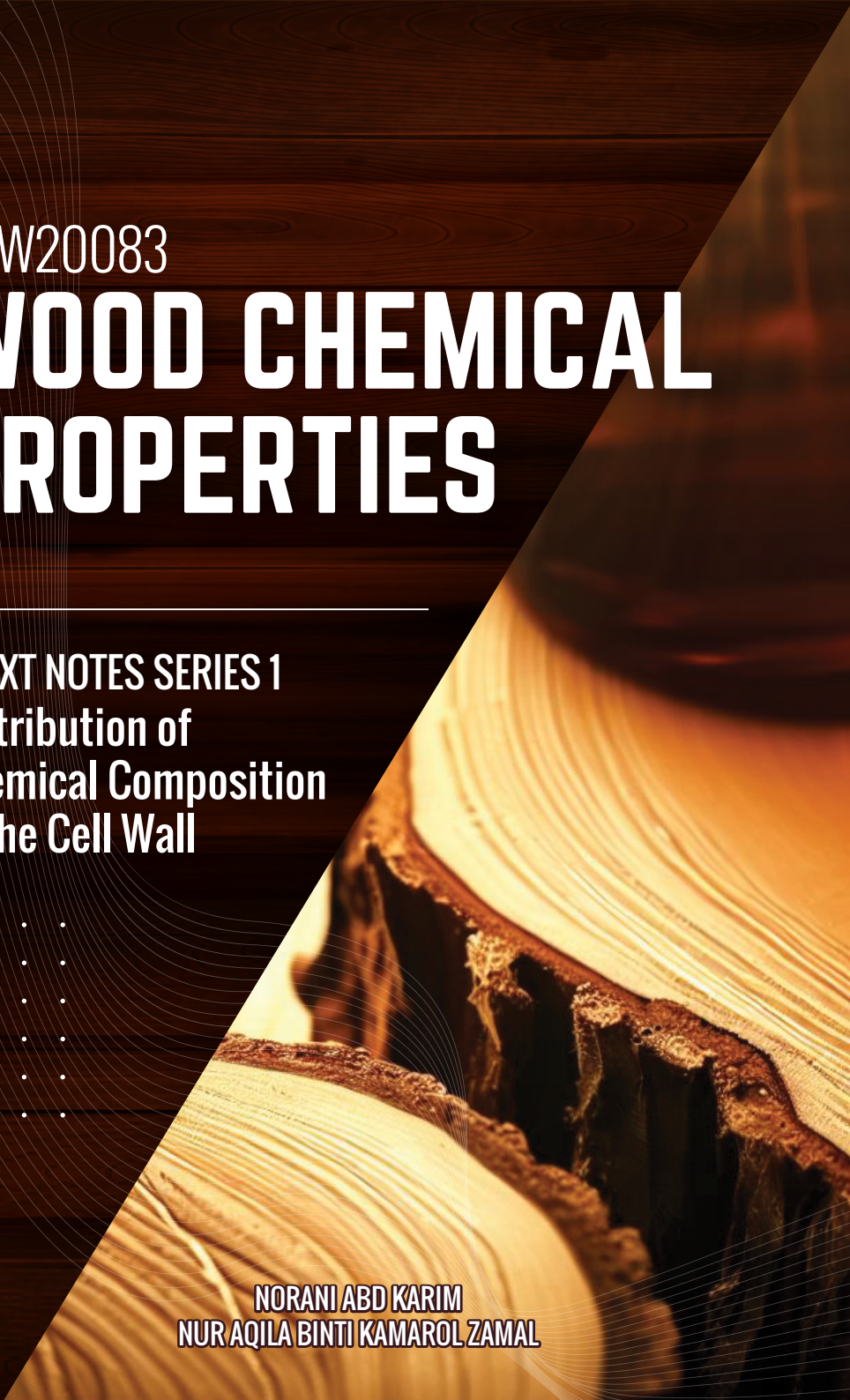
DCW20083

WOOD CHEMICAL PROPERTIES

e-TEXT NOTES SERIES 1
Distribution of Chemical Composition in the Cell Wall



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e-Text Notes

SERIES 1

DISTRIBUTION OF CHEMICAL COMPOSITION IN THE CELL WALL

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e-Text Notes

Series 1 - Distribution of Chemical Composition in The Cell Wall

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SYNOPSIS

This e-Text Notes serves as an additional reference for students of Diploma in Wood-Based Technology who are enrolled in the DCW20083 Wood Chemical Properties subject in Semester 2. In Series 1, students will learn about the definition of wood, the sources of wood, wood structure, photosynthesis process, chemical compounds in wood, and the relation of chemical composition to the strength and quality properties of wood.

