Welcome to 3.091

Lecture 26

November 13, 2009

Acids and Bases

Fall 2009 Wulff Lecture

Tuesday, November 17, 2009
4:00–5:00 pm
Room 10-250
Reception immediately following

Nature Inspired Materials Science

Professor Michael F. Rubner
TDK Professor of Materials Science and Engineering
Director, Center for Materials Science and Engineering
MacVicar Faculty Fellow

More and more, materials scientists are looking to nature to find clues to create highly functional materials with exceptional properties. The fog-harvesting capabilities of the Namib Desert beetle, the iridescent colors of the hummingbird, and the super-water-repellant abilities of the lotus leaf are a few examples of the amazing properties found in the natural world. This lecture explores synthetic mimics to the nano- and micro-structures responsible for these properties with many potential applications.

The Wulff Lecture is an introductory, general-audience, entertaining lecture which serves to educate, inspire, and encourage MIT undergraduates to take up study in the field of materials science and engineering and related fields. The entire MIT community, particularly freshmen, is invited to attend. The Wulff Lecture honors the late Professor John Wulff, a skilled, provocative, and entertaining teacher who inaugurated a new approach to teaching the popular freshman subject: 3.091 Introduction to Solid State Chemistry.

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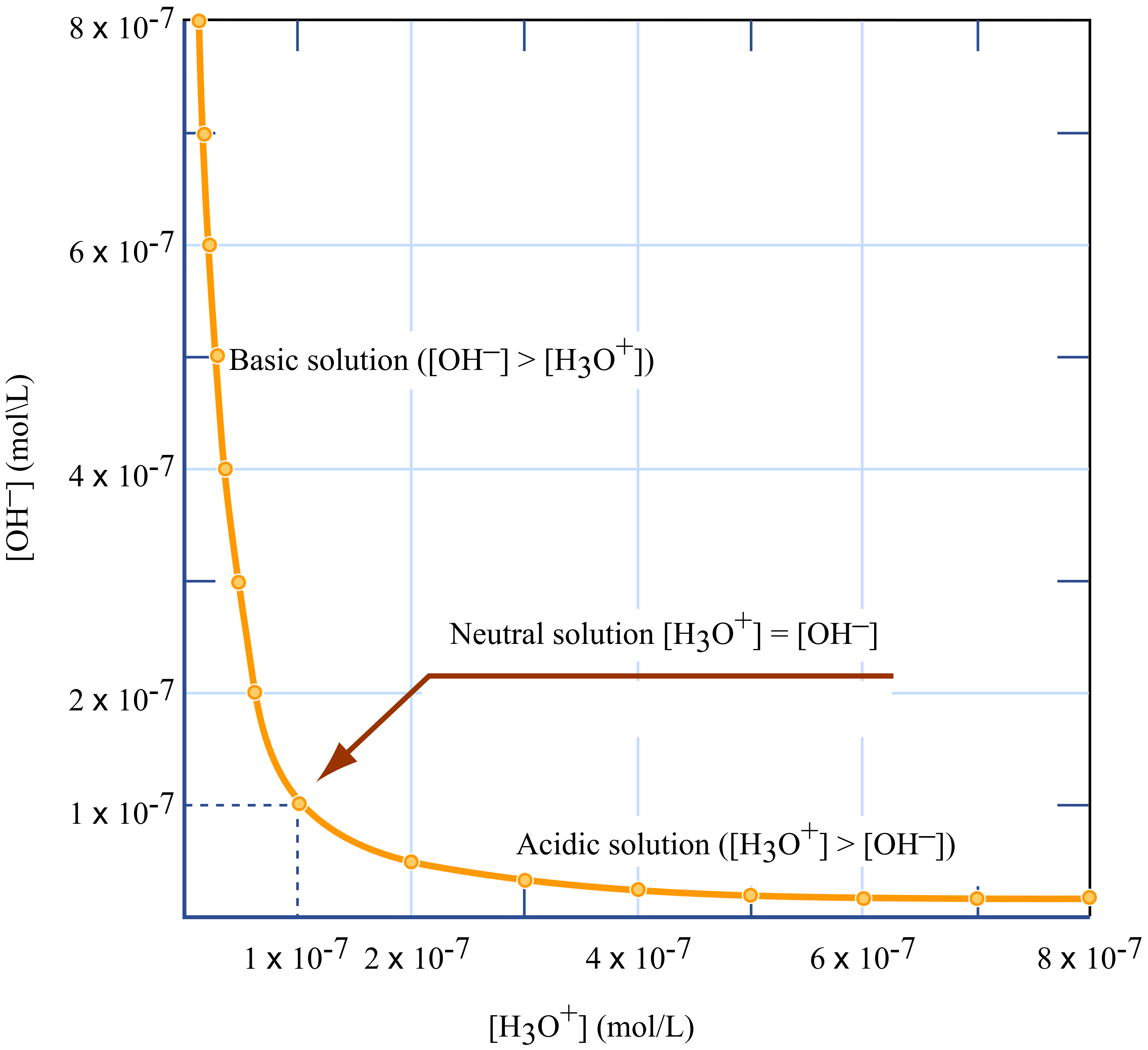
Antoine Lavoisier and Marie-Anne-Pierrette Paulze by Jean-Louis David 1788



