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Esters have high potential in industry because of their wide use in fragrances and perfumery, as flavors in food chemistry, surfactants, as pheromones for controlling plagues, plasticizers and as solvents. Generally they are obtained by catalytic acetoxylation of starting alcohols with DMAP or PPY in presence of acid chlorides or acid anhydrides. Several reports detail the esterification of alcohols catalyzed by Bu_3P , $Sc(NTf_2)_3$, $Ce(SO_4)_2$, $VO(OAc)_2$, including bentonites and zeolites. All these procedures have disadvantages such as high cost of catalyst, low regioselectivity, potential elimination byproducts or racemization, and epimerization of the substrates and products. We report the **utilization of uranyl acetate $UO_2(AcO)_2$** as a useful (in lab conditions) Lewis acid catalyst in combination with Ac_2O for developing the acetoxylation of alcohols in ecofriendly and mild conditions

The alcohol (2,0 mmole), acetic anhydride (3,0 mmole) and *uranyl acetate* (0,3 mmole) were stirred in $CHCl_3/CH_3CN$ (15 mL) under reflux during 4 h. The catalyst was then filtered and kept for another cycle (5 times). The filtrate was concentrated and subjected to FTIR and NMR-¹H studies.

The series of secondary steroidal alcohols as diosgenine, hecogenine, estradiol, steroidal diols, cetodiols, were used as starting substrates. The alcohols are acetoxyated easily with high selectivity and yields (> 85%) using **$UO_2(AcO)_2$** as catalyst. A great achievement is the re-usability of the catalytic system **uranyl acetate** (5 catalytic cycles) and their minimal ecological impact on environment. The mechanism study of the catalytic action of the proposed system is under way.

Acetoxylation of alcohol under basic conditions using stoichiometric amounts of base viz., Et_3N and pyridine is well established. Some procedures have been developed wherein Lewis acid catalysts $CoCl_2$, $Sc(OTf)_3$, TMSOTf are involved in combination with Ac_2O . The latest procedures reported involves montmorillonites K-10 and KSF; $Mg(ClO_4)_2$ and 2-acylpyridazin-3-ones as catalysts. These methods suffer from inherent disadvantages such as high cost of the catalyst, poor regioselectivity in case of allylic alcohols, elimination byproducts in tertiary alcohols, racemization of optically active ones, epimerization of steroids and tedious work-up procedures. Our previous reports on vanadium oxide and vanadyl acetate catalytic activities prompted us to the developments of new Lewis acid catalyst bearing acetate ligands on uranium U^{6+} for acetylation reaction under heterogeneous and ecofriendly conditions. In this direction, our group has already identified **$UO_2(AcO)_2$** as effective Lewis acid catalyst for acetylation of alcohols with Ac_2O . In this letter we describe the utilization of **uranyl acetate $UO_2(AcO)_2$** as a useful (in lab. conditions) Lewis acid catalyst in combination with Ac_2O for developing the acetoxylation of alcohols in ecofriendly and mild conditions.

The procedure described was efficiently used in the acetoxylation of steroidal alcohols.

Acetylation reactions

Alcohol (10 mmol) and Ac_2O (15 mmol) were added to a stirred heterogeneous mixture of **$UO_2(AcO)_2$** (10 mol %) in Acetonitrile – Chloroform (75-25 v/v). The reaction mixture was stirred at room temperature during 3-4 hours upon completion (TLC control). The mixture was extracted with CH_2Cl_2 (3 x 30 mL). Combined organic layers were washed with brine and dried over Na_2SO_4 . The solvent was removed and the crude products were column chromatographed on silica gel column to afford pure acetate esters which were subjected to FTIR and NMR-¹H spectroscopy.

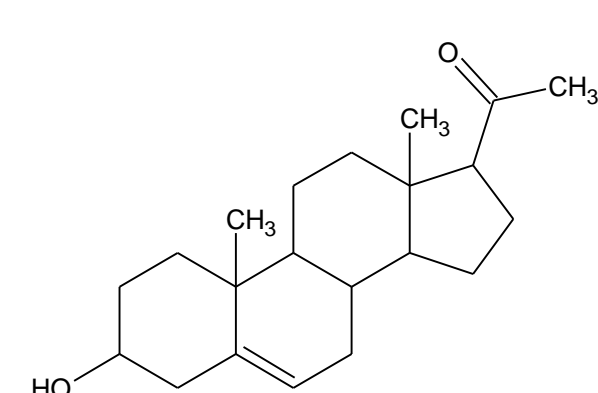
The catalyst, recovered by filtration, was kept for another cycle (5x) with previous activation at 50 °C during 1 hour.

