Peeling Back the Layers of Solar Cells: The Physics, Chemistry, and Biology of Solar Energy

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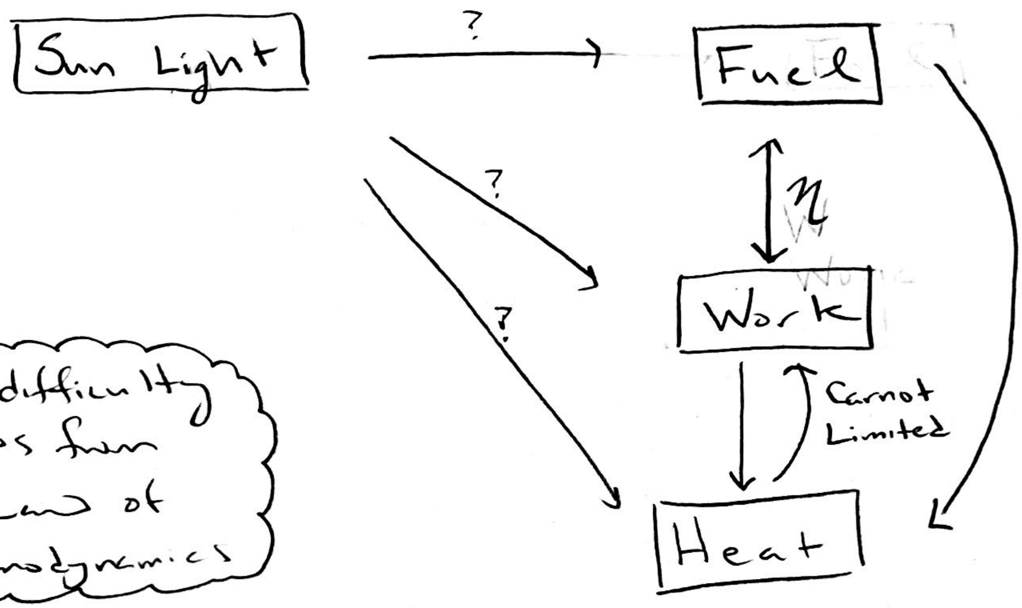
Overview

* 0.1% incident solar output = total consumption on earth *



Energy

"Potential" [Biology Chemistry]

"Ordered" [Chemistry Physics]

"Disordered" [Physics]

Ease/difficulty follows from 2nd Law of Thermodynamics

(bean jar)

Heat

Solar Thermal Collectors (black t-shirt) [50-70%]

- CuO on Cu
- Black Cr on Ni-plated Cu

→ App: Boil H_2O

[?] Why not paint?

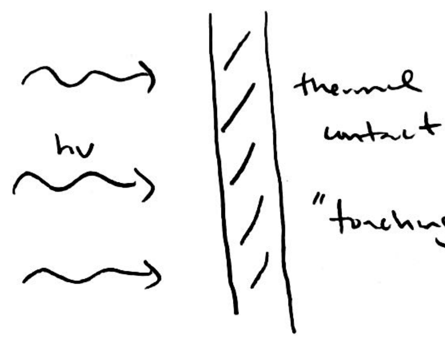
Kirchhoff's Law of Thermal Radiation $\alpha = \varepsilon$ (\$ T → inf E draw)

$\Rightarrow \alpha(\text{vis}) > \varepsilon(\text{IR})$

Schematic:

Absorb
↓
use

"easy"



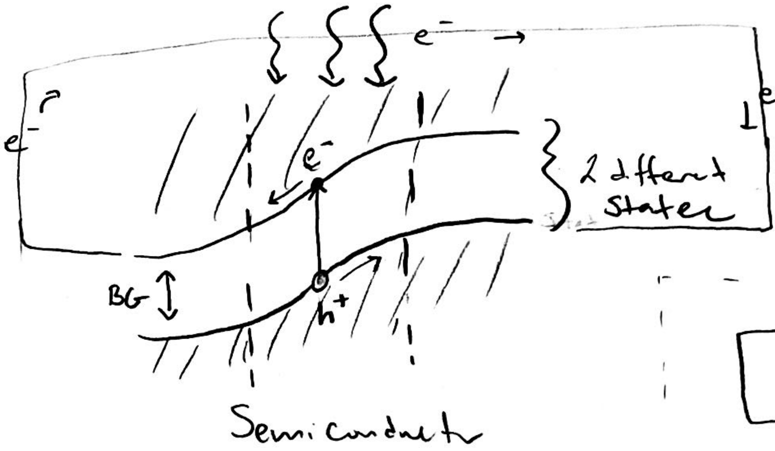
1 Layer

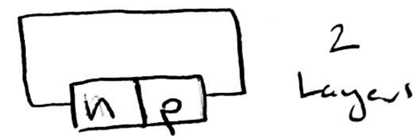
Work

Semiconductors "Photovoltaic"

Schematic:

Absorb
↓
Sep e^-
↓
use





$E = h\nu = \frac{hc}{\lambda}$ [?] Peak of solar spectrum

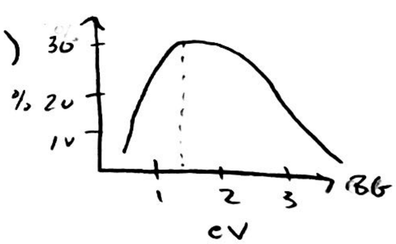
Key:

1. Only absorb $h\nu$ if E > BG
2. All E−BG lost (usually, multiexciton generation for exception)

[?] Tradeoff, which do we want? ↑BG or ↓BG

↳ Shockley-Queisser Limit (+ physics of losses in SC)

· 1 layer 33.7% → ∞ layers 86.8%
[28 %] [46 %]



- Perovskites - specific crystal structure of SC
  - cheaper, better match BG*
  - degrade easily

[21 %]

App: Roof panels [14−17%]

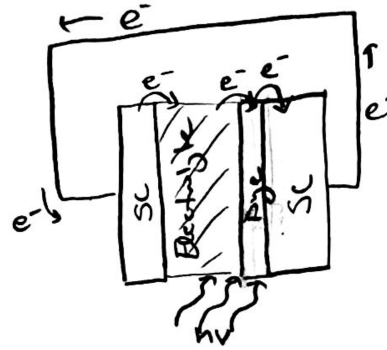
END CLASS 1

Dye-Sensitized Solar Cells

Schematic:

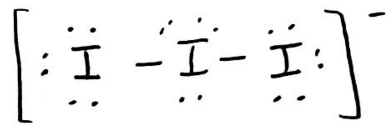
Absorb → Sep e^- → use

4 Layer
different phases
electrical contact



Redox-Couple:

$I_3^- + 2e^- \rightleftharpoons 3I^-$



[?] Why need electrolyte?

- Dye e^--h^+ not seperate well ("excitons")
  - → thin layer → push e^- into SC
    - * no e^--h^+ recombine

(w electrolyte)

Main difference is mobility of e^-!!!

Ex: $Ru(bpy)_3$ [11.5%]

- low light operation, flexible
- liquid electrolyte

Fuel

Biology [0.1-0.3%]

$$6\,CO_2 + 6\,H_2O \xrightarrow{hv} C_6H_{12}O_6 + 6\,O_2$$ [?]

- light-activated reaction - moves e^- w/in molecule "radical"
  - → ADP/NADPH → Power protein mechanisms →
  - (neither arrow well understood)

Absorb → Sep e^- → Store

N Layers / e^- jumps

where N is very, very large

Solar Electrolysis (split H_2O) [30%]

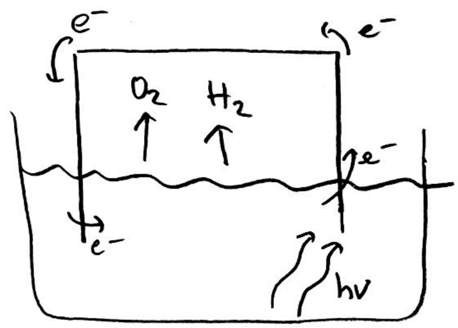
$2H_2O \rightarrow 2H_2 + O_2$ $\Delta G = 286$ kJ/mol (taken E)

- catalyst to oxidize H_2O
  - photocatalyst is reactive in excited state (very careful design molecule)

App: H_2 fuel cells
- $2°$ η, explosive

Schematic:

Absorb
↓
Sep e^-
↓
Store



3 Layers:
Catalytic coating

★ Here liquid between electrodes is active in reaction. ≠ Electrolyte couple just a transport mechanism.

Solar Thermal Cells

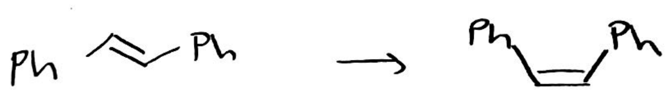
Key: store E w/in molecule by changing its orientation / e^- density

$\overset{hv}{\rightsquigarrow}$ low E molecule ⇄ high E molecule → heat

- Electrocyclic: norbornadiene → quadricyclane

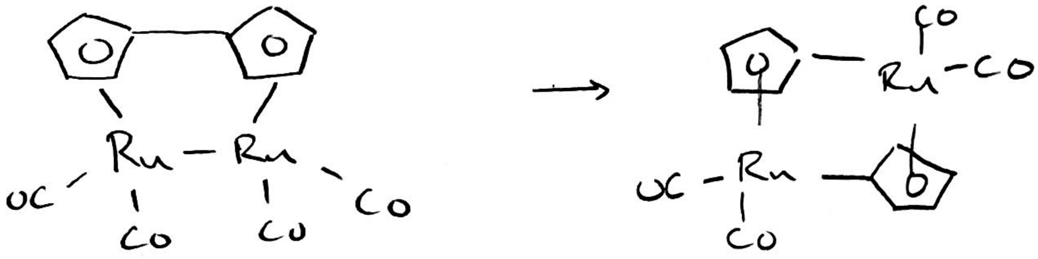
(model)
3-mem ring strain

- Double Bond Isomerization: azobenzene [0.4%]



[?] crowded v apart

· Ligand Reorientation (break C–C bond)



(fulvalene) tetracarbonyl-diruthenium

App: no electrical grid (ǁ solar collectors), but also able to store
* "recyclable" fuel

Summary

· Always think about goal on hierarchy, and how going to get there
  Ex: electrodes for 2 very different cells
· Cost to maintaining order in the efficiencies
  · H_2 exception b/c coupling η (but very promising)

Fuel	Work	Heat
· H_2 · STC -electrocyclic -double bond -ligand r · biology	· Semiconductors - Perovskites · DSSC	· Solar Thermal Collectors

← Complex Apparatus/Goal