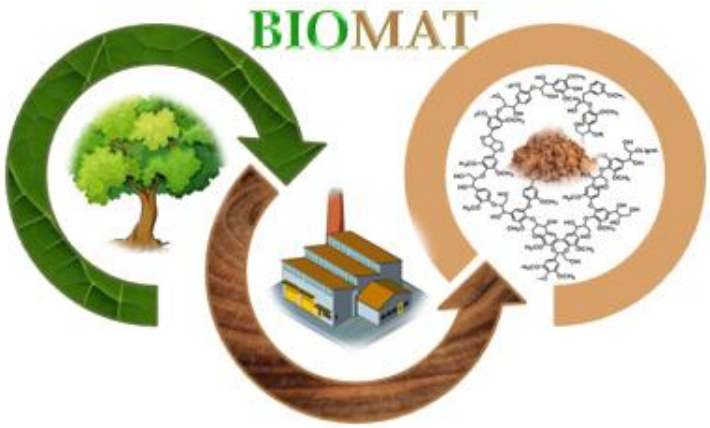
KTH ROYAL INSTITUTE OF TECHNOLOGY, SWEDEN



Part 1
E-test

Lignin isolation, characterization, fractionation, and modification

author:

OLENA SEVASTYANOVA

Sweden 2025

Co-funded by the European Union

"Improving teaching competencies in design of new generation biomaterials from wood waste"
Project reference: 2024-1-PL01-KA220-HED-000246133 from the Erasmus+ programme:
KA220-HED - Cooperation partnerships in higher education

The e-test was created

as part of the project titled

"Improving teaching competences in the field of designing new generation biomaterials from wood waste "

Project no.: 2024-1-PL01-KA220-HED-000246133

Erasmus+ Programme:

KA220-HED – Collaborative Partnerships in Higher Education.

Choose and mark one correct answer:

1. Lignin is the primary natural source of which type of carbon in biomass?
A. aliphatic carbon
B. aromatic carbon
C. carbonyl carbon
D. carboxylic carbon

2. Which of the following linkages is NOT a common interunit bond in lignin?
A. β–O–4 ether
B. β–5 phenylcoumaran
C. α–1,4 glycosidic bond
D. 5–5′ biphenyl bond

3. In softwoods (gymnosperms), which lignin monomer dominates the structure?
A. syringyl (S) unit
B. p-hydroxyphenyl (H) unit
C. guaiacyl (G) unit
D. coniferyl aldehyde

4. The most common interunit linkage in native lignin is:
A. β–5 (phenylcoumaran)
B. β–β (resinol)
C. β–O–4 ether bond
D. 5–5′ biphenyl bond

5. Which compound is NOT a monolignol precursor of lignin?
A. coniferyl alcohol
B. sinapyl alcohol
C. p-coumaryl alcohol
D. glucose

6. Hardwood lignin is generally:
A. more condensed and crosslinked than softwood lignin
B. rich in syringyl units and more linear than softwood lignin
C. exclusively composed of guaiacyl units
D. less reactive due to higher crosslinking density

7. The method developed by Björkman (1956) for isolating native lignin is called:
A. sulfite pulping
B. kraft process
C. milled wood lignin (MWL) method
D. acid hydrolysis

8. Which industrial pulping process produces lignosulfonates as a main lignin by-product?
A. kraft process

B. sulfite process
C. soda process
D. organosolv process

9. Soda lignin is mainly obtained from:
A. softwoods such as pine and spruce
B. hardwood eucalyptus plantations
C. non-wood biomass like wheat straw and bagasse
D. mixed forestry residues only

10. Organosolv lignin is considered more "native-like" than kraft lignin because:
A. it is obtained under extremely harsh chemical conditions
B. it retains more β–O–4 linkages and has low sulfur content
C. it contains high ash impurities
D. it has very high molecular weight and polydispersity

