Photoactive nanoscale devices and machines

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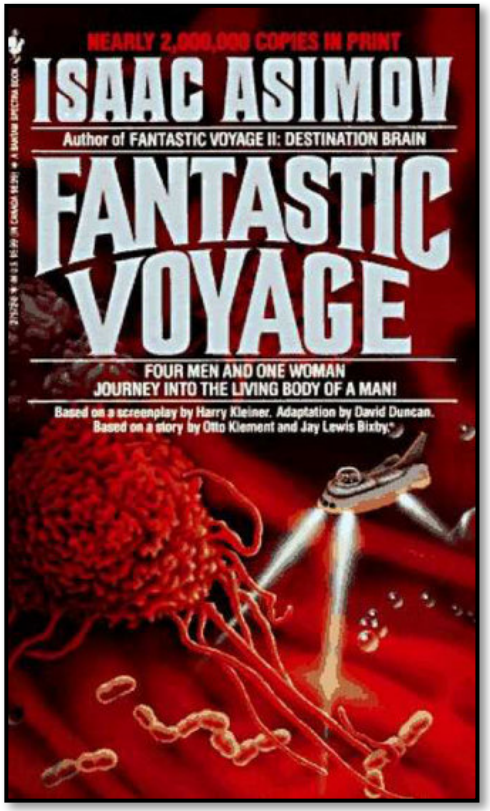
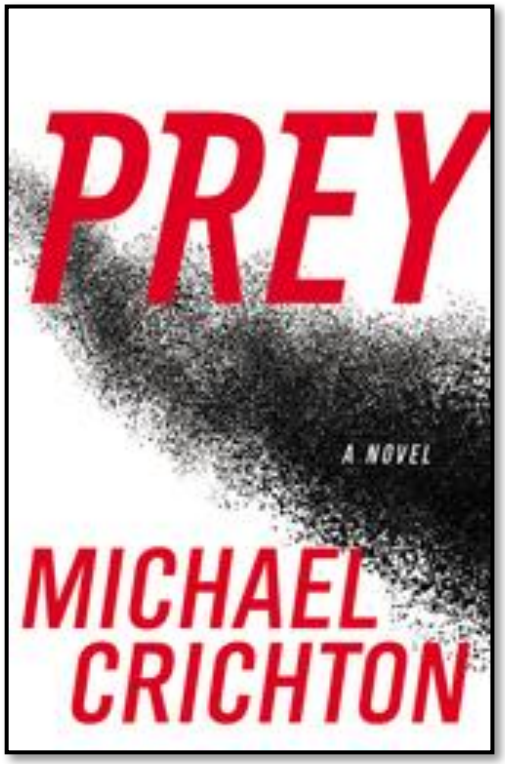
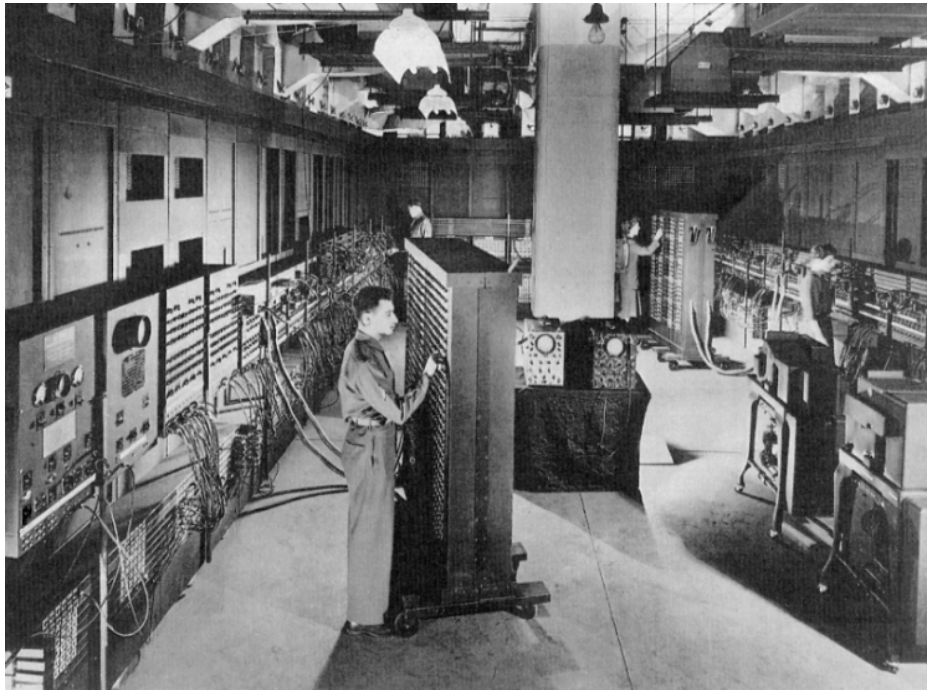

NEARLY 2,000,000 COPIES IN PRINT
ISAAC ASIMOV
Author of FANTASTIC VOYAGE II: DESTINATION BRAIN
FANTASTIC VOYAGE
FOUR MEN AND ONE WOMAN
JOURNEY INTO THE LIVING BODY OF A MAN!
Based on a screenplay by Harry Kleiner. Adaptation by David Duncan.
Based on a story by Otto Klement and Jay Lewis Bixby.


VIAGGIO
ALLUCINANTE


PREY
A NOVEL
MICHAEL
CRICHTON

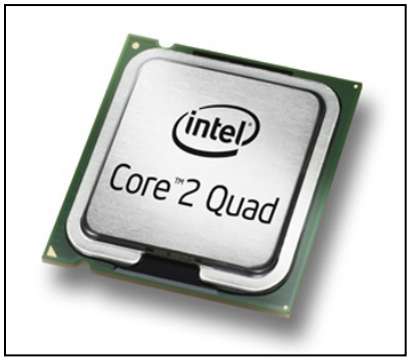
Why miniaturization?

ENIAC: the first electronic computer (1944)



Weigth: ca. 30 t
N. tubes: 19000
Power consumption: 200 kW

Integrated microprocessor (today)

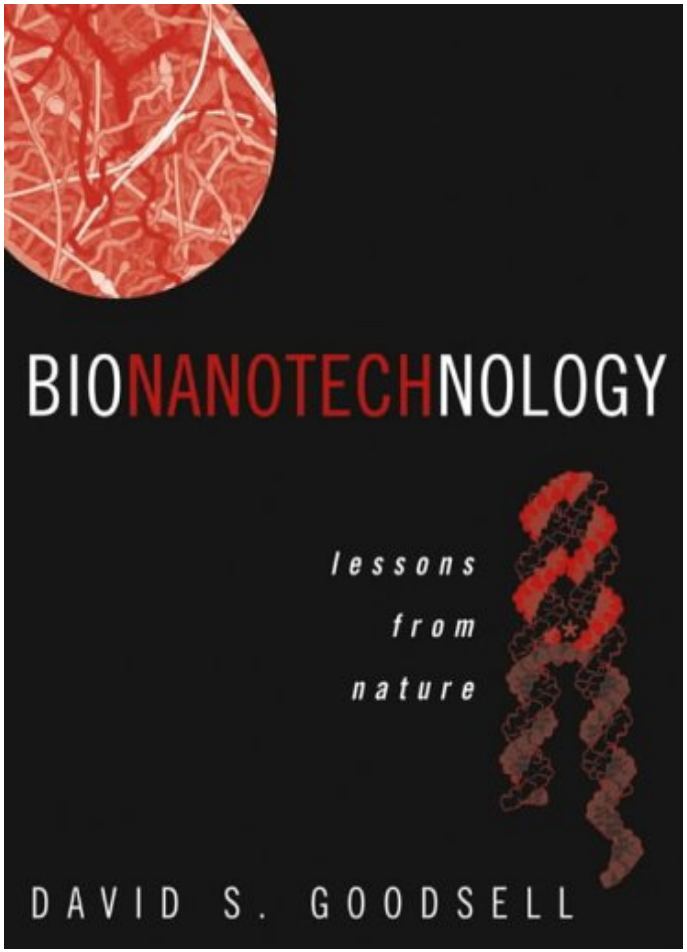


Weigth: ca. 2 kg
Power consumption: ca. 60 W (CPU)

