understanding chemistry by understanding photocatalysis
understanding photocatalysis by understanding chemistry

Division of Environmental Material Science, Graduate School of Environmental Science
The first semester of Fiscal 2017
08:45—10:15, Thursday at Lecture Room D103

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objectives/goal/keywords

objectives
Understanding the mechanism of decomposition of pollutants, methods of photocatalysts preparation, design of practical photocatalytic reaction systems, and strategy for enhancement of photocatalytic activity.

goal
To understand principle of photocatalytic reaction from the standpoint of chemistry and strategy for practical applications. To obtain scientific method for research on functional solid materials.

keywords
Photocatalyst, Photoinduced oxidative decomposition, Superhydrophilicity, Excited electron-positive hole, Structure-activity correlation, Higher photocatalytic activity, Visible-light response
## schedule

<table>
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<th>Date</th>
<th>Topic</th>
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<td>introduction of photocatalysis</td>
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<tr>
<td>Apr 20</td>
<td>interaction between substances and light</td>
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<tr>
<td>Apr 27</td>
<td>electronic structure and photoabsorption</td>
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<tr>
<td>May 11</td>
<td>thermodynamics: electron and positive hole</td>
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<td>May 18</td>
<td>adsorption</td>
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<td>May 25</td>
<td>environmental application of photocatalysis (Professor Ewa Kowalska)</td>
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<td>Jun 1</td>
<td>kinetic analysis of photocatalysis</td>
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<td>Jun 8</td>
<td>steady-state approximation</td>
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<td>Jun 15</td>
<td>kinetics and photocatalytic activity</td>
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<td>Jun 22</td>
<td>artificial photosynthesis (Professor Mai Takashima)</td>
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<td>Jun 29</td>
<td>(no class)</td>
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<td>Jul 6</td>
<td>action spectrum analysis (1)</td>
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<td>Jul 13</td>
<td>action spectrum analysis (2)</td>
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<td>Jul 20</td>
<td>crystal structure</td>
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<td>Jul 27</td>
<td>design and development of photocatalysts</td>
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<tr>
<td>Aug 3</td>
<td>summary: photocatalysis A--Z</td>
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photocatalysis industries in Japan = ca. 350 million USD (2015)
practical applications

Q Which application impressed you the most? What is the reason for that?

Q What is the general chemical reaction(s) included in the practical applications of photocatalysis? Show a reaction formula(s).
(1) Photocatalysts such as titanium(IV) oxide coated or fixed on the solid materials adsorb organic compounds from water or air.
(2) The adsorbed organic compounds are completely decomposed into carbon dioxide (mineralization).
(3) The surface of photocatalytic coatings becomes superhydrophilic.

point 1: Molecular oxygen (O₂) in air leads to mineralization
point 2: Reduction as a counterpart of oxidation is for O₂.
point 3: Intermediate species from O₂ are known to act as oxidants.
point 4: In the absence of O₂, other reduction reactions may proceed.

mechanism
photocatalysis: two major phenomena

superhydrophilicity: the surface of photocatalytic (titania) coatings becomes super hydrophilic, i.e., contact angle to be almost zero.

photocatalytic oxidation: organic and inorganic compounds are oxidized under air to be inorganic materials, i.e., mineralization.
principle of photocatalytic reaction

electronic structure of semiconductors and insulators
conduction and valence bands separated by bandgap
photoexcitation beyond the bandgap

1) photoexcitation
   = electron and hole
2) relaxation
3a) reduction & oxidation
3b) recombination
catalysis and photocatalysis

- Catalysis and photocatalysis should be thought different.
- There are many common methods for characterization
photoexcitation

Photoreaction proceeds through excited state.

various excited states

• electronic (ultraviolet-visible): photosynthesis, photocatalysis
• vibrational (infrared): water warmed by sunlight
• rotational (microwave): microwave oven

the easiest way for making excited states:

photoabsorption
what is electromagnetic wave

Light is electromagnetic wave. Which are electromagnetic waves?

alpha beam, beta beam, gamma beam, X ray, ultraviolet light, visible light, infrared light, microwave, radio wave, electron beam
what is electromagnetic wave

Light is electromagnetic wave. Which are electromagnetic waves?
- alpha beam, beta beam, gamma beam, X ray, ultraviolet light, visible light, infrared light, microwave, radio wave, electron beam
Q: speed of light

- The shorter the wavelength, the higher the energy.
- The speed of light is constant in vacuum, not depending on its wavelength:
  - number of vibration per unit time = frequency (Hz)
  - wavelength x frequency = (speed of light)
  - (speed of light)/wavelength = frequency
Q: speed of light

- The shorter the wavelength, the higher the energy.
- The speed of light is constant in vacuum, not depending on its wavelength:
  \[
  \text{ca. } 3 \times 10^8 \text{ m s}^{-1}
  \]
- number of vibration per unit time = frequency (Hz)
- wavelength \times frequency = (speed of light)
- \((\text{speed of light})/\text{wavelength} = \text{frequency}\)
light: wave and particle

- no weight
- electron: particle and wave at the same time with weight
energy of light

- Even if the total energy is the same, the effect of light may different depending on the energy of each photon.
Q: boundary of ultraviolet and visible light

Various electromagnetic wave

Q: Answer the boundary wavelength of ultraviolet and visible light.
Q: boundary of ultraviolet and visible light

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<th>エネルギー/10^9 J</th>
<th>/10^8 eV</th>
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ca. 400 nm

Q: Answer the boundary wavelength of ultraviolet and visible light.
boundary of ultraviolet and visible light

- "Visible" means one can see the light.
- The wavelength of light sensible is different individually.
- Ordinary speaking, it is approximately 400 nm, certain people can be sensible for the light of wavelength shorter than 380 nm.
Q: Why leaves look green?

interaction of light and substances
the three primary colors: red, green and blue
Think complimentary color(s).
Q: Why leaves look green?

interaction of light and substances
the three primary colors: red, green and blue
Think complimentary color(s).

(1) Solar radiation contain all light of colors (white).
(2) Chlorophyll in leaves absorbs the light of red and blue (blue-violet).
(3) Remaining green light is reflected to make leaves look green.
comments on this lecture

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pc20170420-XXXXXXXX
zzz@yyy.hokudai.ac.jp
<full name>
<nickname>
<comments on this lecture>
<question(s) if any>

JPY1,200 (77%)  JPY3,500 (79%)
to: ohtani@cat.hokudai.ac.jp
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pc20170420-12345678
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大谷文章
某教授
光触媒の応用例について知り、その基本が化学であることを学びました。光と物質のかかわりについてさらに知りたいので本を調べてみます。
絶版になっている「光触媒標準研究法」はどこかで入手可能ですか。

sample mail