A-Level Notes for Pearson Edexcel

Michael Tang

Compile Date: December 30, 2024

Contents

Chapter 1

Math

Chapter 2

Biology

2.1 Molecules, Transport and Health

2.1.1 Chemistry for Biologists

1A.1 Chemistry of Life

Ionic Bonding (离子键)

- **Definition:** Atoms transfer electrons to achieve a stable electron configuration, resulting in positively charged cations and negatively charged anions.
- **Key Properties:**
  - High melting and boiling points.
  - Solubility in polar solvents like water.
- **Example:** Sodium (Na 钠) and chlorine (Cl 氯) form sodium chloride ($NaCl$ 氯). Sodium donates an electron to chlorine, forming a strong ionic bond.

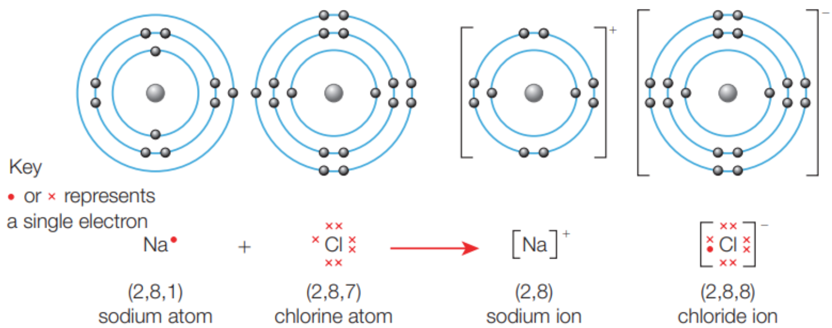

Figure 2.1: The formation of sodium chloride.

Covalent Bonding (共价键)

- **Definition:** Atoms shere electrons to achieve stability.
- **Polarity** (极性)**:** Unequal sharing of electrons leads to polar molecules (极性分子 e.g., water).
- **Dipoles** (偶极子)**:** Partial charges within the molecule, represented as δ^+ (positive) and δ^- (negative).

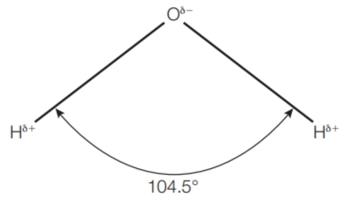

Figure 2.2: A model of a water molecule showing dipoles.

- **Examples:** Formation of hydrogen (H_2 氢气) molecules and the formation of water (H_2O 水).

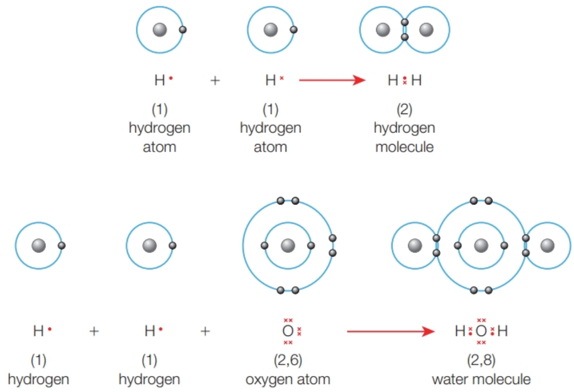

Figure 2.3: The formation of hydrogen molecules and water molecules are examples of covalent bonding.

Chemistry of Water

- **Molecular Structure**
  - **Polar Molecule:** Water (H_2O) has a bent structure with a partial charges (see figure 2.2) - oxygen is δ^-, and hydrogen is δ^+.
  - **Hydrogen Bonding (氢键):** Weak attractions between water molecules, providing cohesion (凝聚力) and a relatively high boiling point.

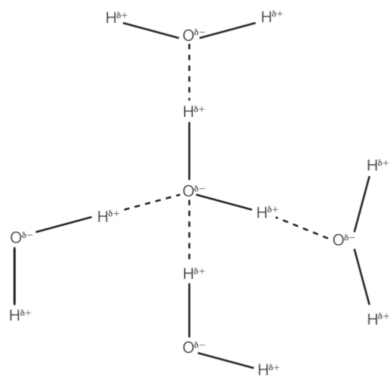

Figure 2.4: Hydrogen bonding in water molecules, based on attraction between positive and negative dipoles.

- **Unique Properties**

- **Solvent (溶剂) Properties**
  - Excellent solvent for ionic and polar substances (物质).