N. transistors: 1.4 billions*
Elements size (min): 25 nm*

* Intel i7 quad core processor (22-nm lithography), released Q3 2013. See http:\\ark.intel.com

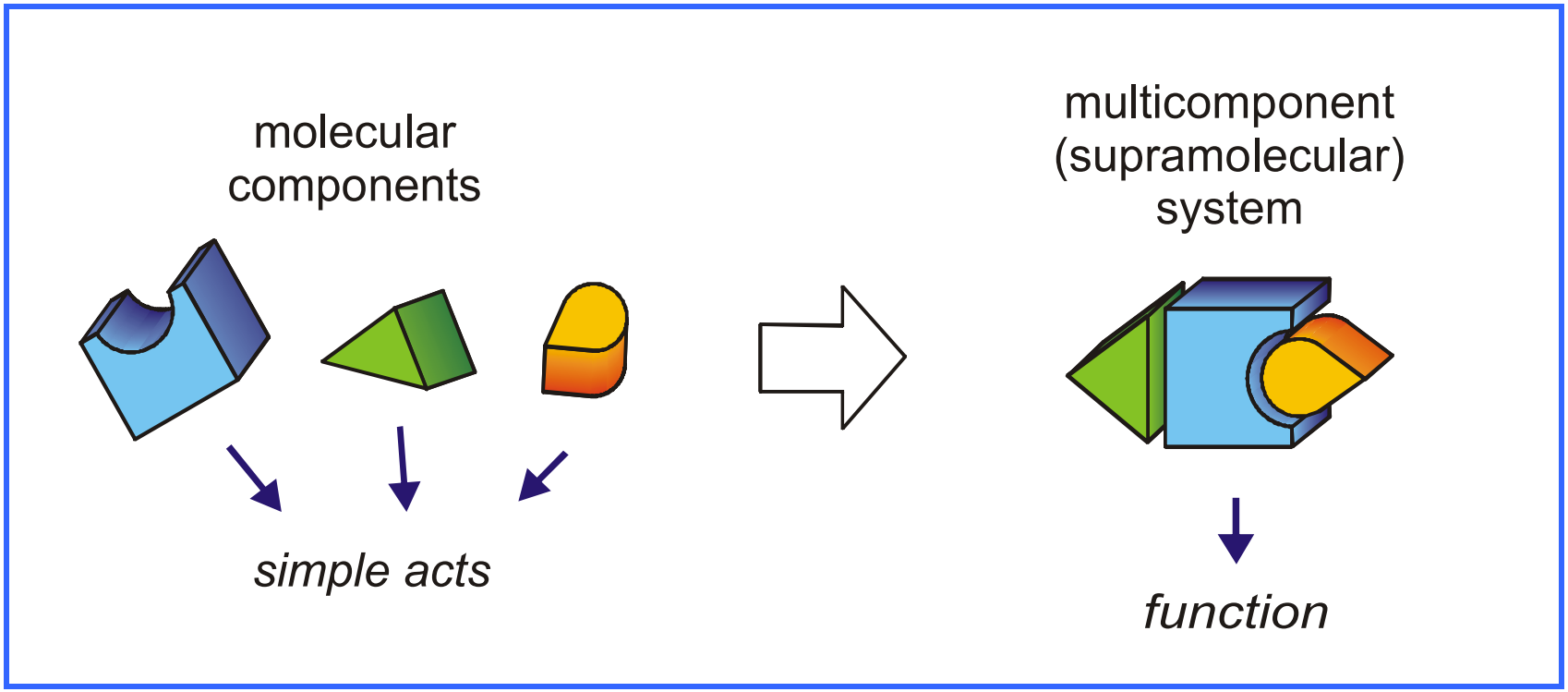
Naturally occurring molecular machines



Wiley, New York, 2004

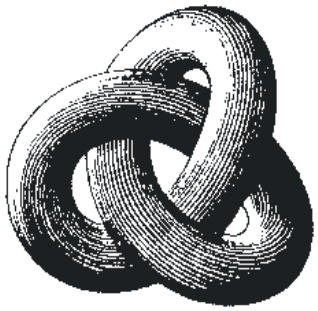
Cells have hundreds of different types of molecular motors, each specialized for a particular function.
Many biological motor-like proteins have been discovered and characterized in recent years.

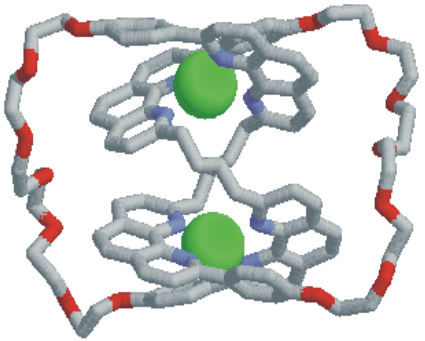
Artificial molecular devices



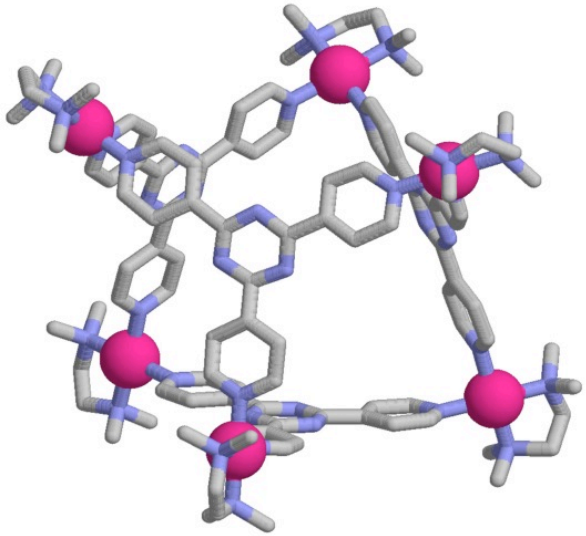
V. Balzani, A. Credi, M. Venturi, *PNAS* **2002**, *99*, 4814; *Chem. Eur. J.* **2002**, *8*, 5524

Complex synthetic structures

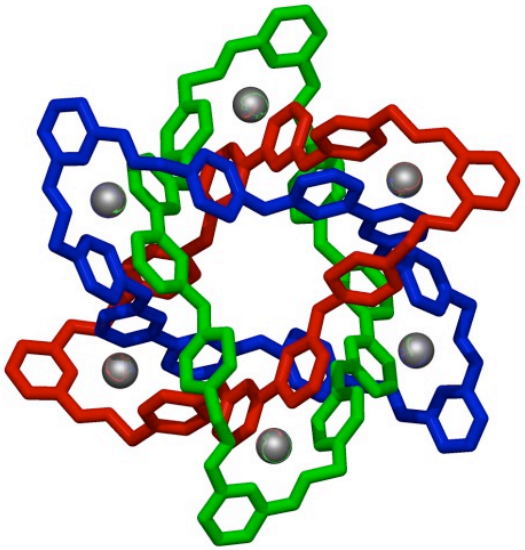




J.-P. Sauvage *et al*.

