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Phosphorus acid: As a multi-purpose catalyst

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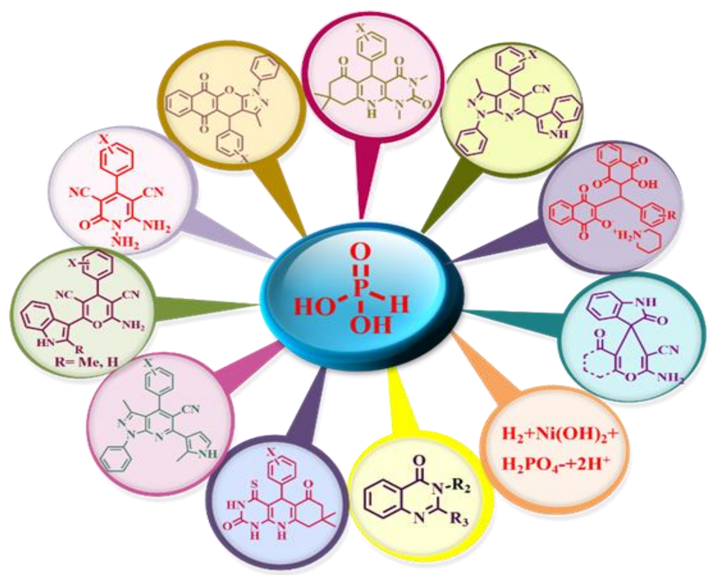
This feature focuses on a reagent chosen by a postgraduate, highlighting the uses and preparation of the reagent in current research.

Introduction

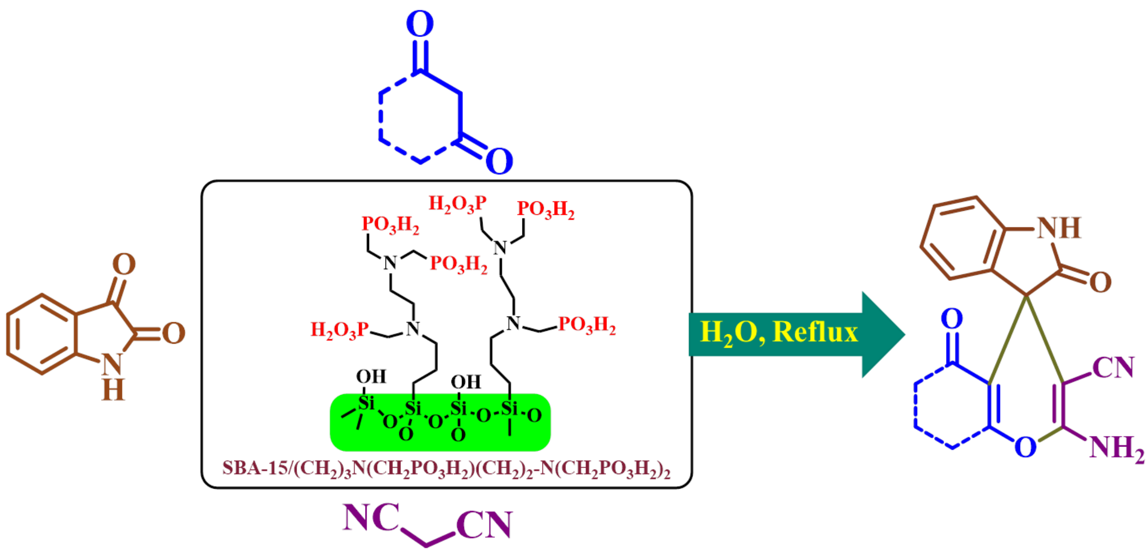
Nowadays, chemists seek to obtain safe catalysts and low-cost processes with the optimum efficiency, so they focus on designing and using catalysts with lower risks and costs [1-3]. Heterogeneous catalysts are particularly important due to their ease of separation, ease of operation, high activity, high recyclability, safety, and good efficiency [4]. Among these, Phosphorus acids with ease of separation, ease of use, dramatic increase in chemical reactions, safety, and adherence to the principles of green chemistry in various chemical reactions have recently found many uses. Other properties of phosphorus acids that have attracted a lot of attention include their use as reagents, absorbents, catalysts for the preparation of food additives, as a precursor for the synthesis of phosphate fertilizers and also as catalysts that conform to the principles of green chemistry [5]. Phosphorus compounds play an important role biologically [6], and they are used as drugs such as antisense and antigen [7]. Fossil fuels are becoming obsolete due to the environmental pollution that they create and have been replaced by clean energy sources [8]. Phosphorus acids are one of the substances that can be used in the production of clean energy sources. In fact, phosphorus acid as a photocatalytic agent converts solar energy into hydrogen energy. Placing these phosphorus acids on mesoporous and nano-compounds significantly increases the rate and efficiency of the reaction. It also improves the easy separation of these catalysts from the reactions' medium, and this feature has made it possible to reuse these catalysts. Phosphorus acids are used as catalysts in various chemical reactions such as preparation of spiro compounds, pyridine compounds, 1,4-dihydropyridine compounds, 2-methylquinazolin-4(3*H*)-one compound, amine compounds, etc (**Scheme 1**).