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ABOUT THE AUTHOR 1

NORANI ABD KARIM (Ph.D)

- She started her career as a school teacher at Sekolah Menengah Bandar Pusat Jengka, Pahang from 1993 to 1997.
- In 1999, she completed her Bachelor's degree in B.Sc. (Hons.) in Furniture Technology at Universiti Teknologi Mara (UiTM), Shah Alam.
- She began her career as a lecturer in the Civil Engineering Department at Polytechnic Sultan Salahuddin Abdul Aziz Shah in May 1999.
- She completed her Master's degree in Wood Science & Technology at Universiti Putra Malaysia (UPM) in 2011, and then her Ph.D. in Wood Properties at Universiti Sains Malaysia (USM) in 2017.
- With almost 30 years of experience in teaching and learning, especially in the Wood Based Technology field, she is actively involved in research and innovation in her area of expertise.

ABOUT THE AUTHOR 2

NUR AQILA BINTI KAMAROL ZAMAL

- She is an alumnus of the Diploma in Wood-Based Technology Programme at Polytechnic Sultan Salahuddin Abdul Aziz Shah who graduated in 2009.
- Then, she continued her studies to the Bachelor's Degree, Bachelor of Wood Science and Technology at Universiti Putra Malaysia and successfully completed her studies in 2014.
- She started her career as a Lecturer of Diploma in Wood-Based Technology Programme at Polytechnic Sultan Salahuddin Abdul Aziz Shah in February 2015.
- Armed with knowledge and experience in the field of wood science and technology for 17 years, she is now the Head of the Programme for the DBK Programme at PSA.

TABLE OF CONTENT

CHAPTER 1:

DEFINITION OF WOOD

WOOD DEFINITION

Botanical definition:

Wood is a natural material that comes from trees. Trees are woody plants that grow in forests, woodlands, and other natural environments (Rowell,1984).

Technical definition:

Wood is a composite material composed of organic polymers. It consists of cellulose, hemicellulose, and lignin.

Cellulose makes up about 40-45% of the dry weight of normal wood tissue. Hemicellulose is a group of different polysaccharides present in woody plants.

Lignin is a complex molecule of high molecular weight that permeates both cell walls and intercellular regions of wood (Rowell, 1984).

Chemical definition:

Wood tissue is a composite material made of organic polymers.

Cellulose, a long-chain carbohydrate polymer made of glucose monomers, makes up around 40-45% of the dry weight of normal wood tissue.

Hemicelluloses are a group of different polysaccharides found in woody plants. Hemicelluloses are different from cellulose in their conformation and molecular weight, but they are similar enough to be grouped together.

Hemicelluloses contain short side chains made of five- or six-carbon sugars such as xylose, arabinose, glucose, mannose, and galactose (Rowell, 1984).

CHAPTER 2:

SOURCE OF WOOD

SOURCE OF WOOD AS LIGNOCELLULOSIC MATERIALS

Wood is derived from trees, and some common sources include:

- Softwood trees: coniferous trees like pine, spruce, fir, and cedar, which are used in construction, furniture, and paper production.
- Hardwood trees: broad-leaved trees like oak, maple, cherry, and walnut, which are used in furniture, flooring, and cabinetry.
- Recycled wood: sourced from materials like pallets, construction waste, and furniture, to reduce waste and demand for new wood.
- Urban trees: trees removed from urban areas due to disease or safety concerns, can provide a sustainable source of wood.
- Bamboo: a fast-growing grass used as a source of wood material due to its sustainable nature.

Lignocellulose material is a type of biomass that is made up of three main components:

Lignin : natural polymer that gives strength to plant cell walls.

Cellulose : carbohydrate polymer that provides structure and support to plants.

Hemicellulose : mixture of carbohydrates that helps bind cellulose fibers together.