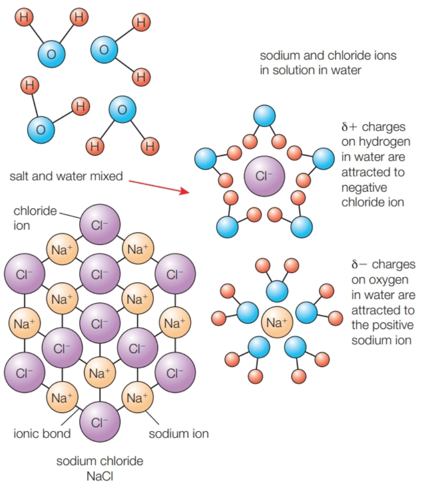

Figure 2.5: A model of sodium chloride dissolving in water as a result of the interactions between the charges on sodium and chloride ions and the dipoles of the water molecules.

  - Facilitates (促进) biochemical (生化) reactions in aqueous solutions (水溶液).
- **Thermal (热) Stability**
  - High specific heat capacity [1] (比热容) moderates temperature changes.
  - Ice floats due to lower density (密度) compared to liquid water, insulating (隔热) the aquatic (水生) life.
- **Cohesion (凝聚力) and Adhesion (粘附力)**
  - Enables water transport in plants.
  - High surface tension due to hydrogen bonding.

Importance of Water

- **Biological Reactions:** All cellular reactions occur in an aqueous environment.
- **Transport Medium:** Dissolves and carries nutrients (营养物质), gases, and waste products (废物).
- **Habitat:** Provides a stable environment for diverse (多样的) life forms.
- **Temperature Regulation:**
  - Evaporation (蒸发) cools organisms.
  - High specific heat stability ecosystems.
- **Structural Support:** Turgor pressure [2] (胀压) in plants depends on water.

[1] **Heat capacity:** Heat capacity refers to the amount of heat energy required to raise the temperature of a substance by one degree Celsius. It reflects the substance's ability to store thermal energy (热能). c is the symbol of heat capacity. The general formula of heat capacity is $c = \frac{Q}{m(t-t_0)} = \frac{Q}{m\Delta t}$. $\mathrm{J\,kg^{-1}\,K^{-1}}$ is the SI unit of heat capacity and $\frac{J}{(kg\cdot{}^\circ C)}$ is the common unit.

[2] **Turgor pressure:** Turgor pressure is the pressure exerted by the water-filled vacuole (液泡)

Importance of Inorganic (无机) Ions

- **Nitrate Ions (NO_3^- 硝酸根离子):** Vital for DNA [3] and protein synthesis (蛋白质合成) in plants. (see sections 1A.5, 2B.3, and chapter 5A).

- **Phosphate Ions (PO_4^{3-} 磷酸根离子):** Essential for ATP [4], DNA [3], and RNA [5] (see section 2B.3 and chapter 5A).

- **Chloride Ions (Cl^- 氯离子):** Needed in all living organisms to make AT and ADP as well as DNA and RNA (see chapters 7C and 8A).

---

against the cell wall in plant cells. It results from water entering the cell by osmosis (渗透) and helps maintain the cell's rigidity (刚性), supporting the plant's structure and preventing wilting (枯萎).

[3] **DNA (Deoxyribonucleic Acid 脱氧核糖核酸):** DNA is a molecule that carries the genetic instructions (遗传信息) used in the growth, development, functioning, and reproduction of all living organisms. It consists of two strands forming a double helix (螺旋), with each strand (股) made up of nucleotide bases (核苷酸碱基) (adenine 腺嘌呤, thymine 胸腺嘧啶, cytosine 胞嘧啶, and guanine 鸟嘌呤). These bases pair (碱基对) specifically (A-T, C-G) and encode the instructions for synthesizing (合成) proteins, which determine an organism's traits (特征).

[4] **ATP (Adenosine Triphosphate 腺嘌呤核苷三磷酸):** ATP is a molecule that acts as the primary energy carrier in cells. It consists of an adenosine molecule (腺苷分子) bonded to three phosphate (磷酸盐) groups. When ATP is broken down into ADP (adenosine diphosphate 二磷酸腺苷/核苷酸) and a phosphate group, energy is released to fuel cellular processes such as muscle contraction, active transport, and chemical synthesis.