11. The kraft pulping process primarily uses which chemicals in the cooking liquor (white liquor)?
A. sodium hydroxide and sodium sulfide
B. sulfurous acid(IV) and bisulfite salts
C. sodium hydroxide only
D. ethanol mixed with acetic acid

12. What is the main role of the kraft cooking step in pulping?
A. to dissolve cellulose completely
B. to remove lignin from the wood matrix and separate fibers
C. to increase the lignin content in the pulp
D. to hydrolyze hemicellulose selectively

13. Compared to organosolv lignin, kraft lignin is characterized by:
A. low phenolic hydroxyl content and high solubility in water
B. high content of phenolic hydroxyl groups and condensed structures
C. very narrow molecular weight distribution
D. being sulfur-free and more native-like

14. In industrial practice, what happens to most of the lignin dissolved during kraft pulping?
A. it is precipitated and sold as vanillin
B. it is combusted in the recovery boiler for energy and chemical regeneration
C. it is transformed into organosolv lignin
D. it remains in the pulp as residual lignin

15. Which statement correctly compares kraft lignin with lignosulfonates?
A. kraft lignin is sulfur-free, while lignosulfonates contain sulfonic acid groups.
B. kraft lignin is water-soluble, while lignosulfonates are hydrophobic.
C. kraft lignin has higher thermal stability but lower solubility in water compared to lignosulfonates.

D. kraft lignin has a much higher molecular weight than lignosulfonates.

16. The LignoBoost® process, developed in Sweden, extracts lignin from black liquor using:
A. enzymatic hydrolysis followed by ultrafiltration
B. acidification with carbon dioxide and sulfuric acid precipitation
C. solvent extraction with ethanol–water mixtures
D. direct oxidation with oxygen and ozone

17. Which company commercialized the LignoForce™ process in North America?
A. Stora Enso (Finland)
B. Domtar (USA/Canada)
C. Borregaard (Norway)
D. WestRock (USA)

18. What is the key difference of the LignoForce™ process compared to LignoBoost®?
A. it uses organic solvents for lignin solubilization
B. it includes a pre-oxidation step with oxygen to reduce sulfur emissions and improve filterability
C. it applies enzymatic hydrolysis before precipitation
D. it produces lignosulfonates instead of kraft lignin

19. Which lignin recovery method uses membrane separation to fractionate lignin directly from black liquor?
A. SILVA™ process
B. LignoBoost®
C. Soda process
D. Organosolv process

20. Which technique is used to fractionate technical lignins into more uniform fractions by molecular weight?
A. Soxhlet extraction
B. ultrafiltration
C. thermal pyrolysis
D. gel electrophoresis

21. The main purpose of lignin fractionation is:
A. to increase the lignin yield in pulping
B. to isolate lignin fractions with narrower molecular weight distributions and tailored properties
C. to remove sulfur completely from lignin
D. to convert lignin directly into vanillin

22. Which advantage does ultrafiltration provide for lignin processing?
A. it hydrolyzes lignin into monomeric phenols
B. it separates lignin fractions by molecular size without pH adjustment
C. it introduces sulfonic groups into lignin

D. it increases the lignin condensation level

23. Drawback of ionic liquid fractionation of lignin is:
A. poor selectivity for lignin over carbohydrates
B. high cost and challenges in solvent recyclability
C. low reactivity of the resulting fractions
D. complete degradation of β–O–4 linkages

24. Which modification strategy introduces new reactive sites such as amino or sulfonic groups into lignin?
A. functionalization of hydroxyl groups
B. creation of new chemical active sites
C. solvent extraction
D. thermal cracking

25. Esterification, etherification, and urethanization of lignin are examples of:
A. functionalization of existing hydroxyl groups
B. introduction of nitro groups
C. depolymerization reactions
D. thermal stabilization processes

26. Which chemical modification makes lignin more compatible with hydrophobic polymers by reducing polarity?
A. phenolation
B. oxidation to aldehydes
C. etherification
D. sulfonation

