Synthesis of Photocatalysts

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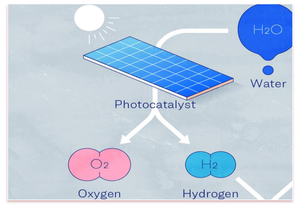
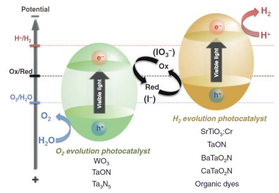
Background

- Energy is vital for everyday activities, and we are constantly searching for sustainable means of energy production.
- In an attempt to mimic photosynthesis in plants, researchers devised a system called Z-scheme water splitting. These schemes are dye-sensitized to convert the solar energy into chemical fuels (in our case, hydrogen).
- To explore the possibilities of improving the photocatalysts, we will look at three different semiconductors with differing band gaps.
- The water-splitting reaction has two components, oxygen evolution and hydrogen evolution. These photocatalysts promote oxygen and hydrogen evolution by attempting to inhibit back electron transfer.



Artificial photosynthesis (Hamana)



Z-scheme example
A. Ryu. *CSJ Jounrals.* **2011,** *84,* 1000-1030

Methods

Grind starting compounds to uniform powder.

1200ºC

Layered $K_4Nb_6O_{17}$

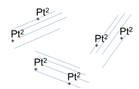
0.5 M HCl proton exchange

Layered $K_{4-x}H_xNb_6O_{17}$

TBA^+OH^-

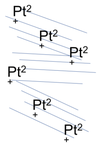
Nanosheet(NS) $K_{4-x}H_xNb_6O_{17}$

$Pt(NH_3)_4Cl_2$



$Pt^{2+}NS - K_{4-x}H_xNb_6O_{17}$

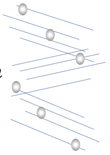
2 M HCl restacking



$Pt^{2+}NS - K_{4-x}H_xNb_6O_{17}$

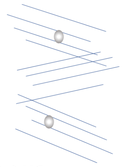
H_2 *reduction*

200ºC



Pt $NS - K_{4-x}H_xNb_6O_{17}$

Aqua Regia



Pt (in)$NS - K_{4-x}H_xNb_6O_{17}$

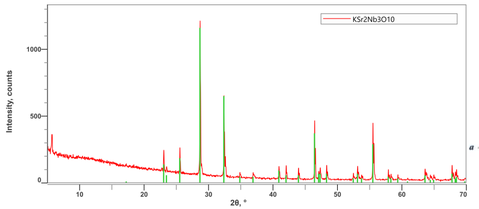
This is the general procedure followed to synthesize all three photocatalysts. From here, we add the dye and test the efficiency of our photocatalysts.

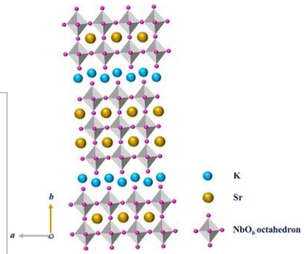
Objectives

- Using previous work in combination with future research, our goal is to continuously increase the efficiency of solar to hydrogen (STH) conversion. Additionally, we aim to synthesize photocatalysts in a manner that is replicable and affordable. In synthesizing and analyzing these three photocatalysts, we are taking steps toward all of these objectives.

$KSr_2Nb_3O_{10}$

Schematic illustration of $KSr_2Nb_3O_{10}$ structure (Pan & Xu et al.)

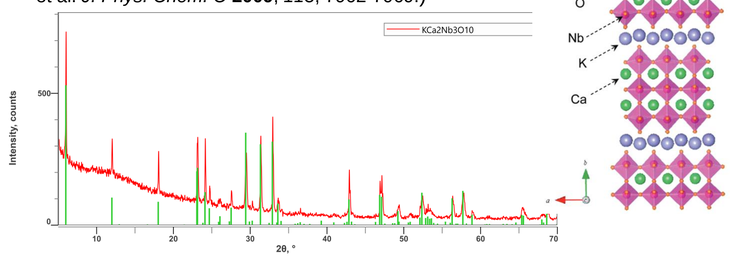




As we can see through the XRD analysis, our photocatalytic compound matches up very well in comparison to the XRD data for $CsSr_2Nb_3O_{10}$. This ensures that are compound reacted in a manner that we desired, and we can replicate the process to create photocatalytic compounds.
In terms of methodology, we found that the strontium niobate-based compound took over a week to exfoliate into nanosheets. This was surprising because previous work and comparison pointed towards the process taking a few days, as it did with the other photocatalysts.

$KCa_2Nb_3O_{10}$

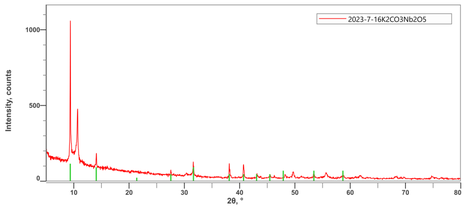
Schematic illustration of $KCa_2Nb_3O_{10}$ structure. (K. Maeda, et al. *J. Phys. Chem. C* **2009**, *113*, 7962-7969.)

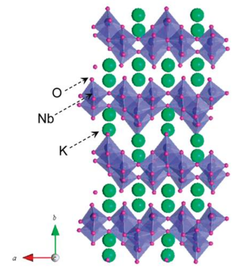


The XRD analysis shows that our calcium niobate-based compound is very pure in comparison to the data that we already have on itself ($KCa_2Nb_3O_{10}$)
New methodology that we found was that the proton exchange process took much longer than the anticipated few days that we expected from previous research.

$K_4Nb_6O_{17}$

Schematic illustration of $K_4Nb_6O_{17}$
(K. Maeda, et al. *J. Phys. Chem. C* **2009**, *113*, 7962-7969.)

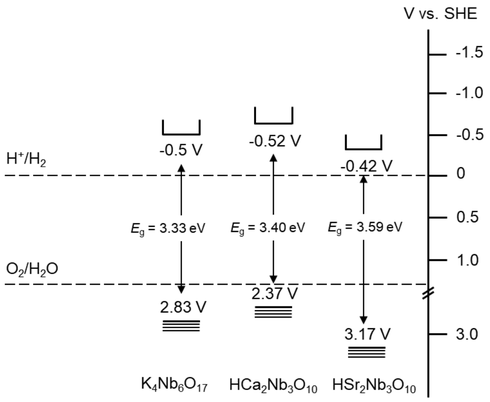




Our XRD comparison of our strontium-niobate based photocatalyst with $K_4Nb_6O_{17}\_3H_2O$ shows that it matches very well, but we might have to further alter our procedure for drying the compound.
When heating the initial powder to 1200ºC, we noticed that the ramping rate had to be altered (faster) in order to ensure a crystalline structure.

Implications

Transient spectroscopy will be used under induced conditions similar to those found in the environment (like solar spectrum UV rays) to analyze the efficiency of solar to hydrogen conversion.



Our three photocatalysts will be tested and hopefully their efficiency will be indicative of a higher efficiency with a lower band height for each semiconductor.

References

A. Ryu. *CSJ Jounrals.* **2011,** *84,* 1000-1030
Hamana, S. (*Photosynthesis—a Dream Technology, converting CO_2 into a resource*. KAITEKI Solution Center. https2023, February 1). *Artificial* ://www.mcgc.com/english/kaiteki_solution_center/solution/01.html
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