[5] **RNA (Ribonucleic Acid 核糖核酸):** RNA is a single-stranded nucleic acid (单链核酸) that plays a crucial role in protein synthesis and gene expression. It is composed of ribose sugar (核糖/单糖), phosphate groups, and four nitrogenous bases (含氮碱基): adenine (A 腺嘌呤), uracil (U 尿嘧啶), cytosine (C 胞嘧啶), and guanine (G 鸟嘌呤). Unlike DNA, RNA contains uracil instead of thymine. Types of RNA include: mRNA [6] (messager RNA 信使核糖核酸), tRNA [7] (transfer RNA 转运核糖核酸), and rRNA [8] (ribosomal RNA 核糖体).

[6] **mRNA:** mRNA is a type of RNA that carries the genetic information from DNA in the cell nucleus to the ribosome (核糖体), where it is used as a template for protein synthesis. It is transcribed from DNA and contains codons [9] (密码子) that specify the amino acids (氨基酸) to be incorporated into the protein.

[7] **tRNA:** tRNA is a type of RNA that helps decode the genetic instructions in mRNA during protein synthesis. It carries specific amino acids to the ribosome, where it pairs its anticodon [10] (反密码子) with the complementary codon on the mRNA sequence. This ensures that amino acids are added in the correct sequence to form a protein.

[8] **rRNA:** rRNA is a type of RNA that is a key structural and functional component of ribosomes, the molecular machines [11] (分子机器) that synthesize proteins. rRNA helps align mRNA and tRNA during protein synthesis and catalyzes the formation of peptide bonds (肽键) between amino acids, facilitating the assembly of proteins.

[9] **Codon:** A codon is a sequence of three nucleotide bases in mRNA that corresponds to a specific amino acid or a stop signal during protein synthesis. For example, the codon AUG [12] (起始密码子) codes for the amino acid methionine (蛋氨酸) and also serves as the start signal for translation.

[10] **Anticodon:** An anticodon is a sequence of three nucleotide bases on a tRNA molecule that is complementary to a codon on the mRNA strand. During protein synthesis, the anticodon pairs with its corresponding codon, ensuring that the correct amino acid is added to the growing polypeptide chain.

[11] **Molecular machines:** Molecular machines are complex biomolecules or assemblies of molecules that perform specific tasks within a cell, often converting energy into mechanical work. Examples include ribosomes for protein synthesis, ATP synthase for energy production, and motor proteins [13] (马达蛋白) like kinesin (驱动蛋白) for intracellular transport (细胞内运输).

[12] **Codon AUG:** The codon AUG serves two critical roles in protein synthesis: start codon, it signals the beginning of translation, indicating where the ribosome should start assembling the protein; and amino acid, AUG codes for the amino acid methionine (Met), which is often the first amino acid in newly synthesized proteins. This dual function makes AUG essential in the initiation of protein synthesis.

[13] **Motor proteins:** Motor proteins are specialized molecular machines that convert chemical energy from ATP into mechanical work to perform cellular movements. They play key roles in intracellular transport, cell division, and structural support. Examples include: kinesin (驱动蛋白), dynein (动力蛋白), and myosin (肌球蛋白).

- **Hydrogencarbonate Ions (HCO_3^- 碳酸氢根离子):** Needed in nerve impulses, sweating, and many secretory systems (分泌系统) in animals (see section 1B.2).
- **Sodium Ions (Na^+ 钠离子):** Critical in nerve impulses and secretory functions (see chapter 8A).
- **Magnesium Ions (Mg^{2+} 镁离子):** Needed for production of chorophyll (叶绿素) in plants (see chapter 5A).
- **Hydrogen Ions (H^+ 氢离子):** Needed in cellular respiration (呼吸) and photosynthesis (光合作用), and in numerous pumps and systems as well as pH balance (see section 2A.4 and chapters 5A and 7A).
- **Calcium Ions (Ca^{2+} 钙离子):** Needed for the formation of calcium pectate (果胶酸钙) for middle lamella (中膜) between two cell walls in plants, and for bone formation and muscle contraction in animals (see section 4A.1 and chapters 7B and 7C).

1A.2 Carbohydrates: Monosaccharides and Disaccharides

What are Organic Compounds?