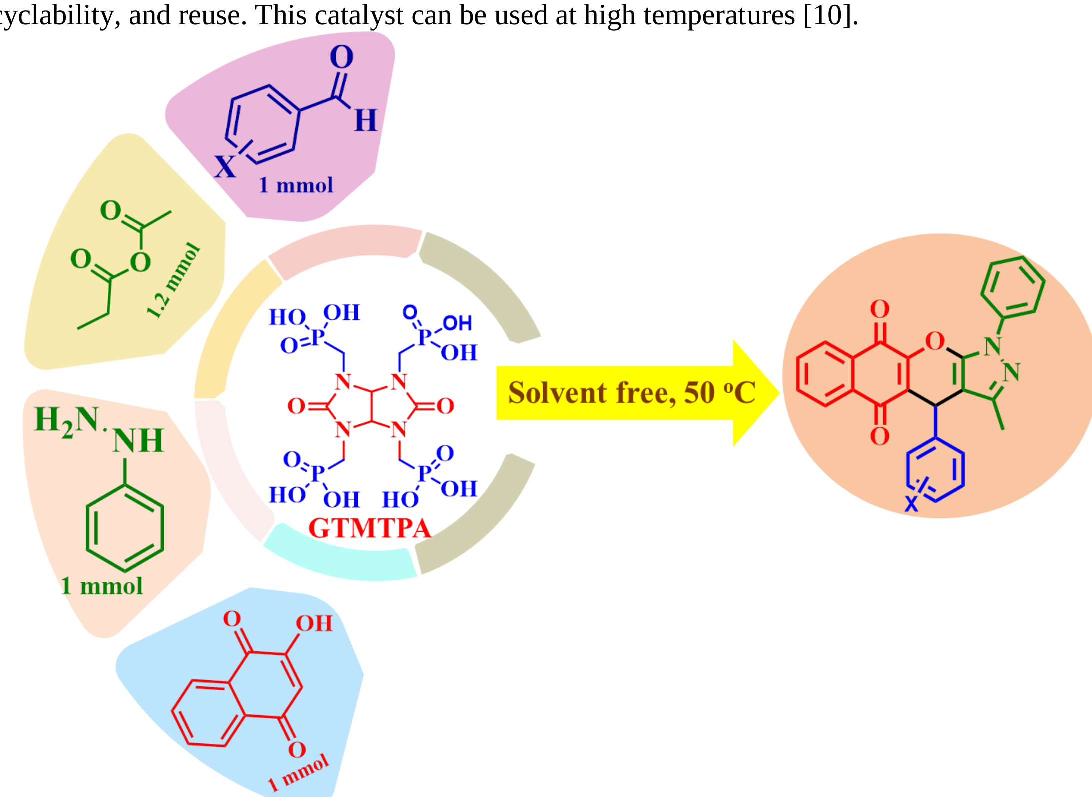
Scheme 1: Structure of a number of compounds obtained by catalysis with phosphorus acid

