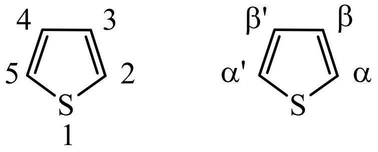
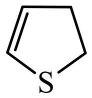
7) Thiophene:

Thiophene is a colorless liquid with a benzene like odor, it is closely resembles benzene in its chemical and physical properties. It occurs with benzene in coal tar, from which source it was first isolated in1882 as undesired compound (b.p.= 84°C while benzene 80°C).

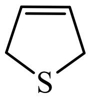
Numbering of the ring start also from the hetero atom like pyrrole and furan as the following:



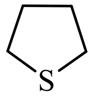
Thiophene



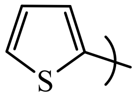
2,3-Dihydro thiophene



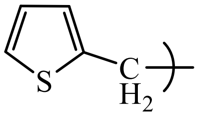
2,5-Dihydro thiophene



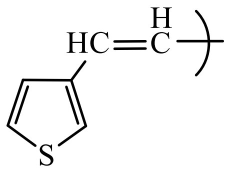
Tetrahydro thiophene



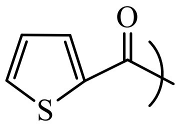
2-Thienyl



2-Thenyl



Thenylidene or
3-Thenal



Thenoyl

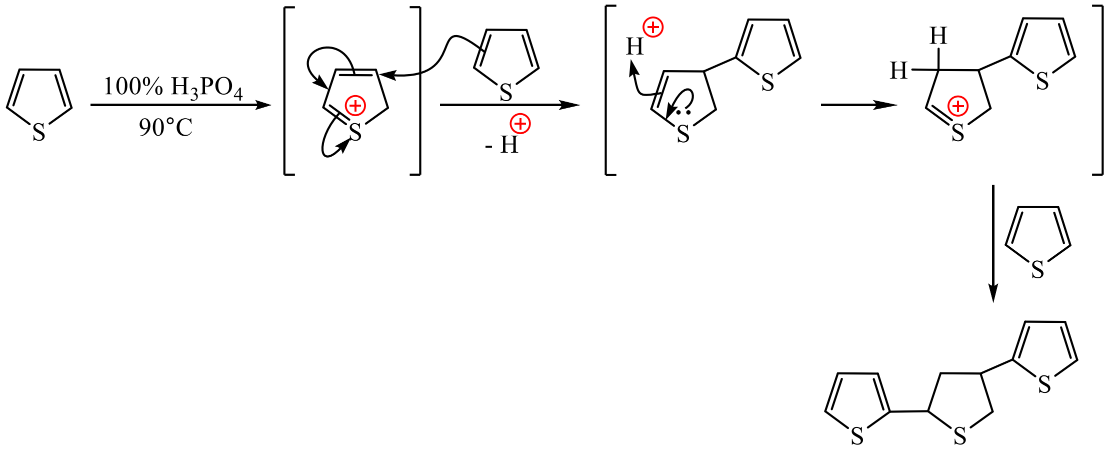
7.1) Chemical reactivity and reactions of thiophene:

As we mentioned previously, thiophene resembles benzene in most of its reactions, but it is more reactive and less stable. Thiophene undergoes reactions like furan and pyrrole at C2 or C5 positions or both of them.

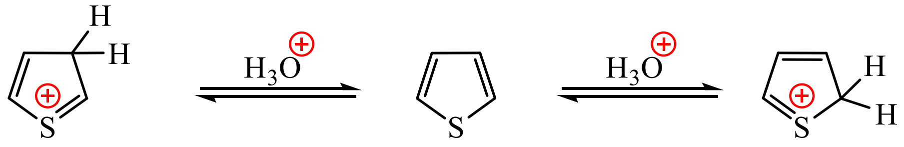
7.1.1) Effect of acids on thiophene:

Thiophene is more stable than pyrrole and furan toward acidic conditions, thus many reagents that would lead to acid – catalyzed decomposition or polymerization of furan or pyrrole can be applied successfully to thiophenes (i.e. like benzene).

The reaction of thiophene with hot concentrated phosphoric acid leads to a trimer.