- **Definition:** Organic compounds are molecules containing carbon atoms bonded to hydrogen and other elements, such as oxygen, nitrogen, and phosphorus. In some carbon compounds small molecules (monomers 单体) bond with many other similar units to make a very large molecule called a polymer (聚合物). The ability of carbon to combine and make macromolecules (大分子) is the basis of all biological molecules and provides the great variety and complexity found in living things.

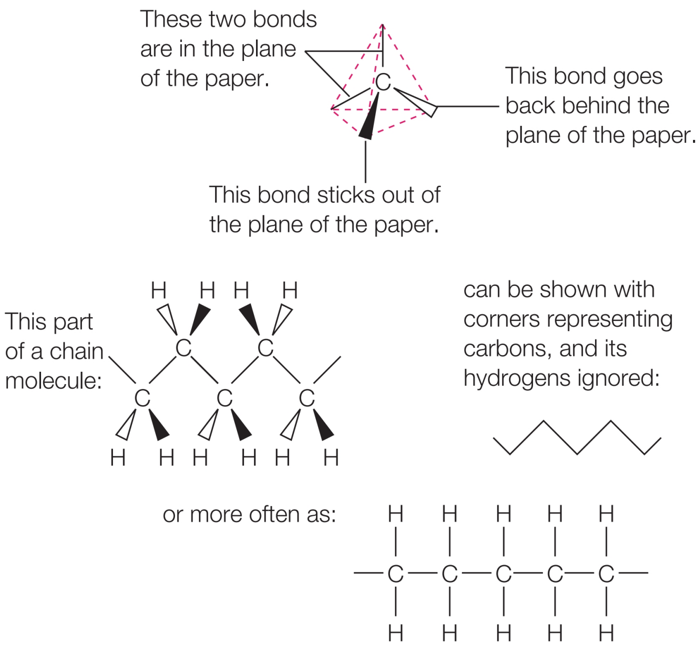

Figure 2.6: The bonds in a carbon atom have a complicated 3D shape. This is difficult to represent, so in most molecular diagrams we use one of several different ways to draw them.

- **Key Features:**
  - Carbon atoms form stable covalent bonds, allowing complex structures.
  - Organic compounds include carbohydrates (碳水化合物), lipids (脂质), proteins (蛋白质), and nucleic acids (核酸).

Carbohydrates Carbohydrates are essential organic molecules, primarily serving as energy sources and structural components. They are composed of carbon (C 碳), hydrogen (H 氢), and oxygen (O 氧), typically in a 1:2:1 ratio - $(CH_2O)_n$.

Monosaccharides (单糖): The Simplest Sugars

- **Key Characteristics:**
  - Simplest form of carbohydrates.
  - General formula: $(CH_2O)_n$, where n is the number of carbon. Although n can be any number, but it is usually low (3-7).
  - Examples:
    * **Triose (3-Carbon 三糖, $n = 3$):** $C_3H_6O_3$. E.g., glyceraldehyde (甘油醛), involved in glycolysis (糖酵解).
    * **Pentose (5-Carbon 五糖, $n = 5$):** $C_5H_{10}O_5$. E.g., ribose (核糖) and deoxyribose (脱氧核糖).

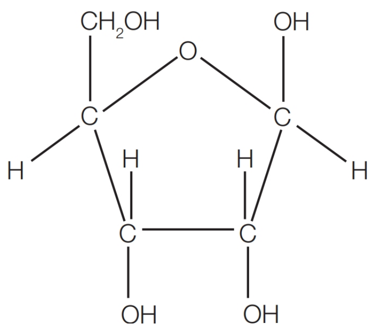

Figure 2.7: Pentose sugars such as ribose have 5 carbon atoms.

    * **Hexose (6-Carbon 六糖, $n = 6$):** $C_6H_{12}O_6$. E.g., glucose (energy source 葡萄糖), fructose (fruit sugar 果糖), galactose (milk sugar 半乳糖).
  - Structure of Glucose
    * Gulcose has two isomers (different forms 同分异构体): α-glucose and β-glucose. The two isomers have different arrangements of the atoms on the side chains of the molecule.
    * **Alpha(α) glucose:** Hydroxyl ($-OH$ 羟基) group on carbon 1 is below the plane.
    * **Beta(β) glucose:** Hydroxyl group on carbon 1 is above the plane.