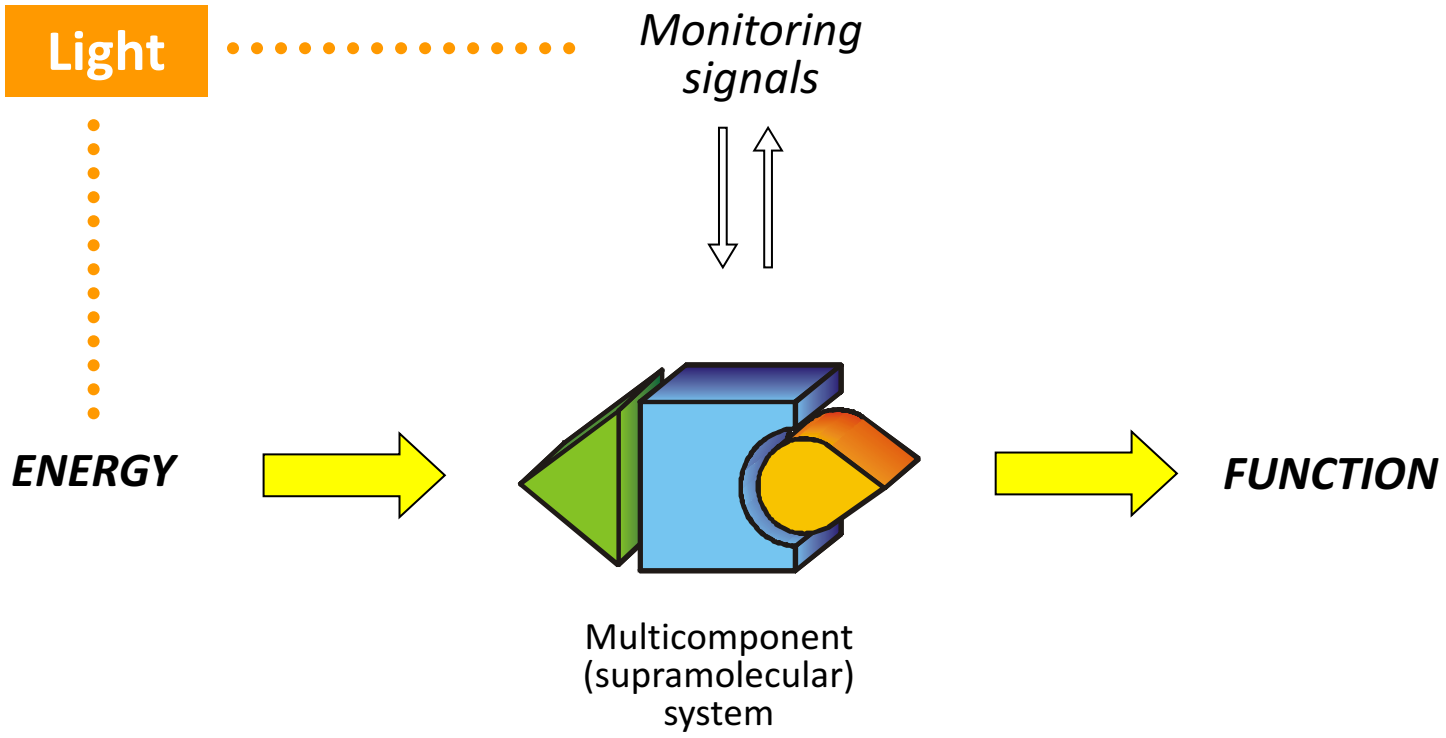


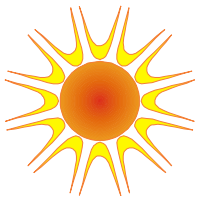
M. Fujita *et al*.



J.F. Stoddart *et al*.

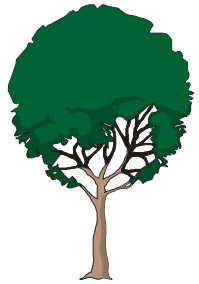
Artificial molecular devices: the role of light





SUN

living matter



photosynthetic processes

ENERGY for life

vision-related processes

INFORMATION for life

Artificial molecular devices

- **Devices for signal (information) processing**

  Wires, plug/socket devices, electrical extension cable systems, antennas, sensors, switches, logic gates,...

- **Devices for harvesting and converting light energy**

  Light harvesting antennas, wires, charge-separation devices, ...

- **Mechanical devices (molecular machines)**

  Tweezers, shuttles, muscles, valves, rotary motors, ...

Artificial molecular devices

Information processing devices

A.P. de Silva, S. Uchiyama, *Nature Nanotech.* **2007**, *2*, 399

K. Szacilowski, *Chem. Rev.* **2008**, *108*, 3481

V. Balzani, A. Credi, M. Venturi, *Chem. Eur. J.* **2008**, *14*, 26

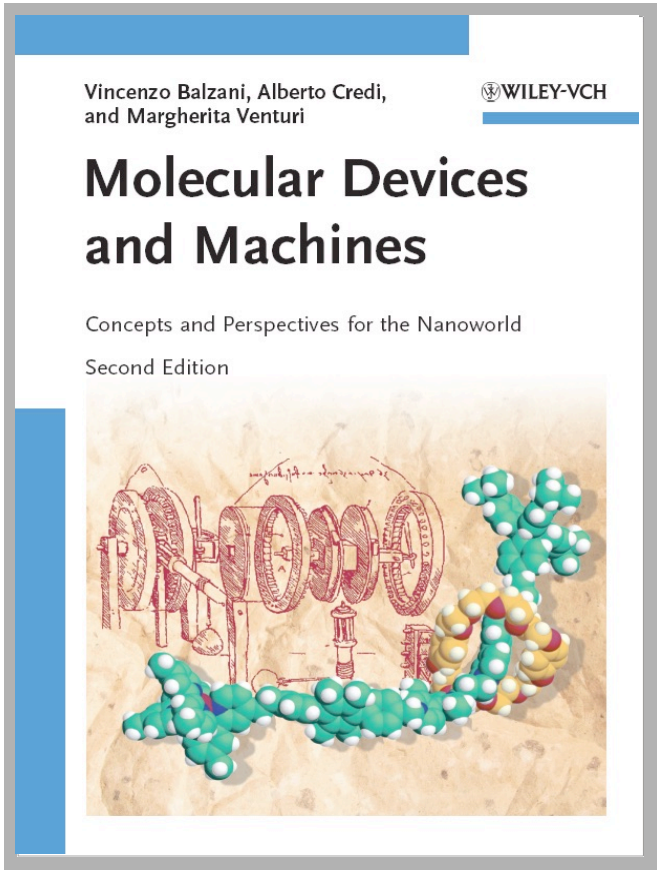
A. P. de Silva, *Molecular Logic-based Computation*, RSC Publishing, Cambridge, **2012**.