Abstracts

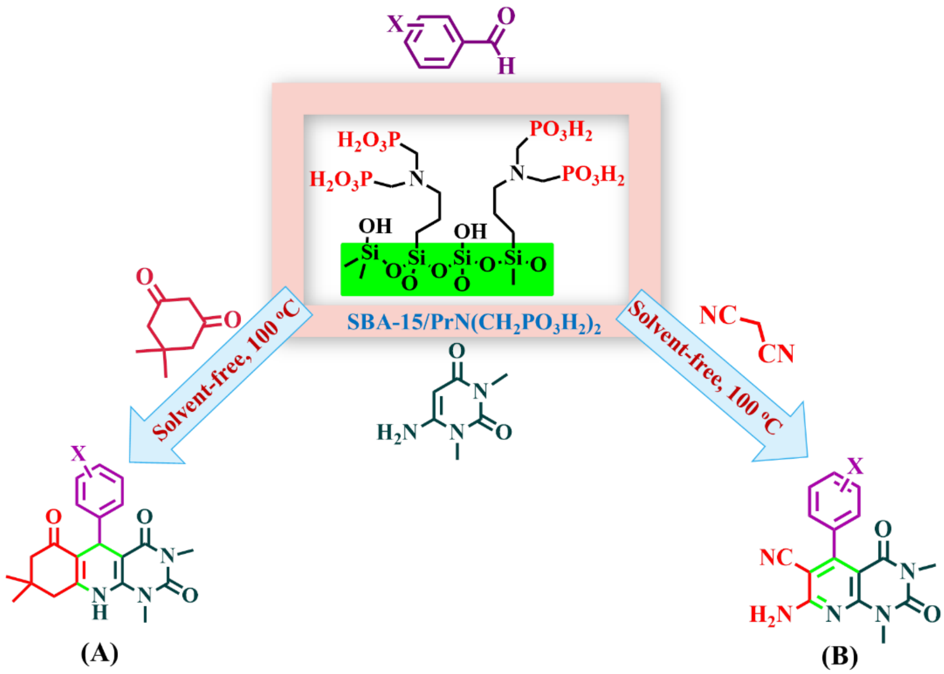
(A) In 2018, Zolfigol *et al*. with the help of phosphorus acid (SBA-15/En bonded phosphorous acid) as a new nanoporous heterogeneous catalyst, succeeded in synthesizing spiropyrans compounds. In this study, it was found that the use of this catalyst caused a significant increase in reaction efficiency, reduced reaction time and reusability of the catalyst [9].



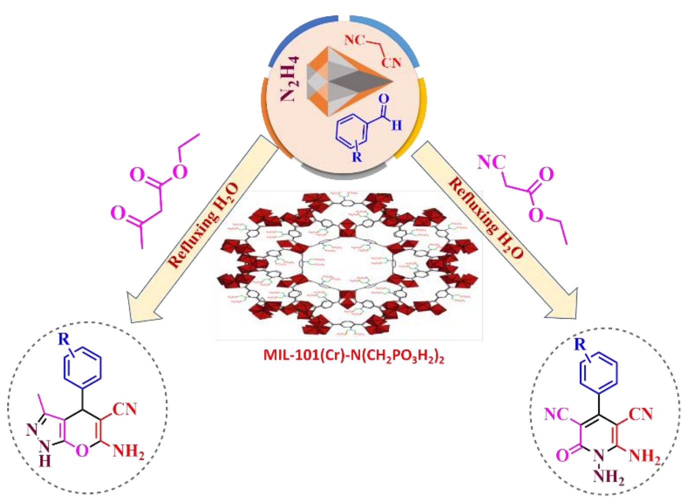
(B) In other studies, researchers have been able to synthesize glycoluril with phosphorous acid compounds. This compound has a nanostructure and is considered a biological compound. This new compound was used as a catalyst in Henna-based reaction, and the features of this catalyst were to increase the speed, reaction efficiency, as well as ease of separation, recyclability, and reuse. This catalyst can be used at high temperatures [10].