These components make up the majority of plant biomass, and are found in materials like wood, straw, and grasses. Lignocellulose material is an important source of renewable energy, as it can be used to produce biofuels like ethanol and biogas. It is also used in the production of paper, textiles, and other materials.


Wood Logs


Straw


Corn Cob


Sugarcane bagasse


Bamboo stalks

Hemp fibers


Tree bark


Recycled paper


Coconut shell

Diagram 1: Samples of lignocellulosic material

CHAPTER 3:
WOOD STRUCTURE

WOOD STRUCTURE

Wood has three different types of characteristics, which are:

Anatomical structure – contribute to wood identification

Chemical characteristics – contribute to colour and odour

Physical properties – contribute to hardness and density

(Conners, 2015).

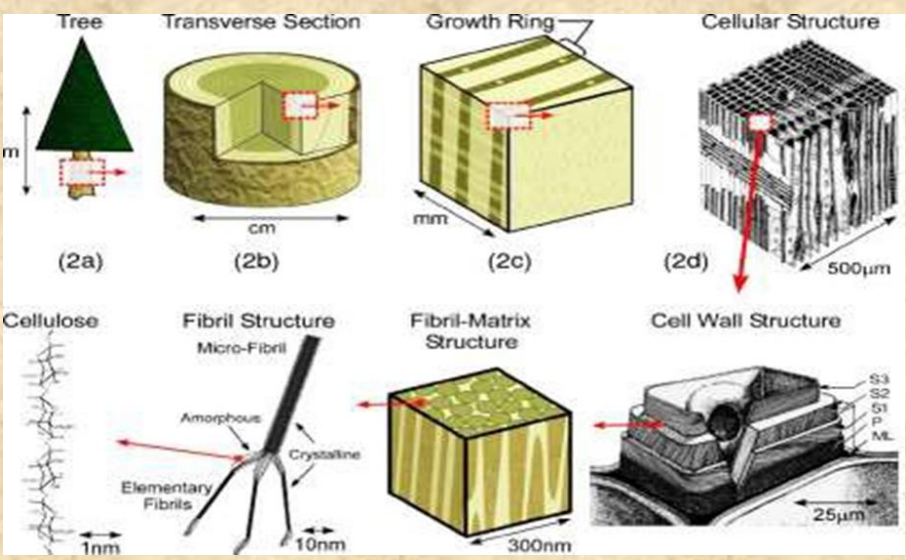


Diagram 2: Wood hierarchical structure from tree to cellulose (Jones et.al, 2009)

WOOD MACROSCOPIC

The macroscopic structure of wood is defined as an object that can be seen without the aid of a microscope or hand lens. The examples of wood macrostructure are structural directions, growth rings, heartwood, sapwood, and ray patterns (Thybring et.al, 2021). Macroscopic characteristics is important in selecting appropriate wood and identifying or addressing defects for optimal performance such as:

Grain	direction of wood fibers or growth rings (straight, curly, wavy, or interlocked)	
Texture	size and distribution of wood cells (fine, medium, or coarse)	
Colour	varies widely between species, heartwood is darker than sapwood	
Figure	patterns or markings on surface of wood (knots, burls, birds' eye, or tiger stripes)	
Defects	which can affect appearance and quality (knots, checks, splits, warping)	

WOOD MICROSCOPIC

Microscopic characteristics of wood are observable only through magnification. Wood is composed of various cell types such as vessel elements, fibers, and ray cells. Cell structure and growth rings can provide information about the age and growth conditions of the tree. The walls of wood cells are composed of cellulose, hemicellulose, and lignin, which contribute to the mechanical and physical properties of the wood. Wood may contain inclusions such as resin canals, mineral deposits, or tyloses, which can affect its appearance and properties.