Mechanical molecular machines

D.A. Leigh *et al.*
Angew. Chem. Int. Ed. **2007**, *46*, 72
Chem. Rev. **2015**, *115*, 10081

S. Silvi, M. Venturi, A. Credi, *J. Mater. Chem.* **2009**, *19*, 2279;
Chem. Commun. **2011**, *47*, 2483 (feature articles)

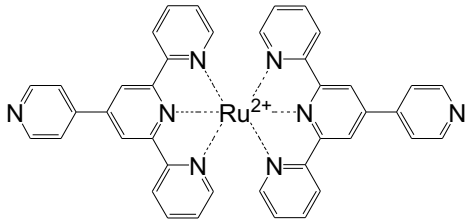
C. Bruns, J. F. Stoddart, *The Chemistry of the Mechanical Bond – From Molecules to Machines*, Wiley, New York, **2016**



Wiley-VCH, Weinheim, Germany, **2008**

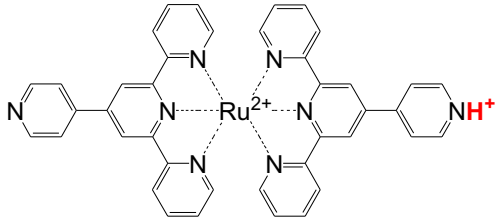
Information processing devices based on transition metal complexes