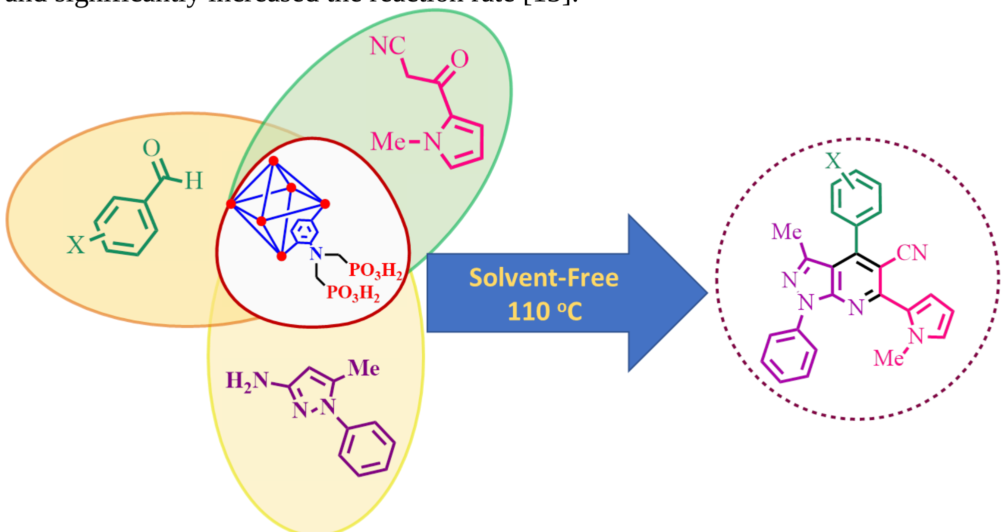
(C) In recent years, solid acids have been recognized as important catalysts in reactions due to their high activity and high recyclability. From the placement of phosphorus acid on the compounds SBA-15, solid acid catalysts are prepared with the said properties. These solid acids can be used as catalysts in various chemical reactions that increase the speed and efficiency of the reaction. Uracil compounds that have biological properties and their synthesis with high efficiency, good separation capability and observance of green chemistry principles, encourage every chemist to design a suitable path to achieve the above. Among these, the use of phosphorus acids on SBA-15 compounds has achieved the above goals. This catalyst reacts with uracil compounds with 1,3-diketones, which leads to the preparation of compounds 1,4 dihydropyridines (A) and in the reaction of uracil with malononitrile, it causes the production of aging compounds (B) [11].



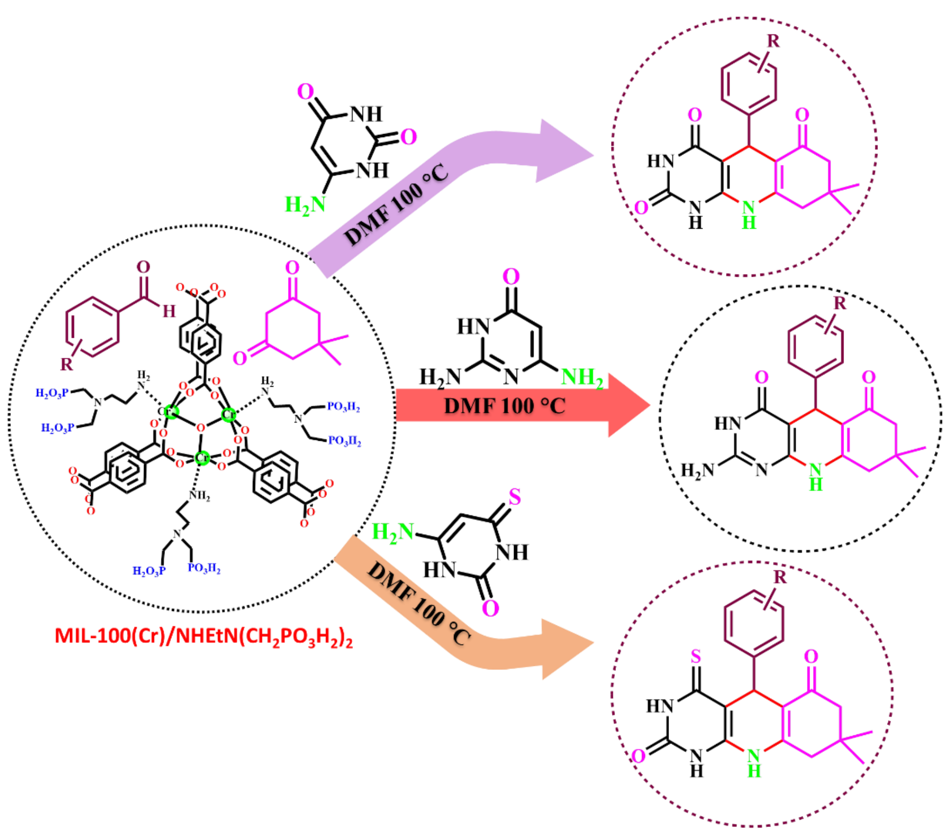
(D) Metal-organic frameworks (MOFs) are a group of nanoporous materials with a high surface area, making them suitable catalysts. Phosphorus acids are considered for their environmental friendliness, so the design and placement of phosphorus acids on metal-organic frameworks (MOFs) have made them suitable catalysts due to their high recovery, reuse, and high efficiency. Metal-organic frameworks functionalized with phosphorus acid groups were used to synthesize *N*-amino-2-pyridone and pyrano [2,3-*c*]pyrazole derivatives via a cooperative vinylogous anomeric-based oxidation [12].