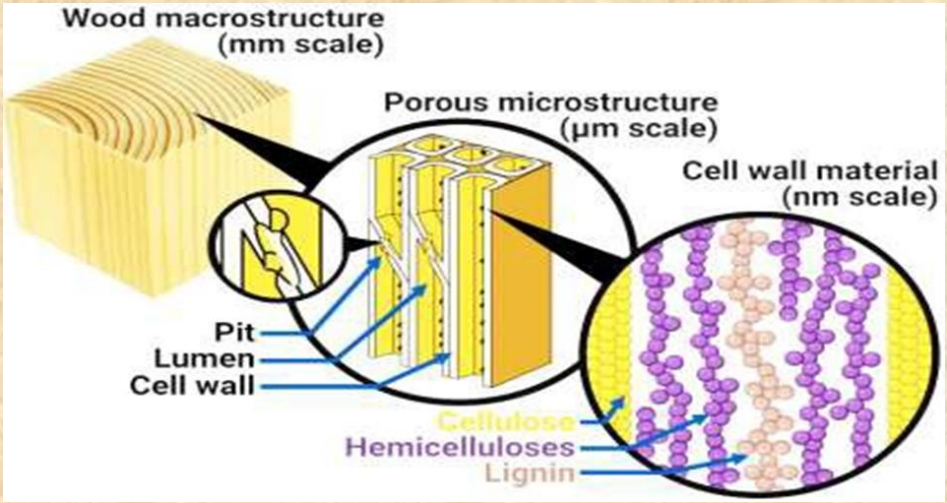


Diagram 3: Wood macrostructure and microstructure (Thybring et.al, 2021)

CHAPTER 4:

CHEMICAL COMPOSITION IN THE CELL WALL

WOOD CHEMICAL COMPOSITION

Wood is made up of cellulose, hemicelluloses, and lignin. Cellulose is the most important component and makes up around 40-45% of the weight of wood, providing strength in tension.

Hemicellulose is a branched carbohydrate polymer that provides additional strength to the cell walls, but is weaker and more hygroscopic than cellulose. It comprises 18-35% of the organic content of wood.

Lignin is a polymer made of phenolic molecules, comprising around 20-35% of dry wood. It has less affinity for water than cellulose and hemicellulose and acts as an adhesive holding wood fiber together and making the wood strong and stiff.

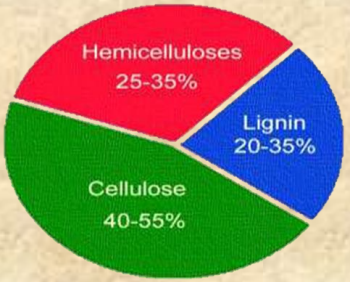


Diagram 4: Main chemical constituents in wood

Other chemicals are present in wood besides cellulose, hemicellulose, and lignin. These chemicals are called extractives. The amount of extractives present in wood varies depending on the species. Extractives give wood its colour, smell, and resistance to decay, fungus, and insects.

WOOD CELL WALL

The cell wall of wood generally consists of cellulose, hemicellulose and lignin, which differ in their chemical structure and physical properties (Zhang, Li & Xu,2022). The cell wall of wood consists of about 45% cellulose and 20-30% hemicelluloses and lignin. The ratio of hemicelluloses to lignin varies depending on the wood species, softwood or hardwood.

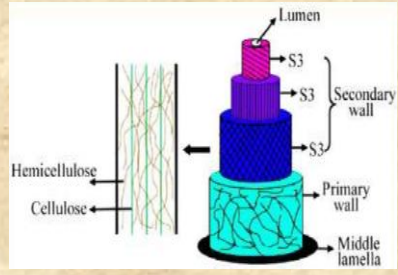


Diagram 4: Wood cell wall structure (Zhang, Li & Xu,2015)

Wood cell walls are made of carbon, hydrogen, and oxygen. The average carbon content is 49%, hydrogen is about 6%, and oxygen is 44% based on dry wood weight. Other chemical elements are found in wood but in very small quantities.

Cellulose, hemicellulose, and lignin are synthesized in the fluid-filled center of a developing cell. Cellulose and hemicellulose make up the polysaccharide fraction of wood substance. Cellulose is a high molecular weight, linear polymer synthesized from glucose. Cellulose occurs in both a crystalline and a non-crystalline (amorphous) form in wood cell walls. Hemicelluloses are branched carbohydrate polymers formed from sugars

produced in photosynthesis. They constitute from 35% to 50% of the total dry weight of wood substance.

Lignin is a complex, high molecular weight amorphous polymer built upon phenylpropane units. Lignin content varies from 15% to 35% of the dry weight.

Percentages of the various chemical components differ among tree species and growth conditions. Wood cells use an efficient incorporation scheme called the 'reinforced matrix process' to fabricate their walls. Crystalline cellulose chains are aligned lengthwise and encased in a shell of hemicellulose to form a long filament. This filament is surrounded by an amorphous matrix of lignin.