An acid-base controlled luminescent switch



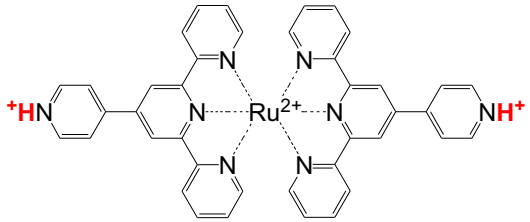
Ru

$- H^+ \uparrow\downarrow + H^+$

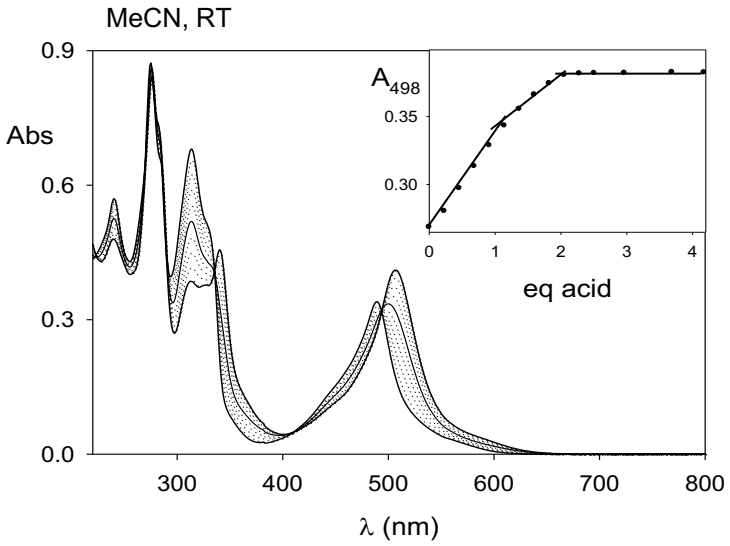


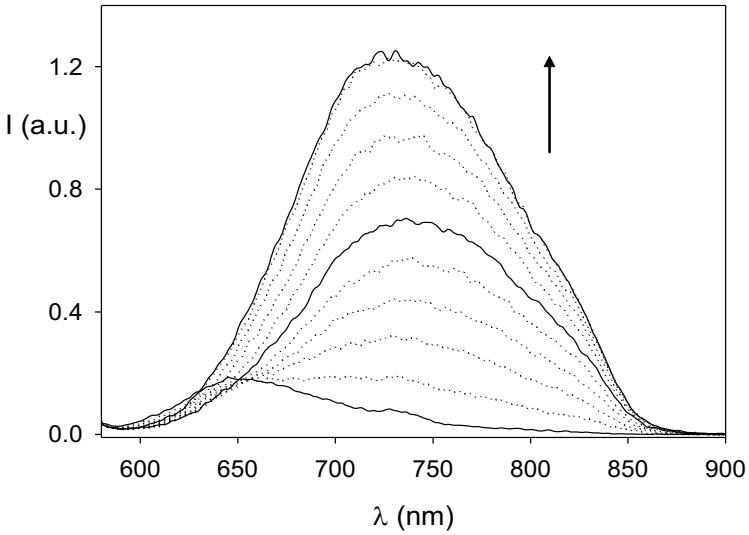
RuH^+

$- H^+ \uparrow\downarrow + H^+$



RuH_2^{2+}

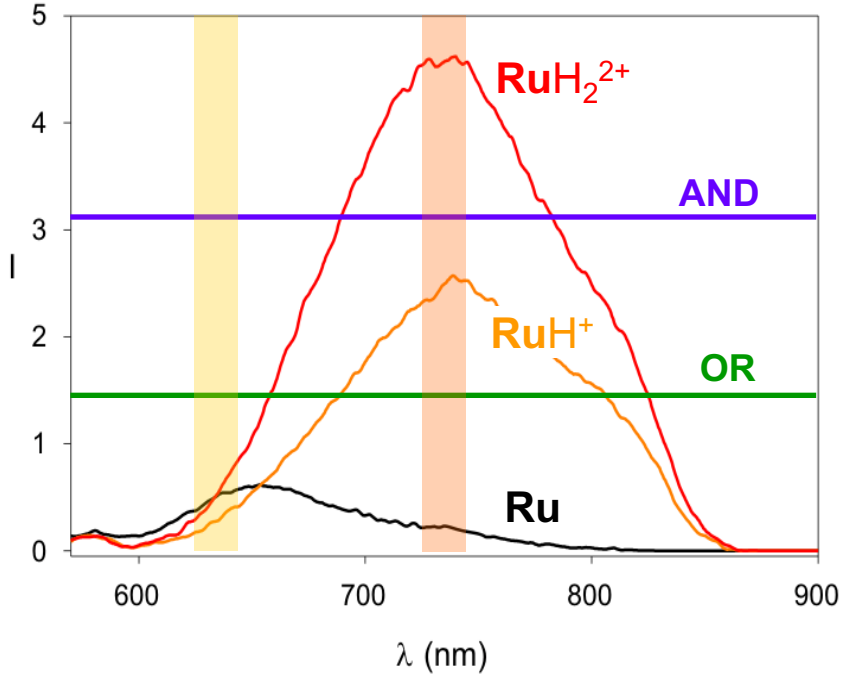


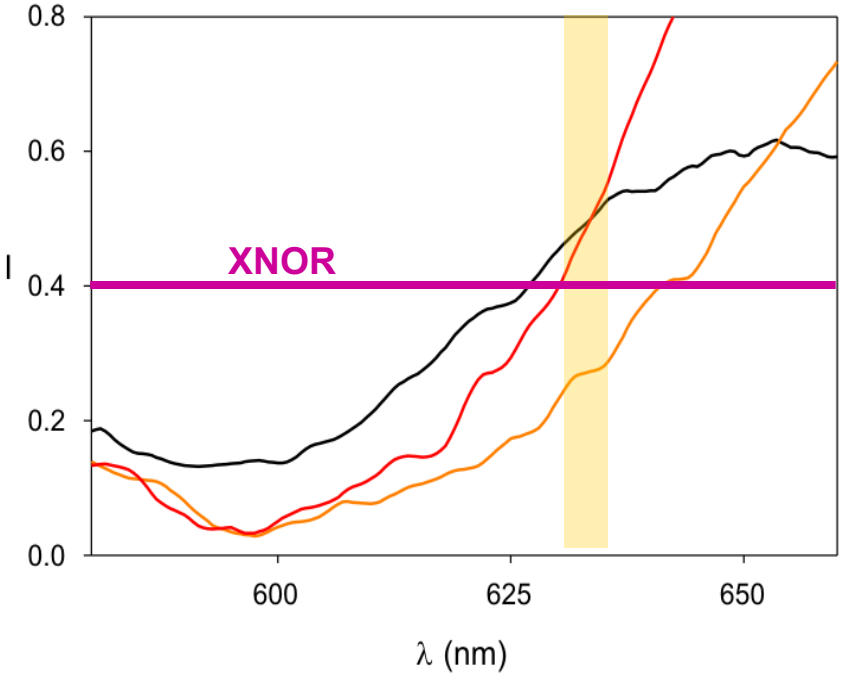


Paolo Passaniti, Serena Silvi

With Ed Constable, University of Basel

Inorg. Chim. Acta **2007**, *360*, 1102





$In_1 = H^+$

$In_2 = H^+$

Out = hν

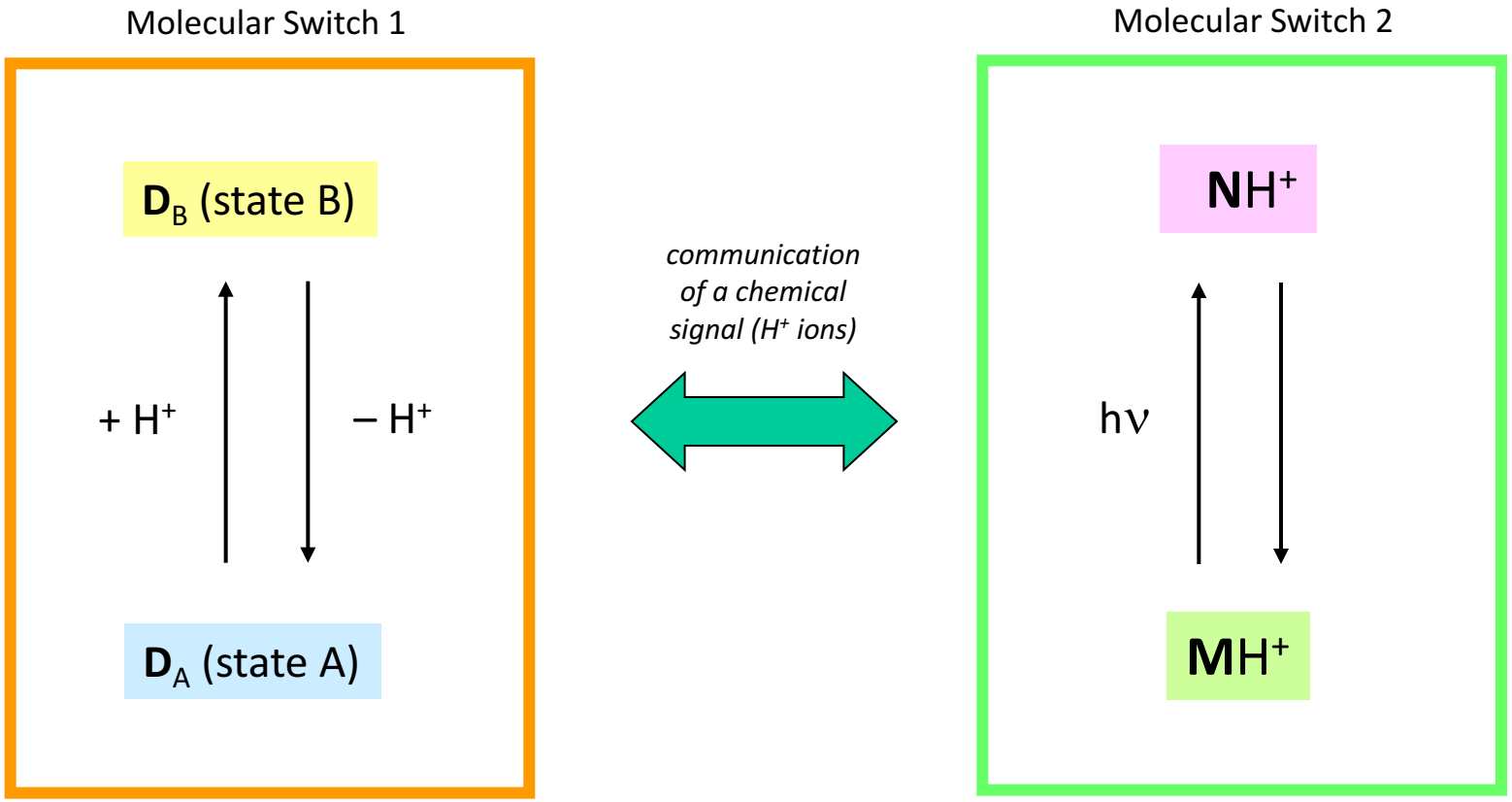
In_1	In_2	Out_{740}	Out_{740}	Out_{630}
0	0	0	0	1
0	1	0	1	0
1	0	0	1	0
1	1	1	1	1

AND

OR

XNOR

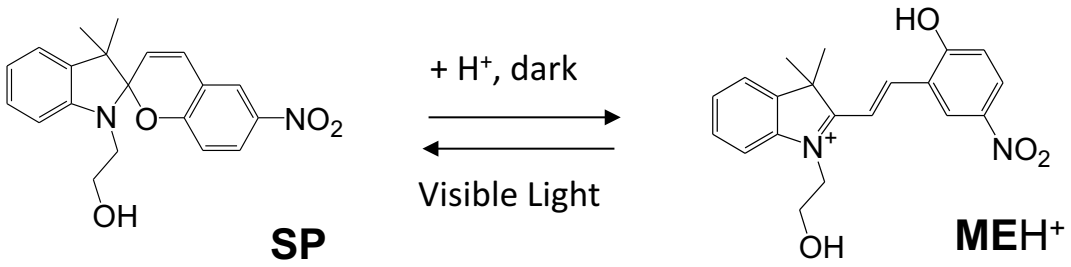
Photochemical operation of pH-controlled molecular switches

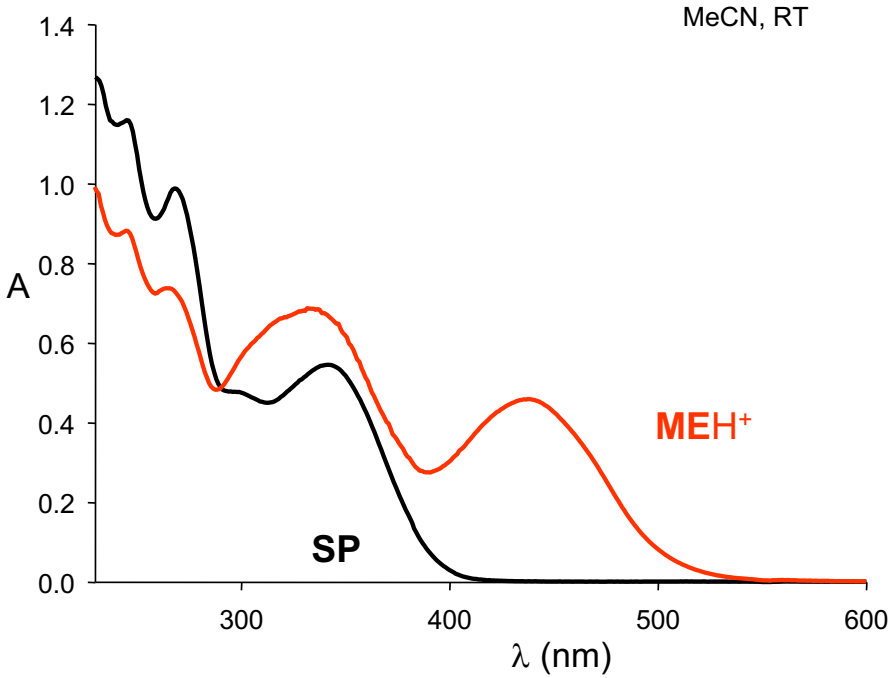


- compatibility of conditions
- no further chemical interactions between MS1 and MS2

- no interference of input/output signals
- correct timing of the switching processes
- $pK_a(\mathbf{N}H^+) < pK_a(\mathbf{D}_A) < pK_a(\mathbf{M}H^+)$