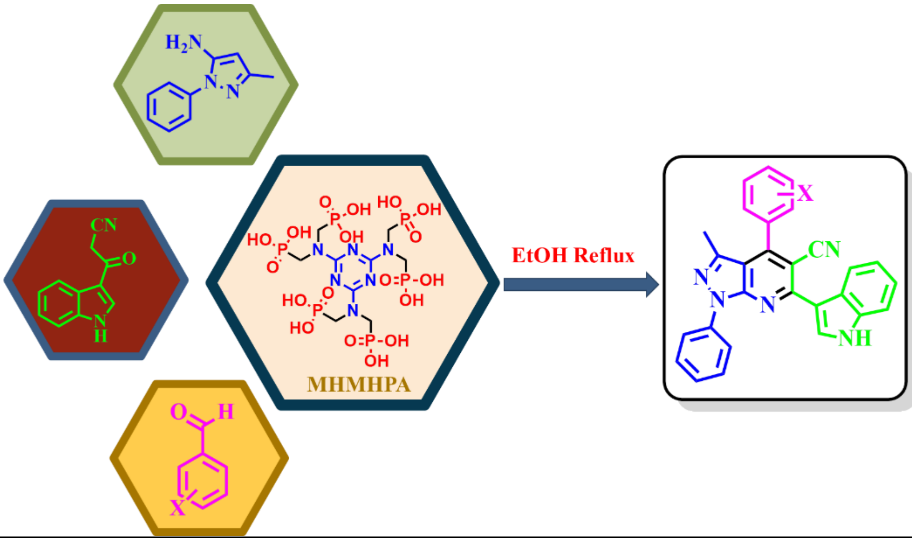
(E) In 2021, Zolfigol *et al*. sought a method based on the principles of green chemistry for the synthesis of their catalysts. They first synthesized metal-organic framework (MIL-53(Al)-NH_2) using electrochemical methods and then placed phosphorus acid functional groups on these MOFs for the synthesis of a new catalyst based on phosphorus acids. Then, to evaluate the catalyst, they used it in the synthesis of new pyridines, and found that the catalyst had good recycling and reuse power and significantly increased the reaction rate [13].



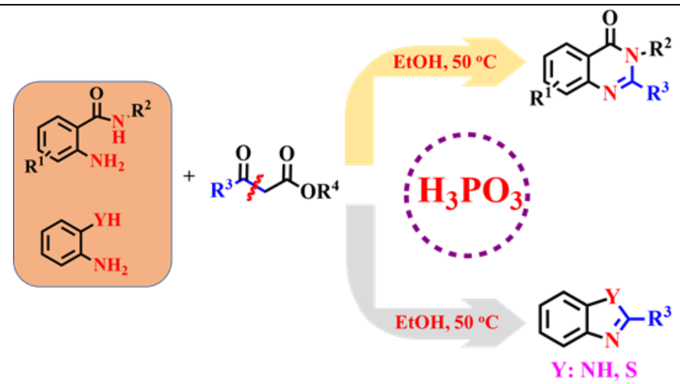
(F) In another exploration, functional groups placed phosphorus acid on metal-organic framework (MOFs) and synthesized a new nanoporous catalyst. They used this catalyst to synthesize new heterocyclic compounds such as *N*-heterocyclic pyrimido[4,5-*b*] quinolines. Among the reported features are high reaction efficiency, short reaction time, thermal stability, easy performance, and reusability of the catalyst. In this reaction, they placed the functionalized materials and catalysts with phosphorus acid functional groups in DMF reflux and finally succeeded in synthesizing their desired product [14].



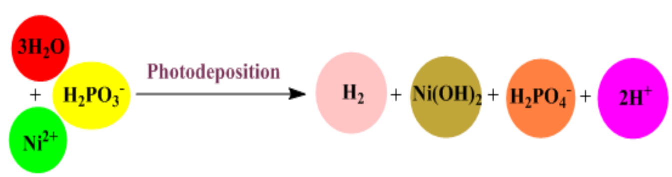
(G) In 2019, anomeric-based synthesis was reported using a phosphorus acid catalyst. They first synthesized a bread-structured solid acid using melamine, which was functionalized with phosphorus acid groups. Then, to find out the efficiency of the catalyst in the reaction between 3-(1*H*-indol-3-yl)-3-oxopropanenitrile, 3-methyl-1-phenyl-1*H*-pyrazol-5-amine, and an aromatic aldehyde, they used 5 mol% of the catalyst in ethanol solvent and finally synthesized their desired product. What distinguishes this catalyst based on phosphorus acid groups from other catalysts is the high efficiency of the reaction product, the need for less reaction time, good separation and reusability [15].