27. Which analytical technique is the standard method for determining the molecular weight distribution of lignin?
A. Fourier Transform Infrared Spectroscopy (FTIR)
B. Differential Scanning Calorimetry (DSC)
C. Nuclear Magnetic Resonance (NMR)
D. Gel Permeation Chromatography (GPC/SEC)

28. In ^{31}P NMR spectroscopy of lignin, hydroxyl groups are quantified after derivatization with which reagent?
A. diazomethane
B. sulfuric acid
C. sodium hydroxide
D. 2-chloro-4,4,5,5-tetramethyl-1,3,2-dioxaphospholane (TMDP)

29. Thermal analysis of lignin by TGA and DSC typically provides data on:
A. interunit linkage distribution (β–O–4, β–5, β–β)
B. lignin carbohydrate impurities
C. solubility parameters in organic solvents
D. glass transition temperature (Tg) and degradation temperature (Td)

30. Which type of lignin currently represents the largest share of the commercial lignin market (≈80%)?
A. lignosulfonates
B. kraft lignin
C. organosolv lignin
D. soda lignin

31. Which are considered the most promising high-value applications for lignin in the future?
A. carbon fibers, aromatic chemicals (e.g., vanillin, adipic acid), advanced polymer precursors
B. boiler fuels for energy recovery only
C. paper fillers and low-grade binders
D. soil improvers with no chemical processing

32. A key challenge for the use of kraft lignin in high-value polymer products is:
A. its low availability compared to organosolv lignin
B. lack of aromatic structures
C. high purity and uniformity
D. its heterogeneity, limited solubility, and condensed structure

33. The Björkman (MWL) method for native lignin isolation involves:
A. sulfuric acid hydrolysis of cellulose
B. extensive ball milling followed by dioxane extraction
C. direct precipitation from black liquor with sulfuric acid
D. steam explosion of wood chips

34. A limitation of the Björkman MWL method is that:
A. it recovers nearly 100% of lignin
B. it produces lignin that is chemically identical to kraft lignin
C. it yields only 20–35% of total lignin and may bias toward soluble fractions
D. it requires high-sulfur reagents

35. In kraft pulping, the cooking liquor (white liquor) mainly contains:
A. sodium hydroxide and sodium sulfide
B. sulfurous acid(VI) and sulfur oxide(IV)
C. sodium hydroxide only
D. ethanol and acetic acid

36. The term "effective alkali (EA)" in kraft pulping refers to:
A. the ratio of sodium to sulfur in black liquor
B. the percentage of NaOH equivalent added on dry wood
C. the total solids content of cooking liquor
D. the lignin removal efficiency at a given H-factor

37. Sulphidity in kraft pulping is defined as:
A. the fraction of total alkali present as sodium sulfide

B. the percentage of hemicellulose lost during cooking
C. the sulfur content of recovered lignin
D. the kappa number of unbleached pulp

38. The liquor-to-wood ratio in kraft cooking typically ranges between:
A. 0.1–0.5 L/kg
B. 1–2 L/kg
C. 3–7 L/kg
D. 10–15 L/kg

39. The H-factor in kraft cooking is a measure of:
A. hemicellulose degradation rate
B. integrated effect of time and temperature on delignification
C. lignin carbohydrate complex formation
D. the white liquor effective alkali concentration

40. A higher H-factor during kraft cooking generally results in:
A. higher pulp yield and lower delignification
B. lower kappa number and reduced residual lignin
C. increased cellulose chain length
D. lower carbohydrate degradation

41. The kappa number of pulp is used to estimate:
A. hemicellulose content
B. fiber tensile strength
C. residual lignin content
D. effective alkali concentration

42. Incomplete fiber separation after kraft cooking leads to:
A. ash formation
B. shives in the pulp
C. higher effective alkali
D. increased sulphidity

43. In the lab protocol for kraft lignin isolation, lignin is precipitated by:
A. cooling to 0°C
B. adding ethanol as an antisolvent
C. acidifying to pH ~2 with sulfuric acid
D. oxidizing with hydrogen peroxide