$UO_2(AcO)_2$ -catalysed direct acetoxylation of steroids

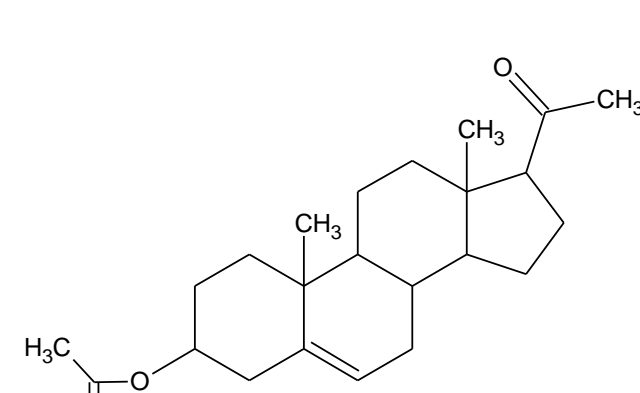
$UO_2(AcO)_2$

Substrates

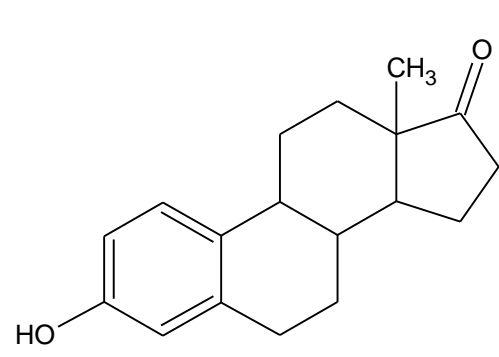
Products



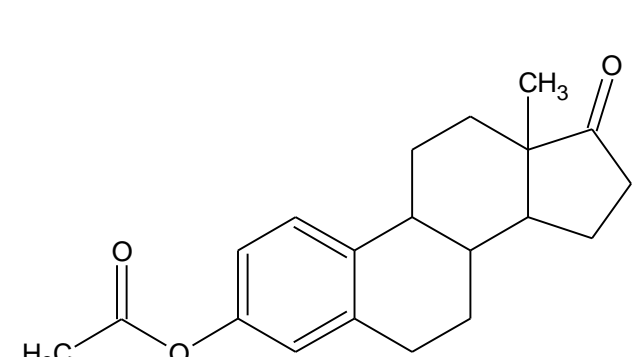
Pregnenolone



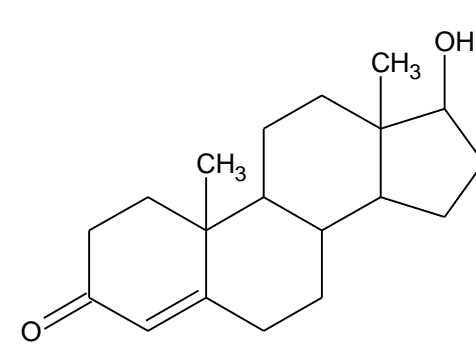
Pregnenolone acetate (M.P-191,70C / 96,8 %)