The high strength of wood is derived primarily from its structure at the microscopic level. Wood is composed of long cells in the axial direction and thin cells in the radial and tangential directions.

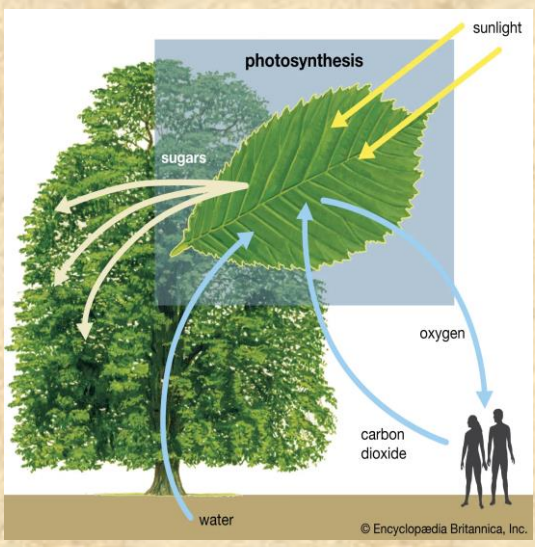
The smallest part of microstructural component of wood is called a microfibril. Microfibrils are bundles of cellulose chains covered first by hemicellulose and then by lignin.

The long, thin wood cells are composed of many layers of microfibrils. The microfibrils are arranged in separate, differently oriented layers. The changing orientation of layers within the structure gives the wood cells better strength in more directions. However, the wood structure is still considered to be very anisotropic.

CHAPTER 5:

THE RELATIONSHIP BETWEEN THE PHOTOSYNTHESIS PROCESS AND CHEMICAL PROPERTIES OF WOOD

PHOTOSYNTHESIS PROCESS



Photosynthesis is a process that begins in the leaves of trees and contributes to tree growth. It produces oxygen, which is released into the atmosphere, as well as basic sugars, such as glucose, mannose, galactose and xylose.

Diagram 5: Photosynthesis process

The glucose units produced by photosynthesis are used to form cellulose, a linear polymer with a degree of polymerization ranging from 20 000 to 30 000 monomer units. Glucose and other five- and six-carbon sugars and sugar derivatives are used to synthesize hemicelluloses, which are components of woody plants (A Zink-Sharp, 2004).

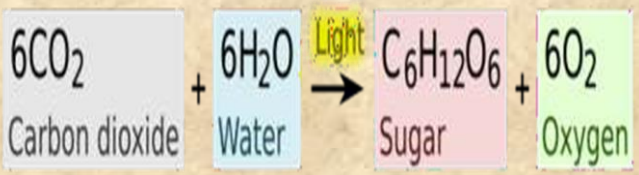
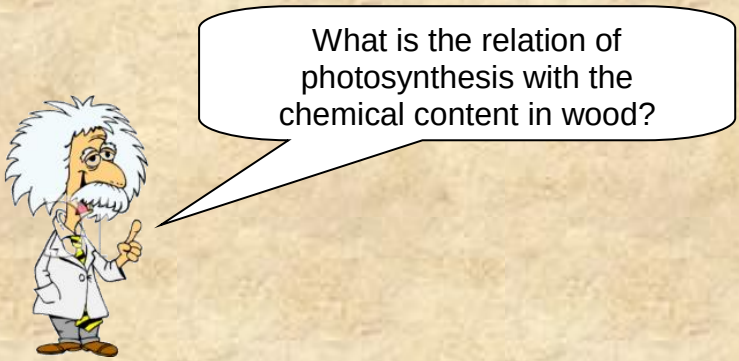


Diagram 6: Chemical composition in wood



Photosynthesis produces organic compounds used as building blocks for wood. Chemical components of wood, such as cellulose, hemicellulose, and lignin, are derived from sugars produced during photosynthesis. Tree species and environmental factors influence the type and amount of chemical components in wood. Photosynthesis is crucial in determining the chemical composition of wood. In Diagram 4 shows the photosynthesis process occurred in the wood tree.