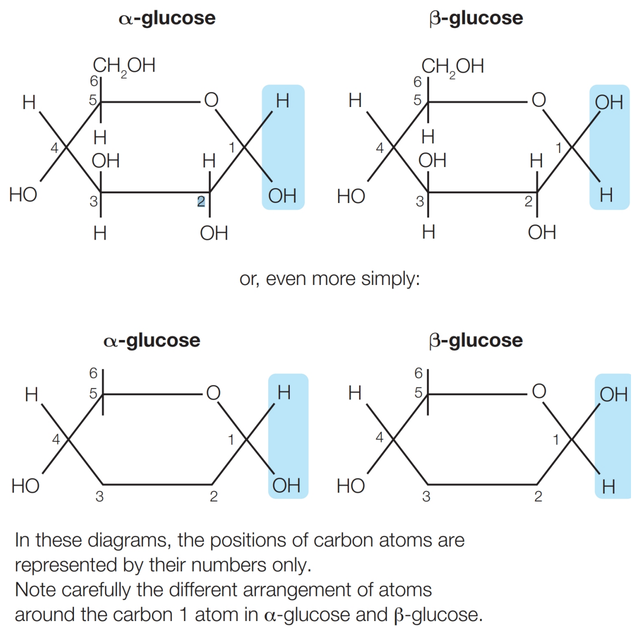

Figure 2.8: Hexose sugars have a ring structure. The arrangement of the atoms on the side chains can make a significant difference to the way in which the molecule can be used by the body. The carbon atoms are numbered in order to identify the different arrangements.

Disaccharides (二糖): The Double Sugars

- **Formation:**
  - **Condensation Reaction (缩合反应):** Two monosaccharides join, forming a glycosidic bond (糖苷键) and releasing a water molecule (H_2O).

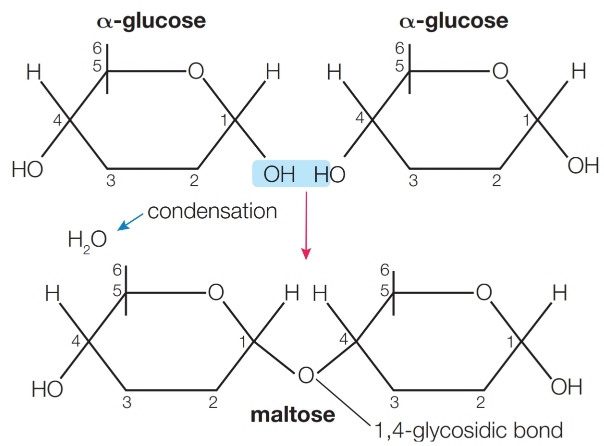

Figure 2.9: The formation of a glycosidic bond. The condensation reaction between two monosaccharides results in a disaccharide and a molecule of water.

  - **Examples:**
    * **Sucrose (蔗糖):** Glucose + Fructose. Stored in plants such as sugar cane (甘蔗).

  * **Lactose (乳糖):** Glucose + Galactose. Milk sugar - this is the main carbohydrate found in milk.
  * **Maltose (麦芽糖):** Glucose + Glucose. Malt (麦芽) sugar - found in germinating (发芽) seed such as barley (大麦).

- **Breakdown - Hydrolysis Reaction (水解反应):** Glycosidic bonds are broken with the addition (添加) of water, yielding (产生) two monosaccharides.

Testing for Sugars - Benedict's Test (本尼迪克特试验)

- **Principle:** Benedict's test is a qualitative test [6] (定性实验) used to detect the presence of reducing sugars (还原糖). These sugars can reduce copper (II) ions (Cu^{2+}) to copper (I) ions (Cu^{+}) due to the presence of a free aldehyde ($R-CHO$ [7] 醛) or ketone ($R-CO-R'$ [8] 酮) group.

[6]**Qualitative Test:** A qualitative test determines the presence (存在) or absence (不存在) of a specific substance in a sample, without providing precise (精确的) numerical data about its concentration (浓度) or quantity (数量)

- **Key Features:**
  * **Purpose:** Identify whether a substance is present.
  * **Outcome:** Results are typically descriptive (描述性的 - e.g., color change, precipitation 沉淀, or effervescence 泡沫) rather than quantitative (定量性的).
  * **Examples in Biology and Chemistry:** Benedict's test for reducing sugars (color change from blue to brick-red), iodine test for starch (color change from yellow-brown to blue-black), and biuret test (缩二脲试验) for proteins (color change from blue to purple).
- **Limitations:**
  * Does not measure the exact amount of a substance.
  * Subjective interpretation (主观解释) of results (e.g., intensity of color change 颜色变化的程度).