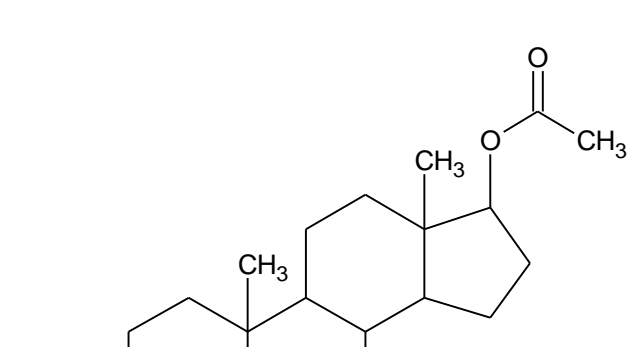
Estrone



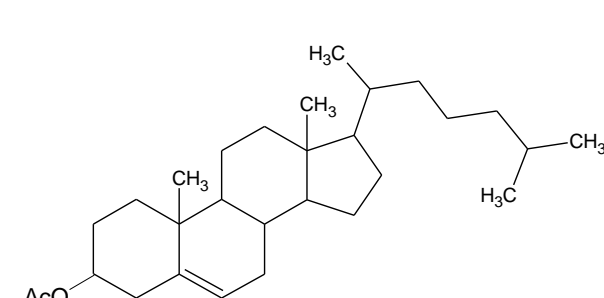
Estrone acetate (M.P-129,7 0C / 97,3 %)



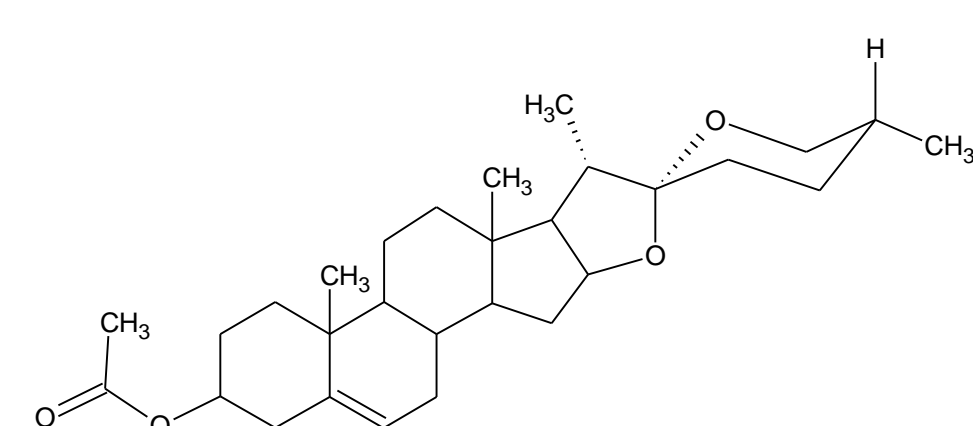
Δ4-androsten-17β-ol



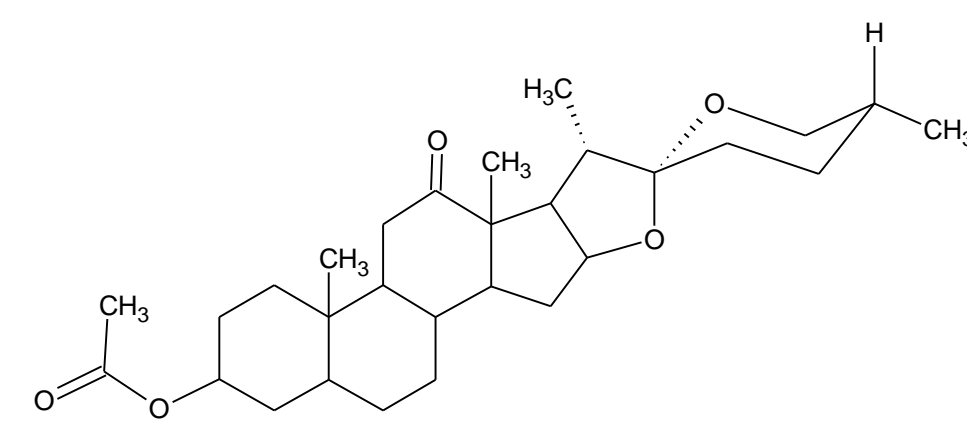
Δ4-androsten-17β-ol –acetate (M.P-142,6 0C / 83,4 %)