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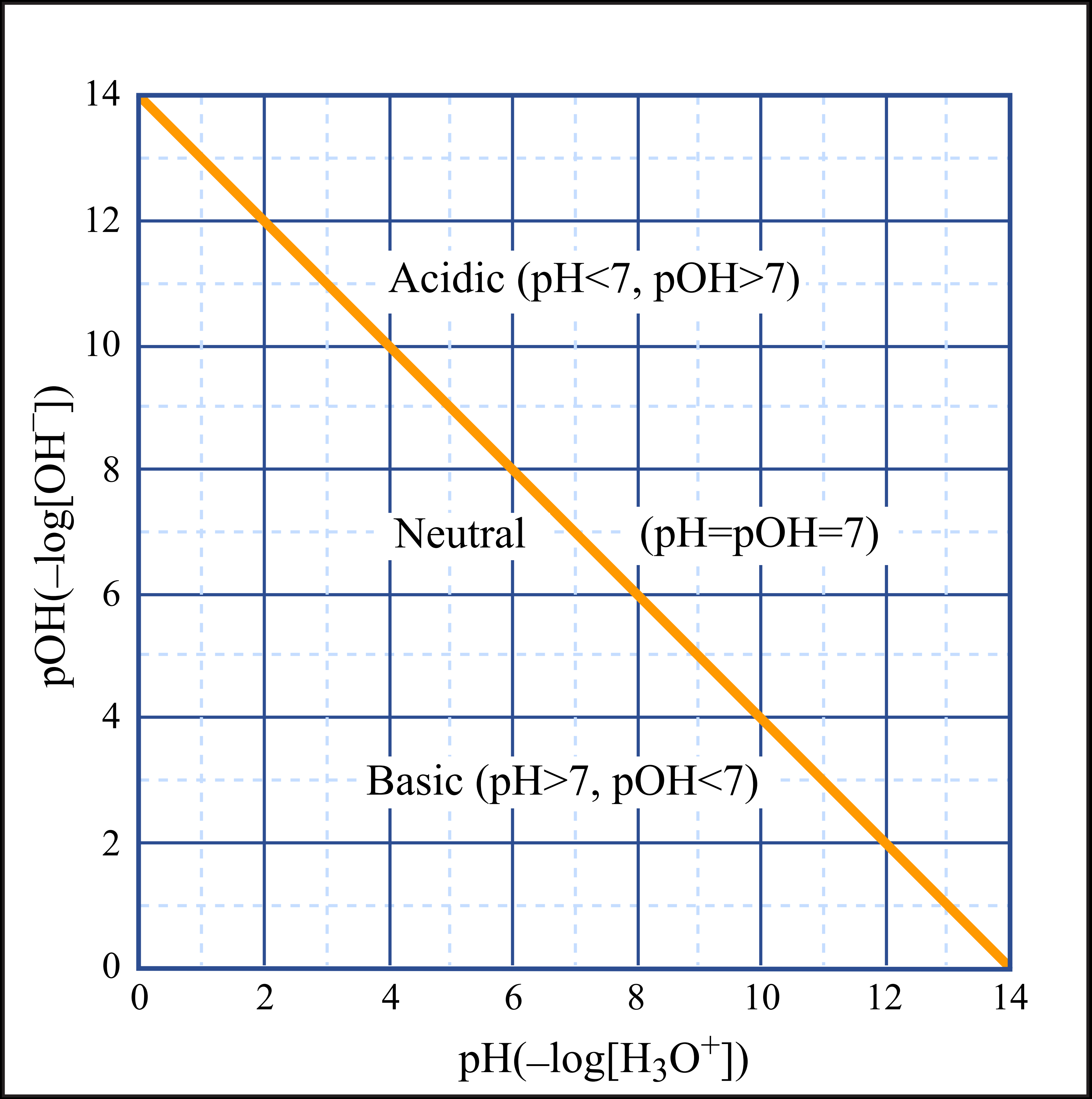