[7]In organic chemistrym R is a shorthand symbol (缩写符号) used to represent a generic alkyl group (烷基) or side chain (侧链) attached to a functional group [9] (官能团). It is a placeholder (占位符) for any group of carbon and hydrogen atoms (and sometimes other atoms) in a molecule.

- **Explanation of R in $R-CHO$:**
  * R: Represents a hydrocarbon (烃/碳氢化合物) chain or group, such as:
    · Methyl group (甲基): CH_3-
    · Ethyl group (乙基): CH_3CH_2-
    · Cycloalkyl group (环烷基): $C_6H_{11}-$
    · Longer or branched alkyl chains: C_nH_{2n+1}
  * CHO: Represents the aldehyde functional group (醛官能团), where a carbon atom is double-bonded (双键) to an oxygen atom ($C=O$) and single-bonded (单键) to a hydrogen atom (H).
- **Purpose of R:**
  1. **Generic Representation:** It simplifies chemical structures when the specific nature of the alkyl group is not important for the discussion.
  2. **Flexibility:** Allows focus on the functional group (CHO) rather than the details of the alkyl chain.
- **Examples:** Methanal (Formaldehyde 甲醛): $H-CHO$, where $R=H$.

[8]$R-CO-R'$ can also write as $>C=O$. In organic chemistry, the symbol $>C=O$ is used to describe the structure of a carbonyl group (羰基), emphasizing that the carbon atom in the carbonyl group is bonded not only to an oxygen atom but also to two other groups (基团). The $>$ symbol indicates that the carbonyl carbon is an internal carbon (内部碳), connected to two other groups or chains (rather than being a terminal carbon).

[9]**Functional group:** A functional group is a specific group of atoms within a molecule that determines the chemical properties and reactions of that molecule. It is the reactive part of the molecule, often defining its behavior in biological or chemical processes. Functional groups are crucial in organic chemistry because they dictate how molecules interact and bond with others.

- **Reducing sugars:** Reducing sugars include monosaccharides like glucose, furctose, and galactose, and disaccharides except sucrose. They have the ability to donate electrons to other molecules due to their reactive carbonyl group.

- **Reagents in Benedict's Test:** Benedict's Solution contains:
  - **Copper (II) Sulfate ($CuSO_4$):** Source of (Cu^{2+}) ions.
  - **Sodium Citrate ($C_6H_5Na_3O_7$):** Stablizes the copper (II) ions in the solution.
  - **Sodium Carbonate (Na_2CO_3):** Provides an alkaline environment.

- **Chemical Reaction:**
  1. In an alkaline medium, the carbonyl group of the reducing sugar reacts with the copper (II) ions.
  2. Reduction Process:
     * Cu^{2+} (blue) is reduced to Cu^{+} (red/orange precipitate of copper (I) oxide, Cu_2O).
     * Reaction: $R{-}CHO + 2Cu^{2+} + 5OH^{-} \rightarrow R{-}COOH + Cu_2O + 2H_2O$ Where $R - CHO$ represents the reducing sugar.

- **Procedure:**
  1. Mix the sample with Benedict's solution.
  2. Heat the mixture in a boiling water bath for about 2-5 minutes.
  3. Observe the color change and precipitate formation.

- **Observation and Results:**

Color Change	**Reducing Sugar Concentration**
Blue (no change)	No reducing sugar present
Green	Low concentration
Yellow	Moderate concentration
Brick-red precipitate	High concentration

Table 2.1: Color changes observed in Benedict's test for reducing sugars.

Figure 2.10: Benedict's test for reducing sugars.

- **Limitations:** Non-reducing sugars like sucrose do not react directly unless hydrolyzed.

1A.3 Carbohydrates: Polysaccharides (多糖)

Carbohydrates and Energy Carbohydrates are a primary source of energy in biological systems, particularly glucose, which is a key monosaccharide used in cellular respiration.

- **Key Points**
  - **Energy Production:** Glucose ($C_6H_{12}O_6$) is broken down through cellular respiration to produce ATP (adenosine triphosphate), which powers cellular activities.
  - **End Products:** The breakdown of glucose result in:
    * Carbon dioxide (CO_2)
    * Water (H_2O)
    * Large amounts of ATP
  - **Glucose Utilization:**
    * **Monosaccharides** such as glucose are rapidly absorbed and used for immediate energy needs.
    * **Disaccharides** like sucrose and lactose are broken into monosaccharides for energy production.
    * **Polysaccharides** are complex carbohydrates made up of many monosaccharide units joined by glycosidic bonds. Note that molecules with between 3 and 10 sugar units are known as **oligosaccharides** (低聚糖), while molecules containing 11 or more monosaccharides are known as true polysaccharides.