The spyropyran/merocyanine photochromic system

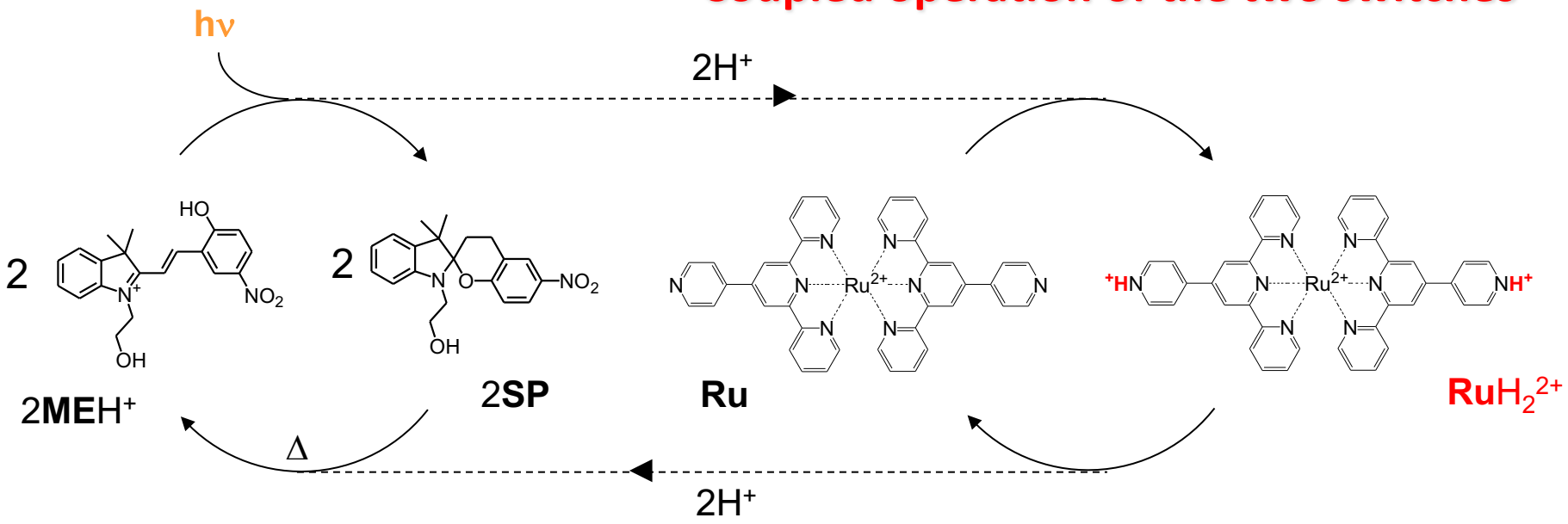


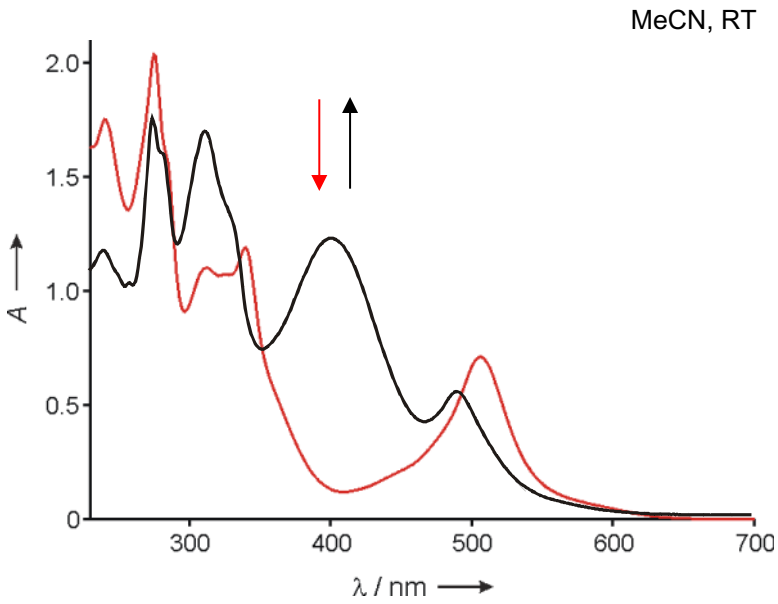


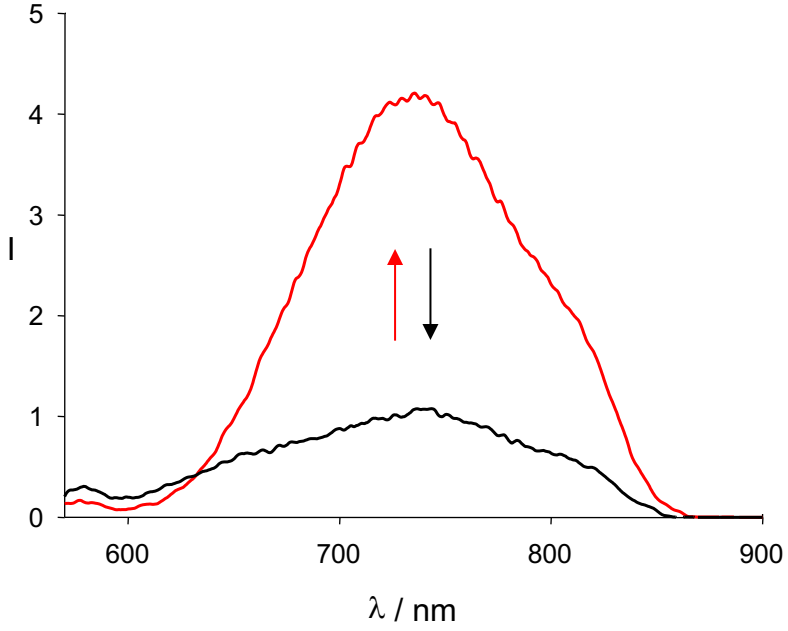
With Françisco Raymo, University of Miami