The rate of proton attack at C2 atom is about 1000 times faster than at C3 atom (as the same as in benzene protonation).



less stable cation

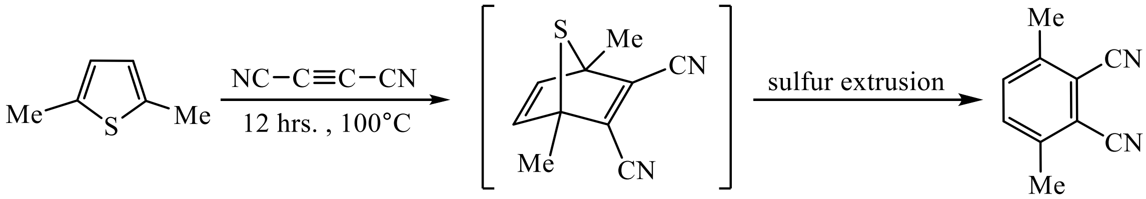
more stable cation

Thiophene react with some Lewis acids like aluminum chloride ($AlCl_3$) to generate tars (or polymer), thus we couldn't use it in Friedel – Crafts reactions, thus we can use tin tetrachloride ($SnCl_4$) instead of ($AlCl_3$).

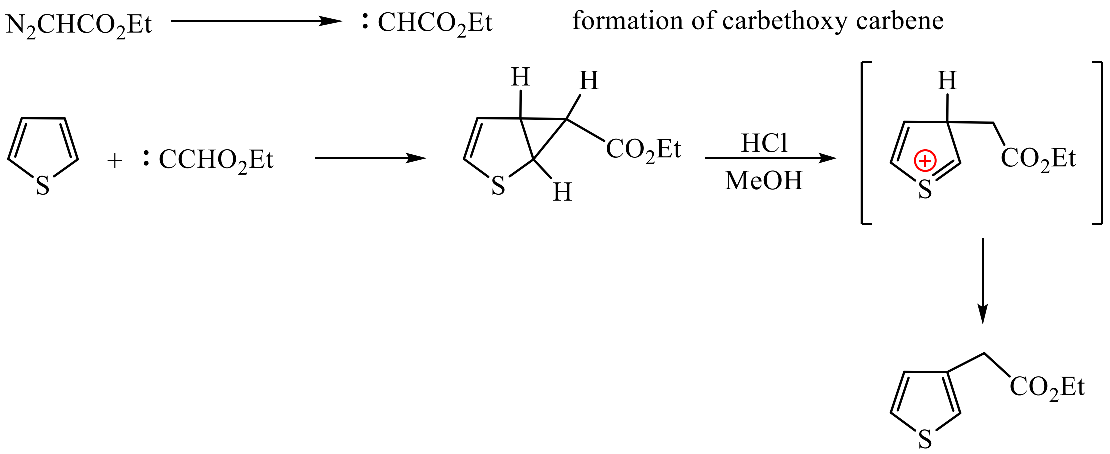
Note: Benzene that used in Friedel – Crafts reactions should be thiophene free to prevent polymerization.

7.1.2) Addition reactions of thiophene:

Thiophene show little tendency (*due to its high resonance energy*) to react as a diene in Diels – Alder reaction. It is unreactive towards common dienophiles like benzyne and maleic anhydride, thus strong dienophiles have been used like tetrafluorobenzyne and dicyanoacetylene to give the 1,4-adduct (addition at C2 and C5 atoms).



Furthermore thiophene undergoes addition reaction at the double bond between C2 and C3 atoms when reacted with carbene (like carbethoxy carbene) to give substituted cyclopropane that on treatment with acid and methanol produce β-acetic ester of thiophen:

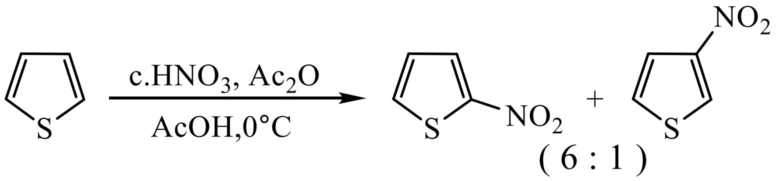


7.1.3) Substitution reaction of thiophene:

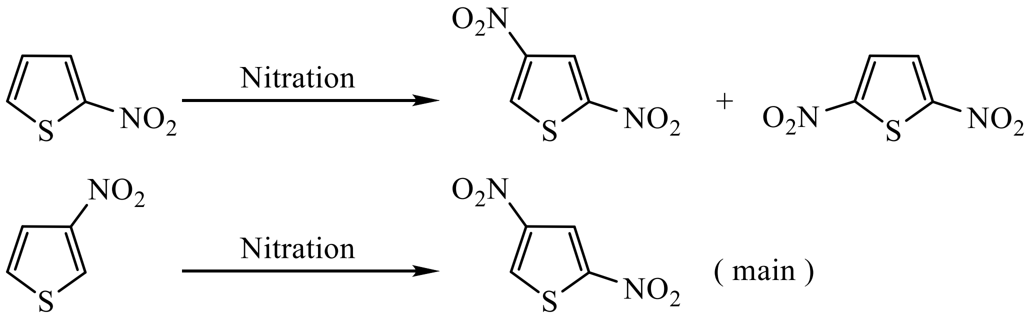
Thiophene undergoes a considerable number of electrophilic substitution reactions with greater ease (*i.e. moderate conditions can be used*) than with pyrrole or furan (even sometimes than with benzene). Substitution takes place at 2 or 5 positions or both of them.