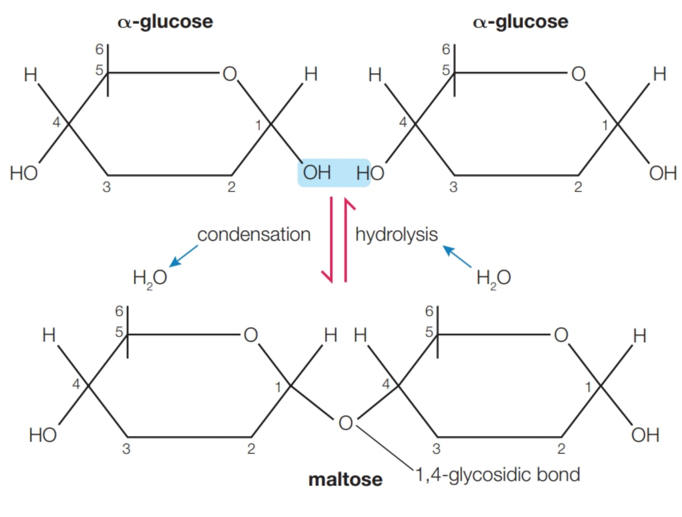

Figure 2.11: Glycosidic bonds are made by condensation reactions and broken down by hydrolysis.

    * **Exam Hint:** Avoid stating that energy is "created". Instead, describe how chemical energy from glucose is transferred to ATP molecules.

- **Properties of Polysaccharides**
  1. **Compact Structure:**
     * Takes up little space within cells.
     * Ideal for storage purposes.

2. **Insolubility:**
   * Reduces osmotic effects [9] (渗透效应) in cells.
   * Does not affect water potential.
3. **Chemical Inactivity:** Does not interfere with cellular reactions.

- **Starch (Plant Energy Store)**
  - Composed of α-glucose units.
  - Two main components:
    * **Amylose (直链淀粉):** Long, unbranched chains of α-glucose units. Forms a compact spiral sturcture due to 1,4-glycosidic bonds.
    * **Amylopectin (支链淀粉):** Branched chains of α-glucose units. Contains 1,4- and 1,6- glycosidic bonds, allowing rapid glucose release.

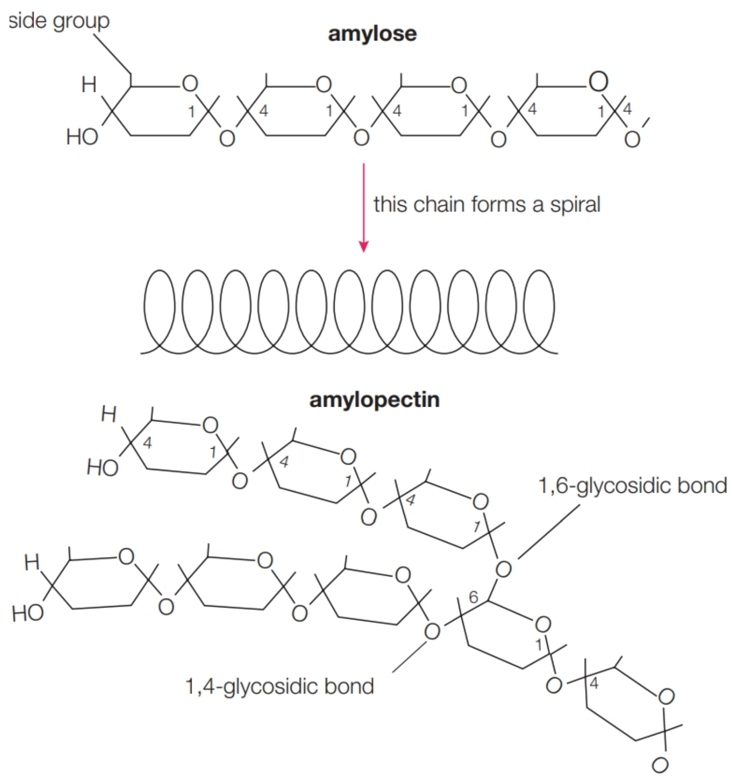

Figure 2.12: Amylose and amylopectin —a small difference in the position of the glycosidic bonds in the molecule makes a big difference to the properties of the compounds.