44. After precipitation in laboratory conditions, kraft lignin is typically purified by:
A. washing with sulfuric acid solution at pH 2 and centrifugation
B. evaporation of the supernatant
C. thermal annealing at 150°C
D. soxhlet extraction with benzene

45. Characteristic UV–Vis feature of lignin is strong absorbance at:
A. 180 nm due to cellulose
B. 280 nm due to aromatic rings
C. 450 nm due to carbonyl groups
D. 600 nm due to polysaccharides

46. In UV–Vis spectra of lignin, a shoulder near 340 nm indicates:
A. protein contamination
B. presence of conjugated or oxidized aromatic structures
C. high glucose content
D. absence of phenolic groups

47. Compared to organosolv lignin, kraft lignin is generally:
A. sulfur-free and more native-like
B. rich in phenolic hydroxyl groups and condensed structures
C. low in molecular weight and polydispersity
D. highly soluble in water at all pH values

48. Which technical lignin type has the highest typical molecular weight (15–50 kDa)?
A. kraft lignin
B. soda lignin
C. lignosulfonates
D. organosolv lignin

49. Which technical lignin type usually has the lowest glass transition temperature (Tg ~90–110°C)?
A. kraft lignin
B. soda lignin
C. lignosulfonates
D. organosolv lignin

50. A drawback of milled wood lignin (MWL) as a model for native lignin studies is that:
A. it may overrepresent soluble, low-MW fractions and requires long extraction times
B. it is obtained from non-wood biomass only
C. it contains sulfur residues
D. it is fully condensed and insoluble

Part 1_ Answer Sheet

E-test

Lignin isolation, characterization, fractionation, and modification

Name and surname: ……..……..… Date: ……..……..……

Points: ……..……/50 pts, Percentages:……/100%

Number questions	Answer	Number questions	Answer	Number questions	Answer	Number questions	Answer	Number questions	Answer
1.		**11.**		**21.**		**31.**		**41.**	
2.		**12.**		**22.**		**32.**		**42.**	
3.		**13.**		**23.**		**33.**		**43.**	
4.		**14.**		**24.**		**34.**		**44.**	
5.		**15.**		**25.**		**35.**		**45.**	
6.		**16.**		**26.**		**36.**		**46.**	
7.		**17.**		**27.**		**37.**		**47.**	
8.		**18.**		**28.**		**38.**		**48.**	
9.		**19.**		**29.**		**39.**		**49.**	
10.		**20.**		**30.**		**40.**		**50.**	

Co-funded by the European Union

"Improving teaching competencies in design of new generation biomaterials from wood waste"
Project reference: 2024-1-PL01-KA220-HED-000246133 from the Erasmus+ programme:
KA220-HED - Cooperation partnerships in higher education

Part 1_ Answer Key
E-test

Lignin isolation, characterization, fractionation, and modification

Each correct answer: 1 point, maximum number of points to be obtained: 50 points.

1. B	**11. A**	**21. B**	**31. A**	**41. C**
2. C	**12. B**	**22. B**	**32. D**	**42. B**
3. C	**13. B**	**23. B**	**33. B**	**43. C**
4. C	**14. B**	**24. B**	**34. C**	**44. A**
5. D	**15. C**	**25. A**	**35. A**	**45. B**
6. B	**16. B**	**26. C**	**36. B**	**46. B**
7. C	**17. B**	**27. D**	**37. A**	**47. B**
8. B	**18. B**	**28. D**	**38. C**	**48. C**
9. C	**19. A**	**29. D**	**39. B**	**49. D**
10. B	**20. B**	**30. A**	**40. B**	**50. A**

Co-funded by the European Union

"Improving teaching competencies in design of new generation biomaterials from wood waste"
Project reference: 2024-1-PL01-KA220-HED-000246133 from the Erasmus+ programme:
KA220-HED - Cooperation partnerships in higher education