-5} M, 10^{-3} M dan 10^{-7} M ($\Delta G^{0'}$ of ATP = 7700 cal.mol^{-1}) respectively ?


TERIMAKASIH
THANK YOU
Спасибо
謝謝
شكراً