Serena Silvi

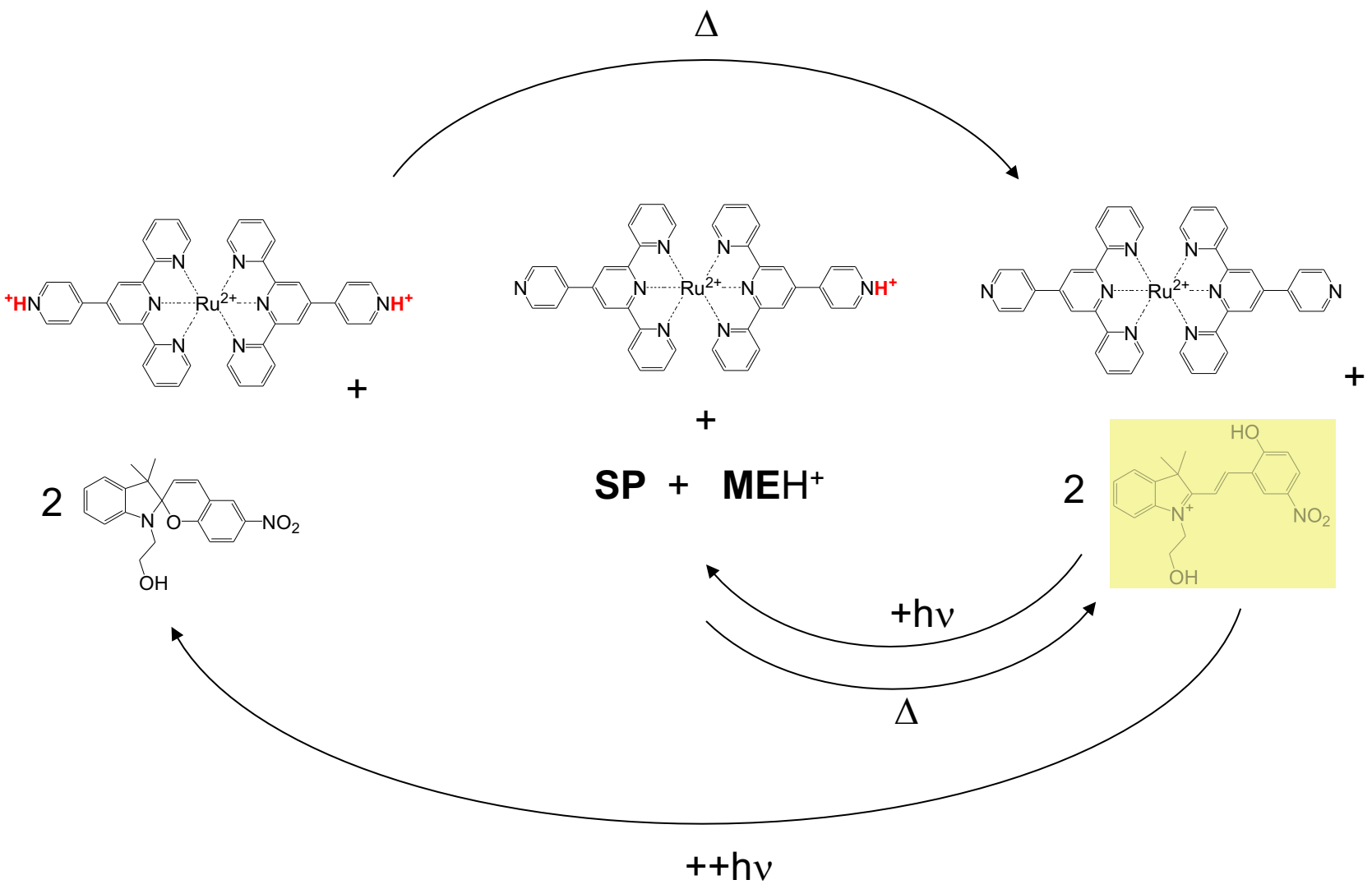
Coupled operation of the two switches



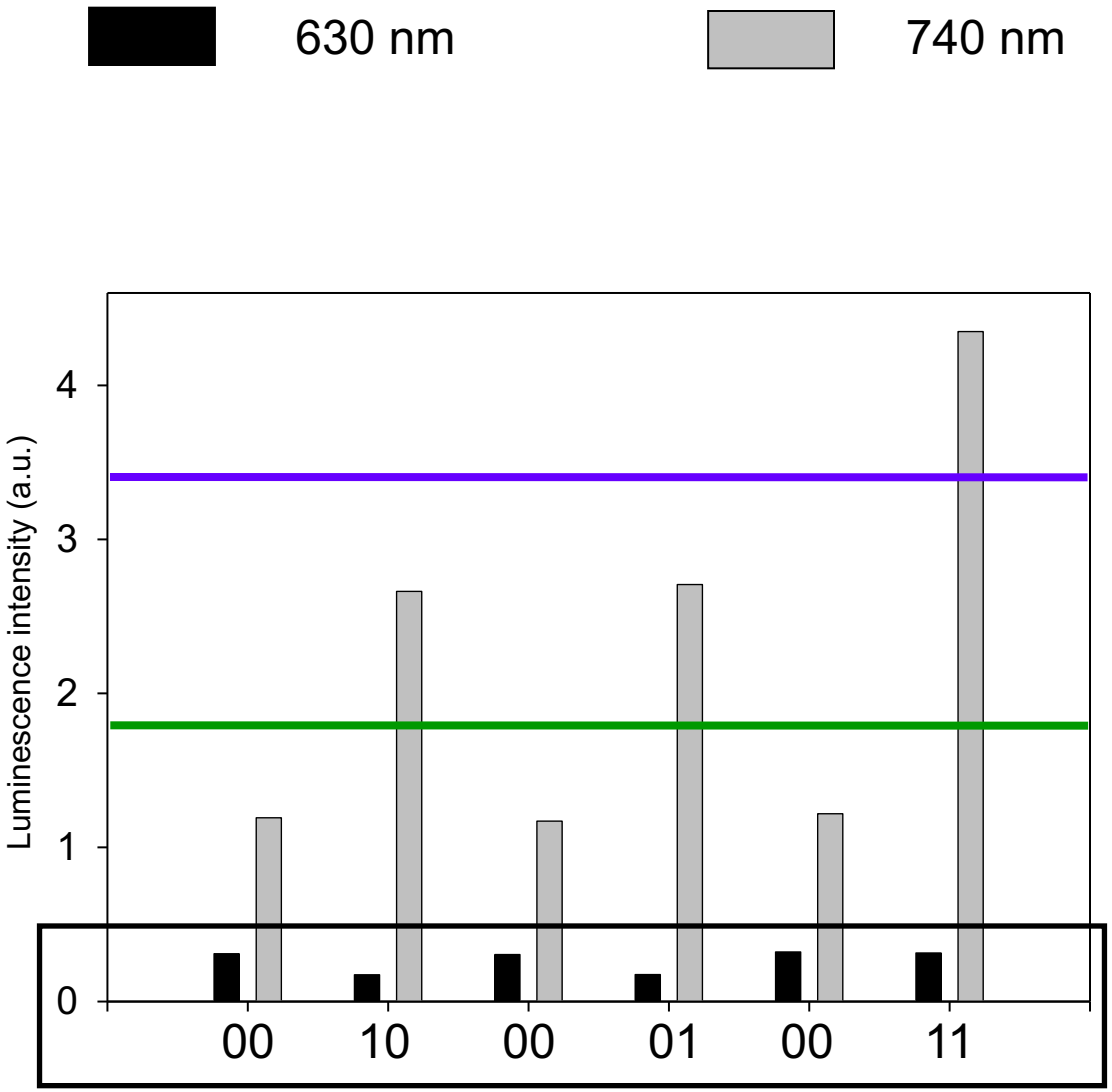




Photocontrol of molecular logic gate operation

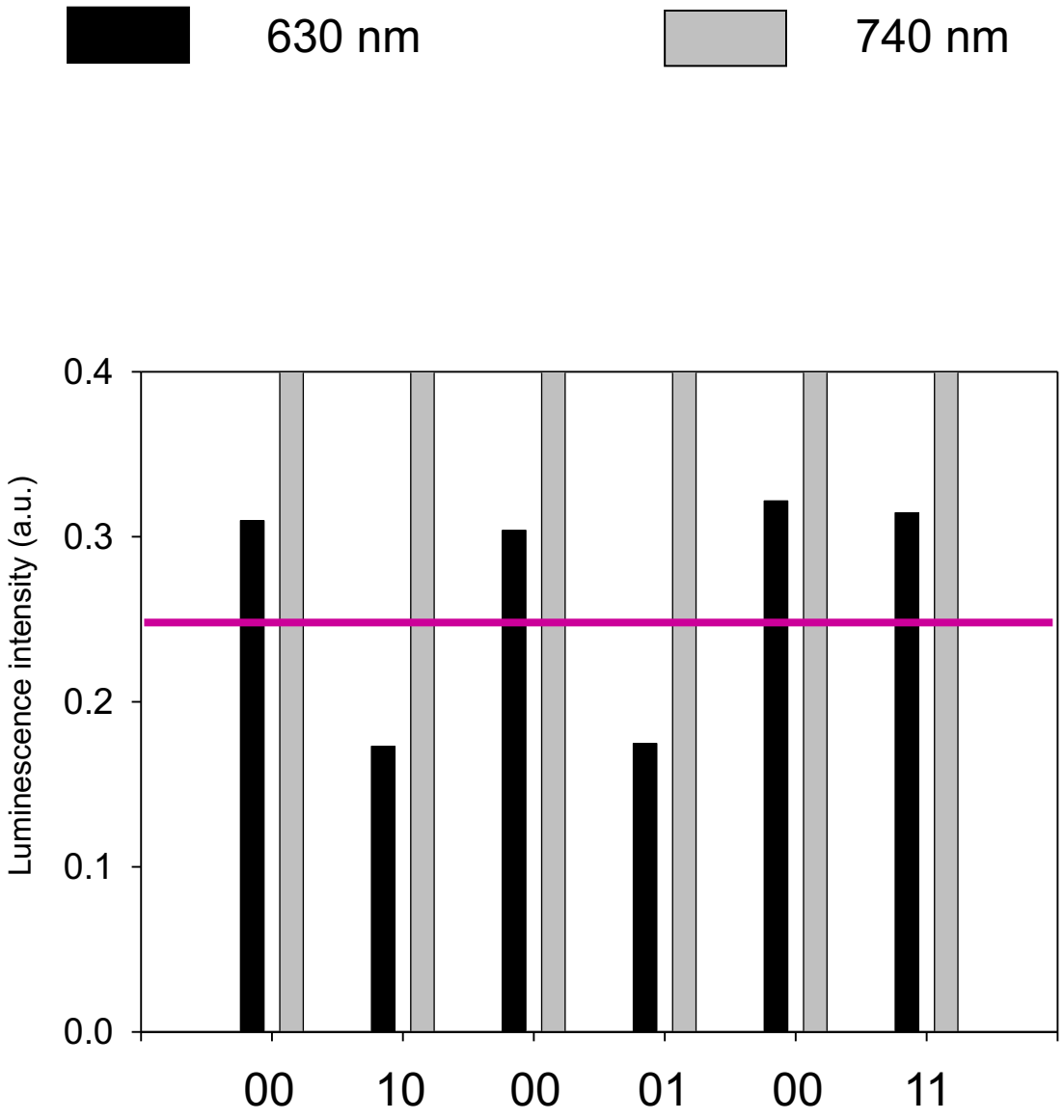


Chem. Eur. J. **2009**, *15*, 178



		AND	OR
In_1	In_2	Out	Out
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	1

Chem. Eur. J. **2009**, *15*, 178