7.1.3.1) Nitration:

Nitration of thiophene under regular conditions (that used in benzene or its derivatives) will lead to its decomposition or an explosion (*i.e. the use of a mixture of acetic acid and nitric acid will also cause an explosive reaction*), thus milder conditions should be used like acetyl nitrate to give 2- and 3- dinitro thiophene in 6:1 ratio.

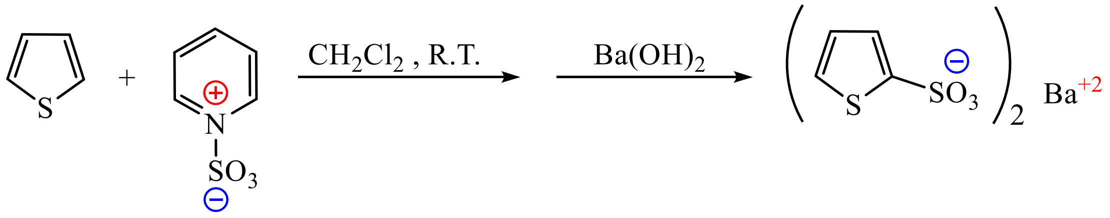


Note: Nitration of 2-nitrothiophene and 3-nitrothiophene will proceed as the following :

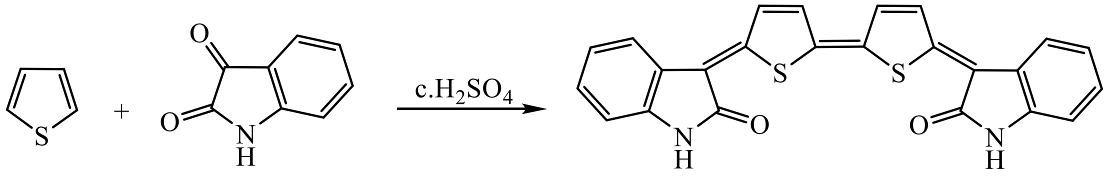


7.1.3.2) Sulfonation:

The ease of sulfonation of thiophene by sulfuric acid at room temperature lead to use this method to get rid of thiophene (as undesired component) from benzene that obtained from crude oil (petrol).

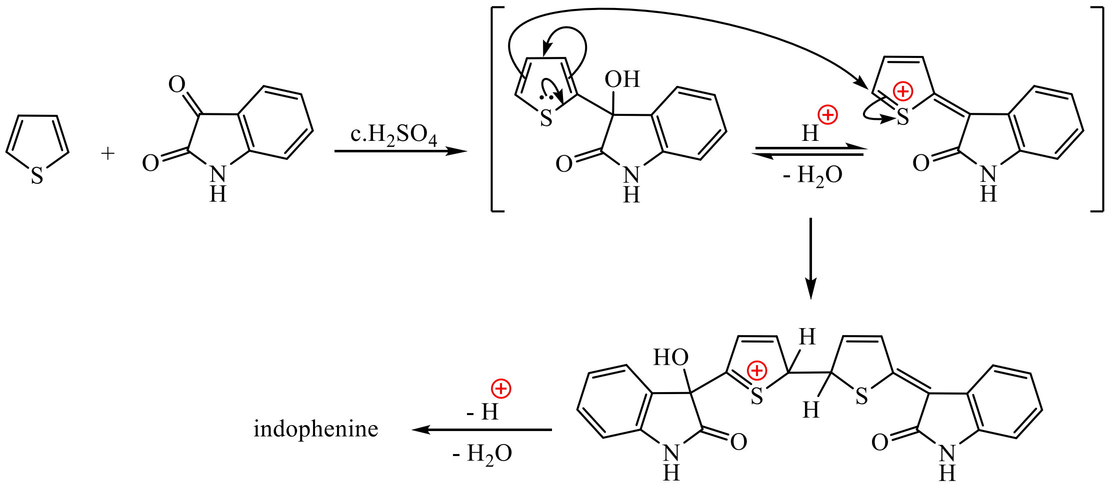


Thiophene react with isatin in the presence of sulfuric acid to give deep blue indophenine, this reaction was used as a test for the presence of thiophene in coal – tar.