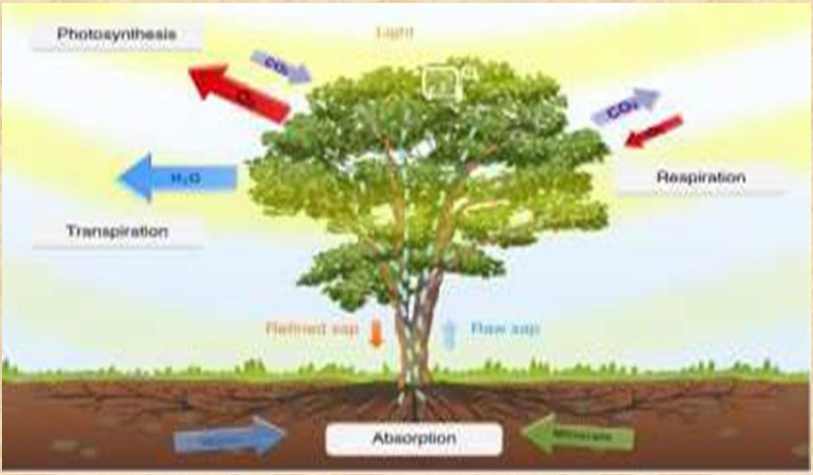


Diagram 7: Photosynthesis process in tree growth

CHAPTER 6:

RELATION OF WOOD CHEMICAL COMPOSITION TO QUALITY AND PROPERTIES OF WOOD

WOOD pH

The pH of wood measures its acidity or alkalinity, with neutral at 7, below 7 being acidic, and above 7 being alkaline. The pH of wood ranges from 4.5 to 6.5, which is slightly acidic. The acidity is due to organic acids produced during the growth and metabolism of the tree. The pH of wood affects various applications, including paper manufacturing and the performance and durability of wood products. A slightly acidic pH in paper manufacturing can improve efficiency, and the pH can affect the resistance to decay and insect attack in wood products.

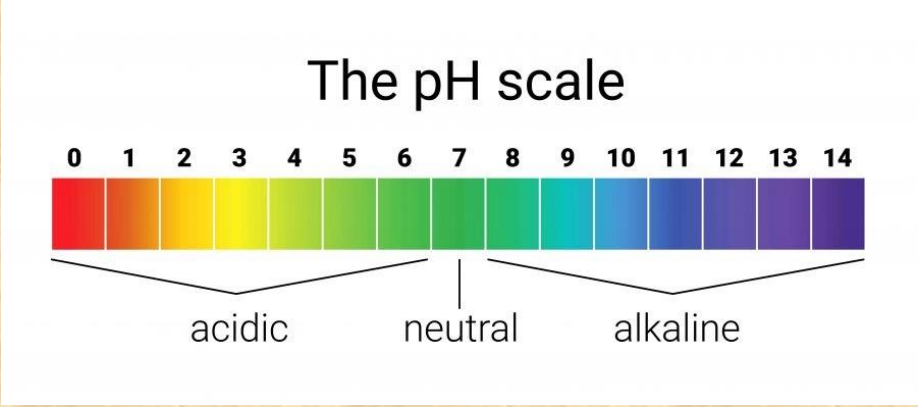
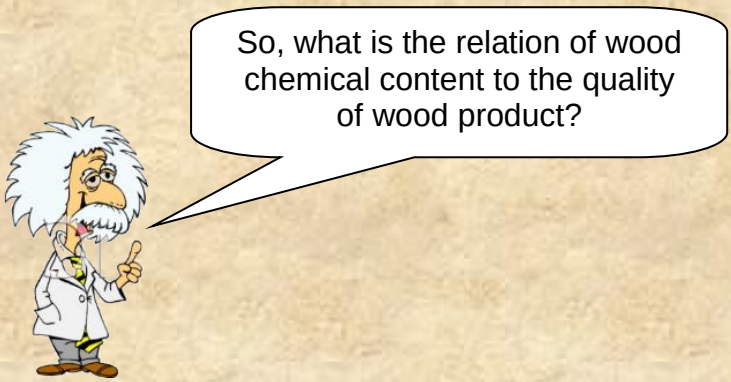