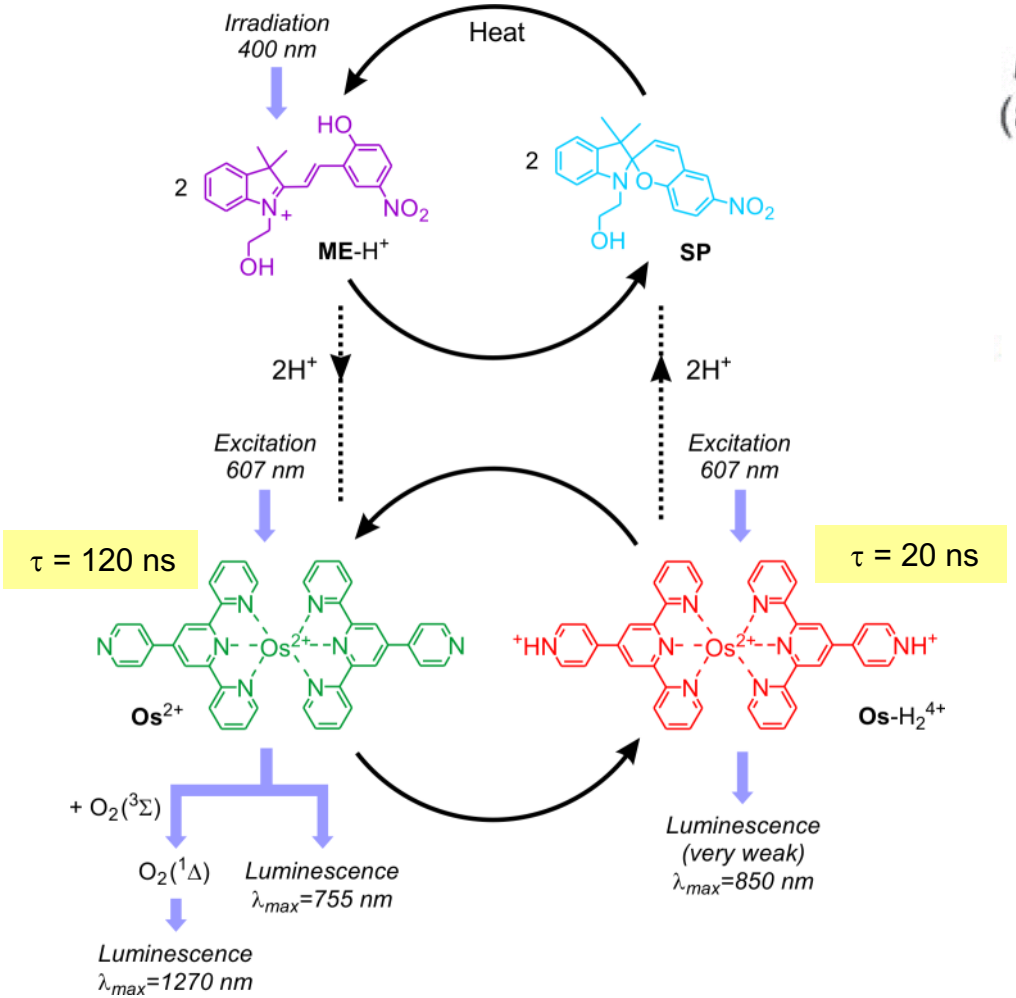


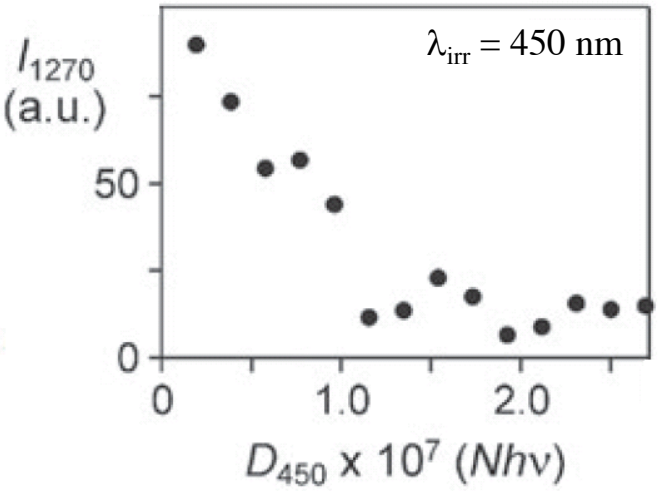
XNOR

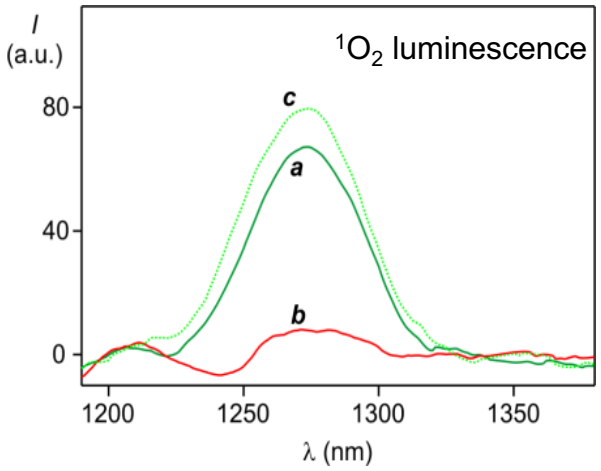
In_1	In_2	Out
0	0	1
0	1	0
1	0	0
1	1	1

Chem. Eur. J. **2009**, *15*, 178

Photochemical switching of luminescence and $^1O_2$ generation







Chem. Commun. **2009**, 1484

Nanoscale devices based on semiconductor nanocrystal quantum dots