isatin indophenine

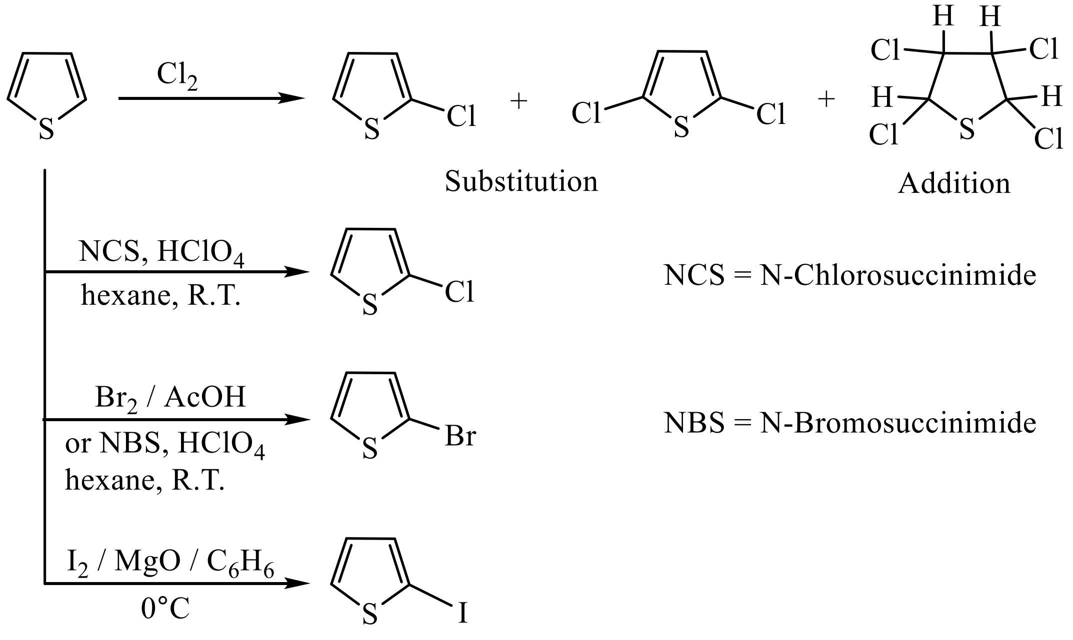
The reaction proceed as the following:



7.1.3.3) Halogenation:

Halogenations of thiophene occurs very readily at room temperature and is rapid even at -30°C in the dark, thus the rate of chlorination of thiophene is 10^7 faster than that of benzene while bromination is 10^9 at the same conditions.

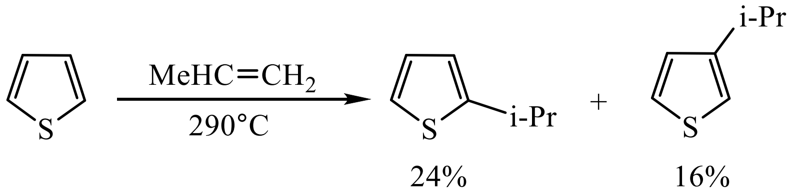
Controlled reaction conditions will control the nature of the product (i.e. mono,di or tetra substituted halo thiophene).

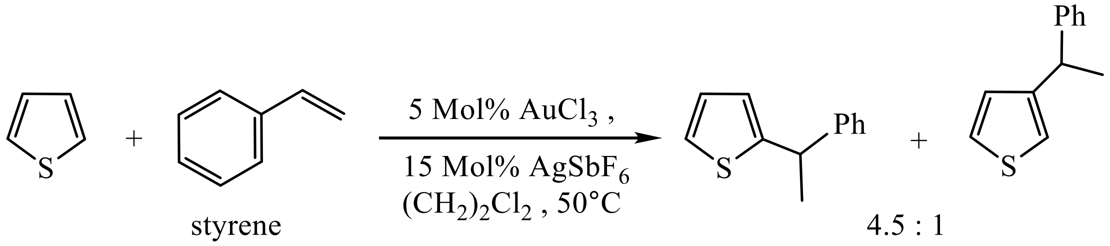


7.1.3.4) Alkylation and Acylation:

As we mentioned previously, thiophene react with some Lewis acids (like $AlCl_3$) resulting in the formation of polymerized material or tar, thus tin tetrachloride used instead or by the gradual addition of the catalyst to a mixture of thiophene and acylating or alkylating agent.

Thiophene can be alkylated at high temperature by the use of olefines, but the disadvantages of this method involve the low yield and the diversity of the products.





Note: $AuCl_3$ = Gold(III) chloride
$AgSbF_6$ = Silver hexafluoroantimonate

On the other hand acylation is much more easier and produce substitution product at 2 position.