Diagram 8: pH Scale

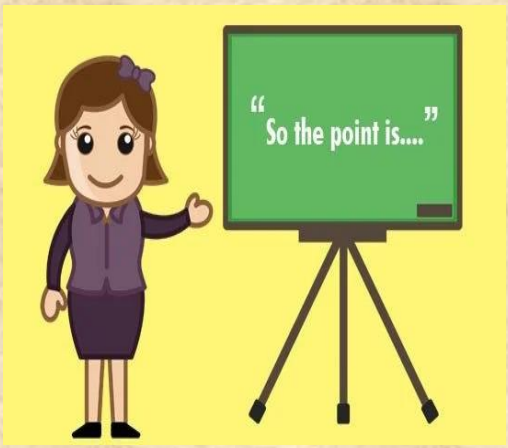


The chemical content of wood has a significant impact on the quality of wood products such as:

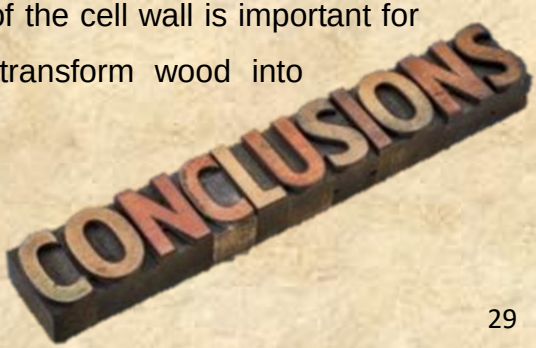
- The amount and distribution of cellulose and hemicellulose affects the strength and durability of the wood product.
- The lignin content affects the density and hardness of the wood product, as well as its ability to absorb water and other liquids.
- Wood with high lignin content tends to be more resistant to decay and insect damage.
- The chemical composition of wood affects its response to various processing techniques, such as sawing, sanding, and gluing.
- The presence of extractives, such as resins and oils, can affect the colour, odour, and stability of the wood product.
- The chemical content of wood can also affect its combustibility and potential for use as a fuel source.

CHAPTER 7:

CONCLUSIONS



- The wood cell wall consists primarily of cellulose, hemicellulose, and lignin. Cellulose provides mechanical strength and rigidity to the wood.
- Hemicellulose helps to bind the cellulose fibers together and affects the water-holding capacity and swelling behaviour of the wood.
- Lignin provides additional mechanical strength and rigidity to the cell wall and affects the colour, durability, and decay resistance of the wood.
- The chemical composition of the cell wall can vary between wood species and within the same tree.
- The chemical composition of the cell wall affects the properties and performance of the wood, including strength, stiffness, hardness, shrinkage, swelling, decay resistance, and colour.
- The chemical composition of the cell wall is important for developing processes to transform wood into various wood products.



CHAPTER 8:

PRACTICAL WORK

PRACTICAL WORK 1A

How to determine wood moisture content using the oven?

Determination of Moisture Content of Wood Sawdust by Junaiza Ahmad Zaki

Click this to see the video!

The procedure:

1. Collect a wood sample and record initial weight (W1)
2. Dry the wood sample in a preheated oven at 103-105°C (218-221°F) for 24 hours and record the dry weight (W2)
3. Calculate the moisture content using the formula: Moisture content (%) = [(W1-W2) / W1] x 100

PRACTICAL WORK 1B

How to measure the wood pH using litmus paper?

Determination of Wood pH Using Litmus Paper by amritacreate

Click this to see the video!

The procedure:

1. Prepare the wood sample by grinding it into small particles.
2. Prepare the litmus paper by moistening with distilled water.
3. Apply the wood sample to the litmus paper and observe the colour change to determine the pH.
4. Note: Ensure the sample is properly ground and mixed with distilled water for accurate pH measurement.

PRACTICAL WORK 1C

How to measure the wood pH using pH meter?

Determination of Wood pH Using pH Meter by Bio-Rad Laboratories

Click this to see the video!

The procedure:

1. Prepare the wood sample by grinding it into small particles.
2. Prepare the pH meter by turning it on and rinsing the electrode with distilled water.
3. Measure the pH by adding the ground wood sample to a beaker of distilled water and placing of the electrode in the solution.
4. Record the pH.

CHAPTER 9:

SHORT THEORY ACTIVITY

ANSWER Short Questions

You are required to answer these questions and discuss the answers in the class.