  - **Function:**
    * Efficient energy storage in plants.

[9] **Osmotic effects:** Osmotic effects refer to the movement of water across a semipermeable membrane [10] (半透膜) due to differences in solute concentration.

[10] **Semipermeable membrane:** It is a membrane that allows certain molecules to pass through while blocking others. It permits solvent molecules (such as water) to pass but prevents solute molecules from doing so. This property makes semipermeable membranes highly useful in various applications, such as desalination (海水淡化), where water and salt in seawater are separated using a semipermeable membrane.

    * Rapid glucose availability during high metabolic demands.

  - **Testing for Starch** If you add a few drops of reddish-brown iodine solution to a sample containing starch (whether it is a solid sample or a sample in solution), the iodine solution will turn blue-black.

Figure 2.13: The iodine test for starch.

- **Glycogen (Animal Energy Store)**

  - Similar to amylopectin but more extensively branched.

  - **Structure:**

    * Contains many 1,6-glycosidic bonds, leading to multiple branches.
    * Compact and can be rapidly hydrolyzed for energy.

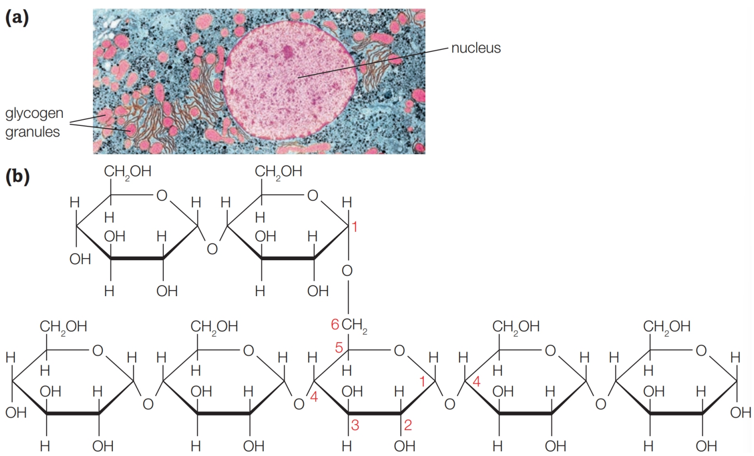

Figure 2.14: In **(a)** you can see liver cells full of small glycogen granules (微粒), stained (染色) pink in this micrograph (显微照片). If your blood glucose levels are low, this glycogen store in your liver can be broken down to provide the glucose you need for cellular respiration. In **(b)** you can see the structure of glycogen with 1,4 and 1,6-glycosidic bonds.

  - **Function:**

    * Found in the liver and muscle cells.
    * Acts as a quick energy source for animal during high activity.

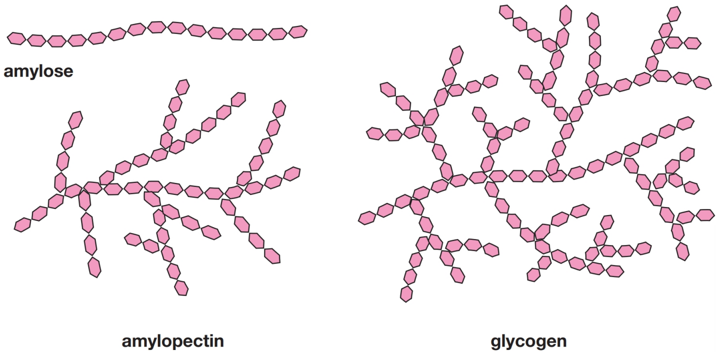

Figure 2.15: You can clearly see the many side branches which allow glycogen to be broken down so quickly when you compare amylose, amylopectin and glycogen.

Chapter 3

Chemistry

Chapter 4

Physics

Bibliography

[1] Ann Fullick with Frank Sochacki. *Pearson Edexcel International AS/A Level Biology Student Book 1*. Pearson Edexcel, 2021.

[2] Ann Fullick with Frank Sochacki. *Pearson Edexcel International AS/A Level Biology Student Book 2*. Pearson Edexcel, 2021.