tert-butyl phenols, and creates another undesirable byproduct. Besides the additional expense, the additional byproducts are unattractive for environmental reasons. Various other methods of producing tert-butyl phenols are disclosed in U.S. Patent No. 4,166,191, but these processes, like the conventional methods, utilize extra steps and expensive materials.

[0006] What is needed in the art is a method of producing a tert-butyl phenol by selectively reacting a phenol with an isobutylene-containing C_4 raffinate stream so that the isobutylene reacts with the phenol while none, or very few, of the butenes present in the C_4 raffinate stream are reacted with the phenol. This invention answers that need.

Summary of the Invention

[0007] This invention relates to a process for producing a tert-butyl phenol, such as 2,6-di-tert-butyl phenol or ortho-tert-butyl phenol that involves reacting an isobutylene-containing C_4 raffinate stream with a phenol or a substituted phenol in the presence of a Group IIIb metal, such as aluminum, or a Group IIIb metal oxide, such as aluminum oxide. The reaction should be run at a reaction temperature ranging from about 50° C to about 150° C, where the molar ratio of isobutylene to phenol ranges from about 0.5:1 to about 3:1.

[0008] The invention also relates to a process for producing ortho-tert-butyl phenol that involves reacting an isobutylene-containing C_4 raffinate stream with a phenol in the presence of an aluminum oxide catalyst. In this process, the reaction temperature ranges from about 150° C to about 200° C, and the molar ratio of isobutylene to phenol ranges from about 0.5:1 to about 1.5:1.

[0009] The invention also relates to a process for producing 2,6-di-tert-butyl phenol that involves reacting an isobutylene-containing C_4 raffinate stream with ortho-tert-butyl phenol in the presence of aluminum or aluminum trisphenoxide. In this process, the reaction temperature ranging from about 0° C to about 30° C, and the molar ratio of isobutylene to ortho-tert-butyl phenol ranges from about 0.5:1 to about 2.0:1.

[0010] The invention also relates to a process for producing a tert-butyl phenol, such as 2,6-di-tert-butyl phenol or ortho-tert-butyl phenol, that involves reacting a phenol with a C_4 raffinate stream containing (a) isobutylene, and (b) 1-butene and/or 2-butene. The reaction is run under reaction conditions that selectively react the isobutylene with the phenol to produce the tert-butyl phenol without substantially reacting the 1-butene or 2-butene with the phenol.

CLAIMS

1. A process for producing a tert-butyl phenol, comprising reacting a phenol with a C_4 raffinate stream containing (a) isobutylene, and (b) 1-butene and/or 2-butene under reaction conditions that selectively react the isobutylene with the phenol to produce the tert-butyl phenol without substantially reacting the 1-butene or 2-butene with the phenol.

2. The process of claim 1, wherein the tert-butyl phenol is a 2,6-di-tert-butyl phenol, ortho-tert-butyl phenol, or a combination thereof.

3. The process of claim 1, wherein less than 1% of the 1-butene and 2-butene present in the C_4 raffinate stream is reacted with the phenol.

4. The process of claim 1, wherein at least about 80% of the available phenol reacts with the isobutylene.

5. The process of claim 1, wherein the tert-butyl phenol composition contains less than 0.1% by weight of sec-butyl phenols.

6. The process of claim 1, wherein the isobutylene-containing C_4 raffinate stream is directly reacted with a phenol, the reaction proceeding without an intermediate step of forming an alkyl-tert-butyl ether.

7. The process of claim 6, wherein the alkyl-tert-butyl ether is methyl-tert-butyl ether or methyl-tert-amyl ether.

8. The process of claim 1, wherein the isobutylene-containing C_4 raffinate stream is directly reacted with a phenol, the reaction proceeding without an intermediate step of introducing an alcohol into the C_4 raffinate stream.

9. The process of claim 8, wherein the alcohol is methanol or amyl alcohol.

10. The process of claim 2, wherein the isobutylene-containing C_4 raffinate stream is reacted with the phenol in the presence of a Group IIIb metal or a Group IIIb metal oxide at a reaction temperature ranging from about 50° C to about 150° C and under pressure ranging from 0 to 500 psig, wherein the molar ratio of isobutylene to phenol ranges from about 0.5:1 to about 3:1.

11. The process of claim 10, further comprising the step of transalkylating the 2,6-di-tert-butyl phenol and/or ortho-tert-butyl phenol to form a compound selected from the group consisting of para-tert-butyl phenol, 2,4-di-tert-butyl phenol, and a combination thereof.

12. The process of claim 10, wherein the isobutylene-containing C_4 raffinate stream contains at least 75% isobutylene.

13. The process of claim 10, wherein the Group IIIb metal is aluminum and the Group IIIb metal oxide is an aluminum oxide.