Q1:	What is the primary Structural component of wood?
Q2:	How much of the dry weight of wood does cellulose make up?
Q3:	What are the roles of cellulose and hemicellulose in the wood cell wall?
Q4:	What is hemicellulose, and how much dry weight of wood does it make up?
Q5:	How does the chemical composition of wood vary between different tree species?
Q6:	How does photosynthesis relate to the chemical composition of the wood cell wall?

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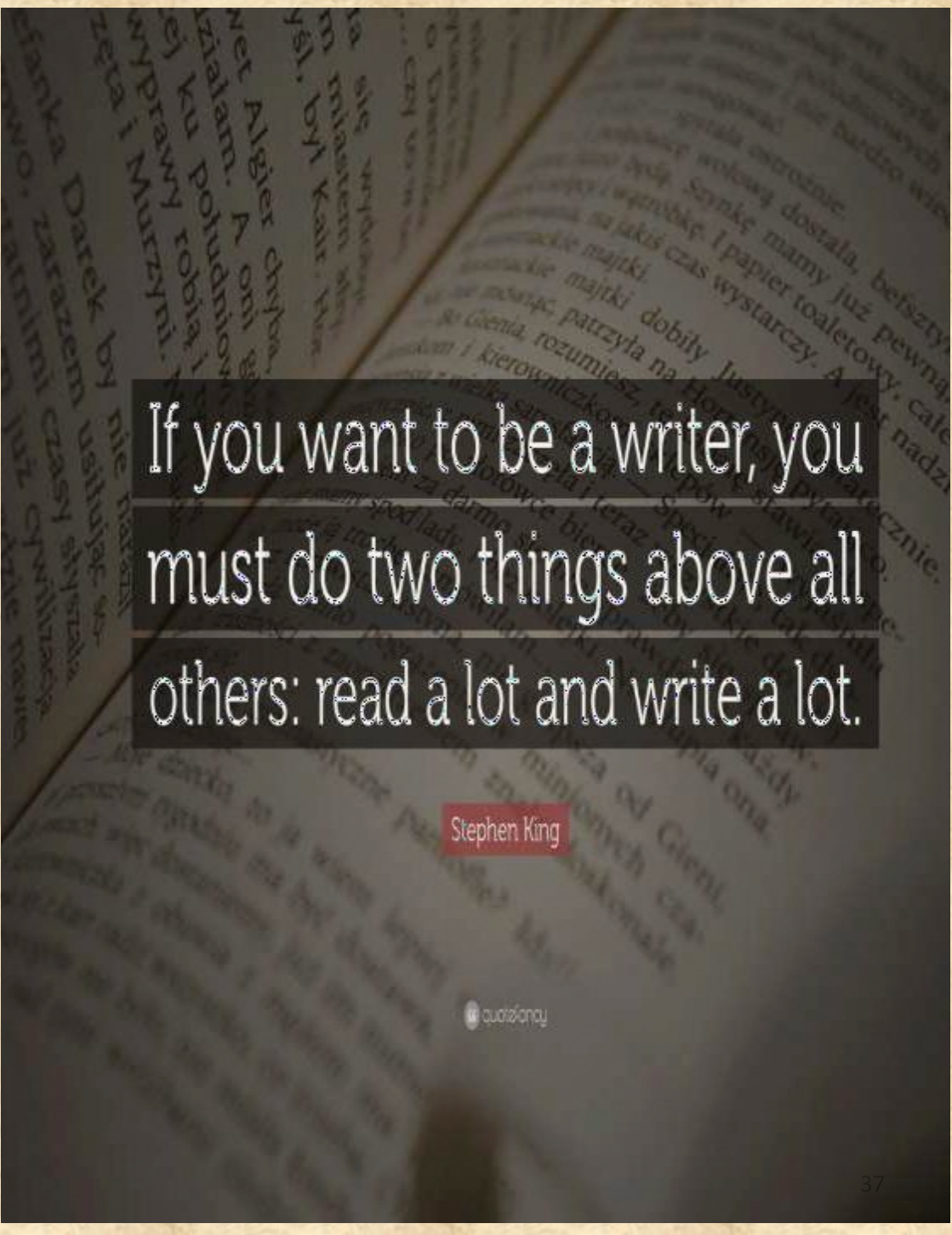
If you want to be a writer, you must do two things above all others: read a lot and write a lot.
Stephen King

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