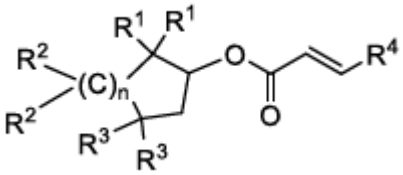
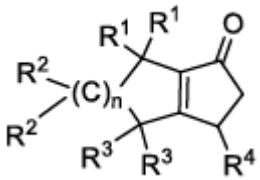
such as acrylic acid or crotonic acid gives a reaction mixture that contains or is free of an ester by-product such as cycloheptyl crotonate, cyclohexyl crotonate, or cyclopentyl crotonate. Relatively how much of the ester by-product is made is said to depend on the amount of phosphorous pentoxide used in the mixture with PPA or the amount of the PPA or $P_2O_5$/PPA mixture relative to the amount of cycloalkene.

## SUMMARY

**[0006]** The present disclosure includes a method of cyclizing, in the presence of a phosphorous pentoxide/methanesulfonic acid reagent (e.g., Eaton's reagent), an alpha,beta-unsaturated carboxylic acid, cycloalkyl ester compound to make a substituted cyclopentenone compound. The synthesis may be run at a lower temperature and yet be higher yielding than a prior PPA-based synthesis of Conia et al.

**[0006a]** In one aspect, the present disclosure refers to a method of synthesizing a substituted cyclopentenone compound, the method comprising (A) contacting a compound of formula (1) ("compound (1)"):  (1), wherein subscript n is 1, 2, 3, or 4; and each of groups R1, R2, R3, and R4 is independently H or ($C_1$-$C_4$)alkyl, or any two adjacent R1 to R3 groups are bonded together to form a ($C_1$-$C_4$)alkylene and the remaining group of R1 to R3 is H or ($C_1$-$C_4$)alkyl, with an effective amount of a phosphorous pentoxide/methanesulfonic acid reagent ($P_2O_5$/$H_3CSO_3H$ reagent) at a temperature of 0°C to 25°C and under reaction conditions sufficient to make a compound of formula (2) ("compound (2)"):  (2) ; wherein subscript n and groups R1 to R4 are as defined above; and with the proviso that the contacting step (A) is free of added polyphosphoric acid (PPA).

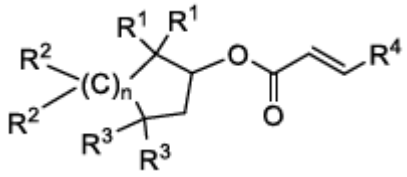
**[0007]** The substituted cyclopentenone compound made by the method may be used as an intermediate in the synthesis of compounds useful as drugs, herbicides, pesticides, or catalysts such as olefin polymerization catalysts such as substituted metallocene compounds.

## DETAILED DESCRIPTION

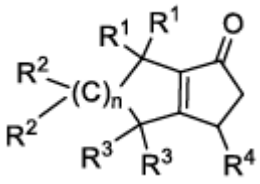
**[0008]** The Summary and Abstract are incorporated here by reference.

CLAIMS

1. A method of synthesizing a substituted cyclopentenone compound, the method comprising (A) contacting a compound of formula (1) ("compound (1)"):



(1), wherein subscript n is 1, 2, 3, or 4; and each of groups R1, R2, R3, and R4 is independently H or ($C_1$-$C_4$)alkyl, or any two adjacent R1 to R3 groups are bonded together to form a ($C_1$-$C_4$)alkylene and the remaining group of R1 to R3 is H or ($C_1$-$C_4$)alkyl, with an effective amount of a phosphorous pentoxide/methanesulfonic acid reagent ($P_2O_5$/$H_3CSO_3H$ reagent) at a temperature of 0°C to 25°C and under reaction conditions sufficient to make a compound of formula (2) ("compound (2)"):



(2) ; wherein subscript n and groups R1 to R4 are as defined above; and with the proviso that the contacting step (A) is free of added polyphosphoric acid (PPA).

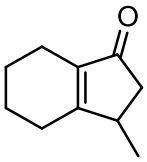
2. The method of claim 1 wherein the ratio of $P_2O_5$ to $H_3CSO_3H$ used to make the $P_2O_5$/$H_3CSO_3H$ reagent is from 0.05/1 to 1/1 (weight/weight).

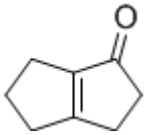
3. The method of claim 1 or 2, wherein the ratio of $P_2O_5$ to $H_3CSO_3H$ used to make the $P_2O_5$/$H_3CSO_3H$ reagent is 0.1/1 (weight/weight).

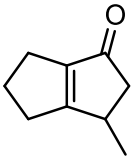
4. The method of any one of claims 1 to 3, characterized by any one of limitations (i) to (xiv): (i) wherein at least one of R1 to R3 is a ($C_1$-$C_4$)alkyl or R4 is H; (ii) wherein each of R1 to R4 is H; (iii) wherein each of R1 to R3 is H and R4 is methyl; (iv) wherein each of R1 and R2 is H and each of R3 and R4 is methyl; (v) wherein R1 and/or R2 is methyl and R3 is H; (vi) wherein R1 is methyl, R2 is 1-methylethyl, and R3 is H; (vii) wherein R1 is 1-methylethyl, R2 is methyl, and R3 is H; (viii) wherein R1 and R2 independently are ($C_1$-$C_4$)alkyl, R3 is H, and the stereochemistry of the carbon atom bonded to R1 is (R) and the stereochemistry to the carbon atom bonded to R2 is (S); (ix) wherein R1 and R2 independently are ($C_1$-$C_4$)alkyl, R3 is H, and the stereochemistry of the carbon atom bonded to R1 is (S) and the stereochemistry to the carbon atom bonded to R2 is (R); (x) both (vi) and (viii); (xi) both (vi) and (ix); (xii) both (vii) and (viii); (xiii) both (vii) and (ix); and (xiv) any two adjacent R1 to R3

groups are bonded together to form a ($C_1$-$C_4$)alkylene and the remaining group of R1 to R3 is H or ($C_1$-$C_4$)alkyl.

5. The method of any one of claims 1 to 4, wherein the compound (2) is selected from the group consisting of any one of compounds (2a) to (2e):

compound (2a) 2,3,4,5,6,7-hexahydro-3-methyl-1H-inden-1-one, having structure (2a):  (2a);

compound (2b) bicyclo[3.3.0]-1(5)-octen-2-one, having structure (2b):  (2b);

compound (2c) 4-methyl-bicyclo[3.3.0]-1(5)-octen-2-one, having structure (2c):  (2c);

compound (2d) 10-methyl-bicyclo[5.3.0]-1(7)-decen-8-one; and

compound (2e) 2,4,6,11-tetramethyl-bicyclo[6.3.0]-1(8)-undecen-9-one.