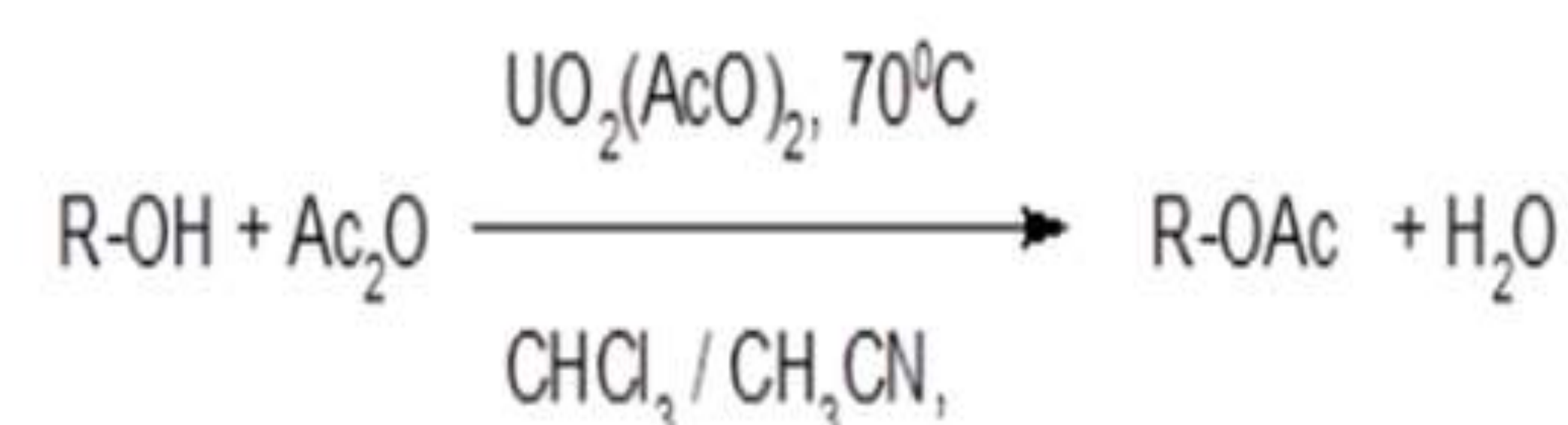
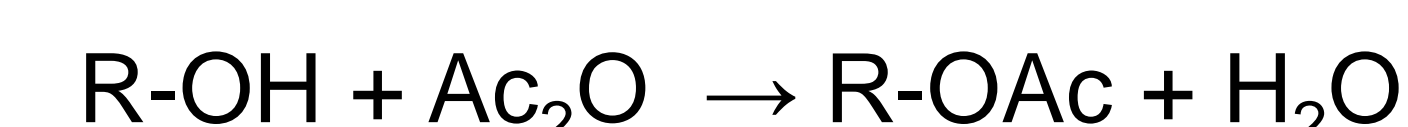
Cholesteryl acetate (M.P-114,20C / 89,2%)



Diosgenin acetate (M.P-195.80C / 93.1 %)



Hecogenin acetate (M.P-243,60C / 90,5 %)



The conversion of a variety of monoterpene and steroidal alcohols to the corresponding ester was simple achieved (with satisfactory yields in laboratory conditions) by treatment of the selected alcohol with 15 mmol (1,5 equiv.) of acetic anhydride at 70 °C for 3-4 hours in the presence of 10 mol % of the catalyst, $UO_2(AcO)_2$.

The most significant achievement is the reusability of the salt of transition metal catalyst for several number of cycles with almost consistently activity.

The advantage of using this catalytic system over the others one can be summarized as follows: Uranyl acetate can be easily prepared directly from uranium oxide and acetic anhydride.

The mixture of $UO_2(AcO)_2$ with selected solvents is stable and not revealed any toxic or hazardous action during the storage (1 year).

The spirocetalic unit of spirostene derivatives remains intact and was not observed any isomerization of the olefinic bound in steroids.

It is not necessary any inert atmosphere or dry conditions for performing the reaction.

The catalyst is easy recovered and could be re-used in 4-5 catalytic cycles after thermal activation.

Not observed any formation of by-products like ketene, olefine o acetoacetate derivatives

Some implications in kinetic resolution and mechanistic studies are underway

References

- Greene, T.W., Wuts, P.G.M. *Protective Groups in Organic Synthesis*. John Wiley & Sons Inc. New York, 2nd. Ed. 1991
- J. L. Leyva, J. Tacoronte et al. **Cuban Patent 23089** (res.2614/05), 2005
- J. L. Leyva, J. Tacoronte et al. **Cuban Patent 23090** (res.2636/05), 2005