14. The process of claim 1, wherein the isobutylene-containing C_4 raffinate stream is reacted with the phenol in the presence of an aluminum oxide catalyst at a reaction temperature ranging from about 160° C to about 180° C and under pressure ranging from 0 to 500 psig, wherein the molar ratio of isobutylene to phenol ranges from about 0.9:1 to about 1.1:1.

15. The process of claim 14, wherein the tert-butyl phenol is ortho-tert-butyl phenol.

16. The process of claim 15, wherein the aluminum oxide catalyst is gamma-alumina in a solid form.

17. The process of claim 1, wherein the phenol is an ortho-tert-butyl phenol.

18. The process of claim 17, wherein the isobutylene-containing C_4 raffinate stream is reacted with ortho-tert-butyl phenol in the presence of aluminum or aluminum trisphenoxide at a reaction temperature ranging from about 10° C to about 20° C and under pressure ranging from 0 to 50 psig, wherein the molar ratio of isobutylene to ortho-tert-butyl phenol ranges from about 0.8:1 to about 1.2:1.

19. The process of claim 18, wherein the tert-butyl phenol is 2,6-di-tert-butyl phenol.

20. The process of claim 18, wherein the aluminum trisphenoxide is formed by the reaction of a trialkyl aluminum with ortho-tert-butyl phenol.

21. The process of claim 1, wherein the reaction is run in a batch mode, continuous mode, stirred-tank reactor, continuous stirred-tank reactor, fixed-bed reactor, or fluidized bed reactor.

tert-butyl phenols, and creates another undesirable byproduct. Besides the additional expense, the additional byproducts are unattractive for environmental reasons. Various other methods of producing tert-butyl phenols are disclosed in U.S. Patent No. 4,166,191, but these processes, like the conventional methods, utilize extra steps and expensive materials. GB 655,124 discloses a method of separating a higher poly-tert-butyl phenol or cresol from partially butylated phenols by cooling or allowing to cool the mixture resulting from the alkylation of a phenol with isobutylene or with a tert-butyl-halide in the presence of an γ-alumina catalyst. US 4,260,833 describes a process of introducing a plurality of alkyl groups into the aromatic ring of a hydroxyl-substituted aromatic compound with an olefin in the presence of doped alumina wherein the alumina contains from about 0.1% to 2% lithium and the olefin is isobutylene. US 2,353,282 relates to the production of substituted phenols at atmospheric pressures by the introduction of alkyl substituents into the nucleus of phenolic compounds in the presence of a catalyst composition of an acid or other oxy compound or boron and oxalic acid or one of its compounds. In CS 276820 phenols and its derivatives are alkylated and/or aralkylated in the gas and/or liquid phases by at least one agent selected from (aryl) alkyl chlorides, (aryl) alkenes, (aryl)alkanols, dialkyl ethers and (aryl) alkene dimers on a heterogeneous acid catalyst at 50-250^{0}C with a mol ratio (aryl) alkylating agent to phenol of 0.1-4:1 and optionally with an inert gas.

[0006] What is needed in the art is a method of producing a tert-butyl phenol by selectively reacting a phenol with an isobutylene-containing C_4 raffinate stream so that the isobutylene reacts with the phenol while none, or very few, of the butenes present in the C_4 raffinate stream are reacted with the phenol. This invention answers that need.

Summary of the Invention

[0007] This invention relates to a process for producing a tert-butyl phenol, such as 2,6-di-tert-butyl phenol or ortho-tert-butyl phenol that involves reacting an isobutylene-containing C_4 raffinate stream with a phenol or a substituted phenol in the presence of a Group IIIb metal, such as aluminum, or a Group IIIb metal oxide, such as aluminum oxide. The reaction should be run at a reaction temperature ranging from about 50° C to about 150° C, where the molar ratio of isobutylene to phenol ranges from about 0.5:1 to about 3:1.

[0008] The invention also relates to a process for producing ortho-tert-butyl phenol that involves reacting an isobutylene-containing C_4 raffinate stream with a phenol in the presence of an aluminum oxide catalyst. In this process, the reaction temperature ranges from about 150° C to about 200° C, and the molar ratio of isobutylene to phenol ranges from about 0.5:1 to about 1.5:1.

[0009] The invention also relates to a process for producing 2,6-di-tert-butyl phenol that involves reacting an isobutylene-containing C_4 raffinate stream with ortho-tert-butyl phenol in the presence of aluminum or aluminum trisphenoxide. In this process, the reaction temperature ranging from about 0° C to about 30° C, and the molar ratio of isobutylene to ortho-tert-butyl phenol ranges from about 0.5:1 to about 2.0:1.

[0010] The invention also relates to a process for producing a tert-butyl phenol, such as 2,6-di-tert-butyl phenol or ortho-tert-butyl phenol, that involves reacting a phenol with a C_4 raffinate stream containing (a) isobutylene, and (b) 1-butene and/or 2-butene. The reaction is run under reaction conditions that selectively react the isobutylene with the phenol to produce the tert-butyl phenol without substantially reacting the 1-butene or 2-butene with the phenol.