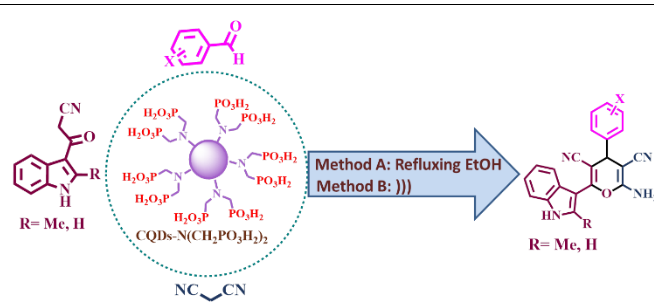
(**H**) In 2018, Zhou *et al*. used phosphorus acids catalysts to synthesize quinazolinones from β-ketoesters with *o*-aminobenzamides. This reaction works well in metal-free and oxidant-free conditions and shows very good efficiency [16].



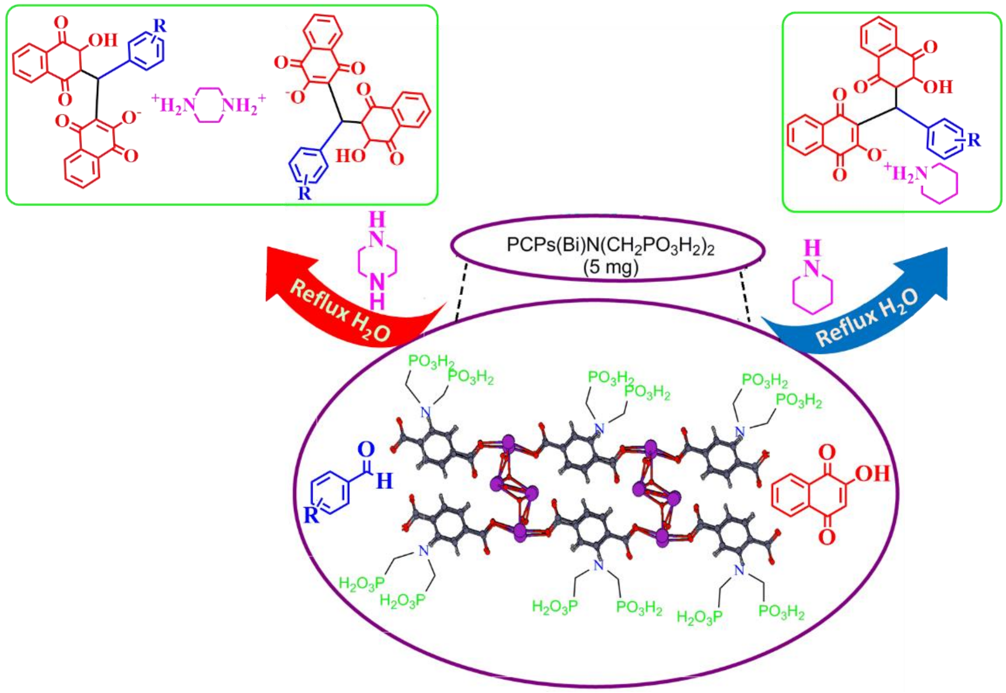
(**I**) In 2019, Dong et al. used phosphorus acid-based cocatalysts to produce photocatalytic hydrogens. Today, hydrogen is considered as a clean and low-cost energy source, and its importance has increased due to increasing environmental pollution and the crisis of super-natural energy [17].



(**J**) In another report, in 2021, using carbon quantum dots functionalized with phosphorus acid groups, they succeeded in synthesizing 4*H*-pyran compounds. The characteristic of this catalyst is the nanoparticle size which causes the reaction speed and reaction efficiency to increase dramatically and, the absence of toxic metals in this catalyst, makes it a green catalyst [18].



(**K**) In 2021, Zolfigol *et al*. used henna compounds that have biological properties and with the help of their polymer catalyst, which is functionalized with phosphorus acid groups, succeeded in synthesizing their desired biological compounds. They reported that the use of polymeric catalysts functionalized with phosphorus acid groups increases the reaction efficiency, and increases the catalyst recovery rate [19].



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