CLAIMS

1. A process for producing 2,6-di-tert-butyl phenol, comprising reacting a phenol with a C_4 raffinate stream containing (a) isobutylene, and (b) 1-butene and/or 2-butene under reaction conditions that selectively react the isobutylene with the phenol to produce the 2,6-di-tert-butyl phenol without substantially reacting the 1-butene or 2-butene with the phenol, wherein at least about 76% by weight of the phenol reacts with the isobutylene in forming the 2,6-di-tert-butyl phenol.

2. The process of claim 1, wherein less than 1% by weight of the 1-butene and 2-butene present in the C_4 raffinate stream is reacted with the phenol.

3. The process of claim 1, wherein at least 80% by weight of the phenol reacts with the isobutylene.

4. The process of claim 1, wherein the process produces less than 0.1% by weight of sec-butyl phenols.

5. The process of claim 1, wherein the isobutylene-containing C_4 raffinate stream is directly reacted with a phenol, the reaction proceeding without an intermediate step of forming an alkyl-tert-butyl ether.

6. The process of claim 5, wherein the alkyl-tert-butyl ether is methyl-tert-butyl ether or methyl-tert-amyl ether.

7. The process of claim 1, wherein the isobutylene-containing C_4 raffinate stream is directly reacted with a phenol, the reaction proceeding without an intermediate step of introducing an alcohol into the C_4 raffinate stream.

8. The process of claim 7, wherein the alcohol is methanol or amyl alcohol.

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9. The process of claim 1, wherein the isobutylene-containing C_4 raffinate stream is reacted with the phenol in the presence of a Group IIIb metal at a reaction temperature ranging from about 50° C to about 150° C and under pressure ranging from 0 to 500 psig, wherein the molar ratio of isobutylene to phenol ranges from about 0.5:1 to about 3:1.

10. The process of claim 9, further comprising the step of transalkylating the 2,6-di-tert-butyl phenol to form a compound selected from the group consisting of para-tert-butyl phenol, 2,4-di-tert-butyl phenol, and a combination thereof.

11. The process of claim 9, wherein the isobutylene-containing C_4 raffinate stream contains at least 75% by weight isobutylene.

12. The process of claim 9, wherein the Group IIIb metal is aluminum.

13. The process of claim 1, wherein the phenol is an ortho-tert-butyl phenol.

14. The process of claim 13, wherein the isobutylene-containing C_4 raffinate stream is reacted with ortho-tert-butyl phenol in the presence of aluminum or aluminum trisphenoxide at a reaction temperature ranging from about 10° C to about 20° C and under pressure ranging from 0 to 50 psig, wherein the molar ratio of isobutylene to ortho-tert-butyl phenol ranges from about 0.8:1 to about 1.2:1.

15. The process of claim 14, wherein the aluminum trisphenoxide is formed by the reaction of a trialkyl aluminum with ortho-tert-butyl phenol.

16. The process of claim 1, wherein the reaction is run in a batch mode, continuous mode, stirred-tank reactor, continuous stirred-tank reactor, fixed-bed reactor, or fluidized bed reactor.

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17. A process for producing 2,6-di-tert-butyl phenol, comprising reacting a phenol with a C_4 raffinate stream containing (a) isobutylene, and (b) 1-butene and/or 2-butene under reaction conditions, including a reaction temperature ranging from about 70° C to about 130° C, that selectively react the isobutylene with the phenol to produce the 2,6-di-tert-butyl phenol without substantially reacting the 1-butene or 2-butene with the phenol, wherein the molar ratio of isobutylene to phenol ranges from about 1.8:1 to about 2.8:1.

18. The process of claim 17, wherein less than 1% by weight of the 1-butene and 2-butene present in the C_4 raffinate stream is reacted with the phenol.

19. The process of claim 17, wherein at least 80% by weight of the phenol reacts with the isobutylene.

20. The process of claim 17, wherein the process produces less than 0.1% by weight of sec-butyl phenols.

21. The process of claim 17, wherein the isobutylene-containing C_4 raffinate stream is directly reacted with a phenol, the reaction proceeding without an intermediate step of forming an alkyl-tert-butyl ether.

22. The process of claim 21, wherein the alkyl-tert-butyl ether is methyl-tert-butyl ether or methyl-tert-amyl ether.

23. The process of claim 17, wherein the isobutylene-containing C_4 raffinate stream is directly reacted with a phenol, the reaction proceeding without an intermediate step of introducing an alcohol into the C_4 raffinate stream.

24. The process of claim 23, wherein the alcohol is methanol or amyl alcohol.

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25. The process of claim 17, wherein the isobutylene-containing C_4 raffinate stream contains at least 75% by weight isobutylene.

26. The process of claim 17, wherein the isobutylene-containing C_4 raffinate stream is reacted with the phenol in the presence of a Group IIIb metal.

27. The process of claim 26, wherein the Group IIIb metal is aluminum.

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