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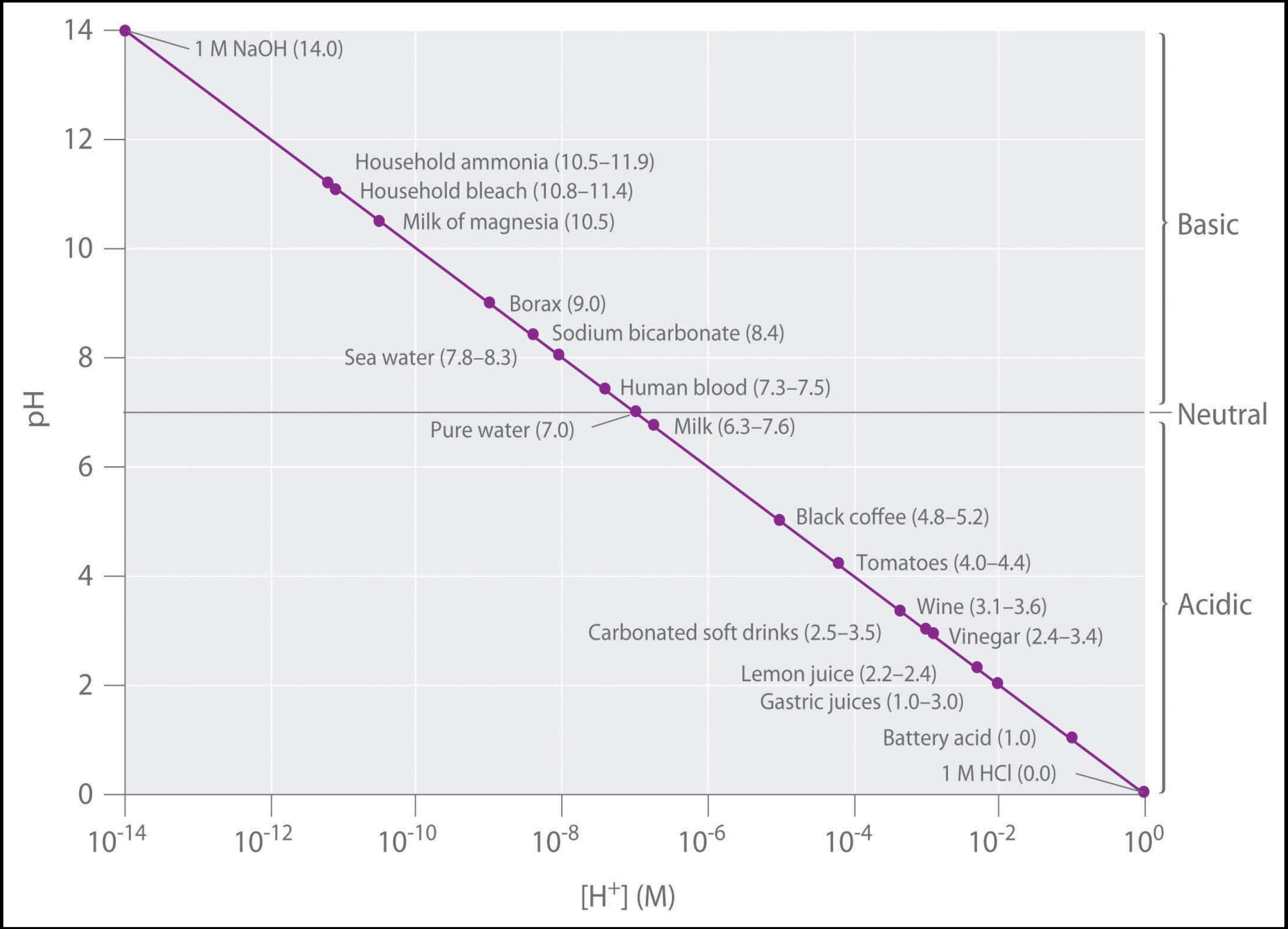
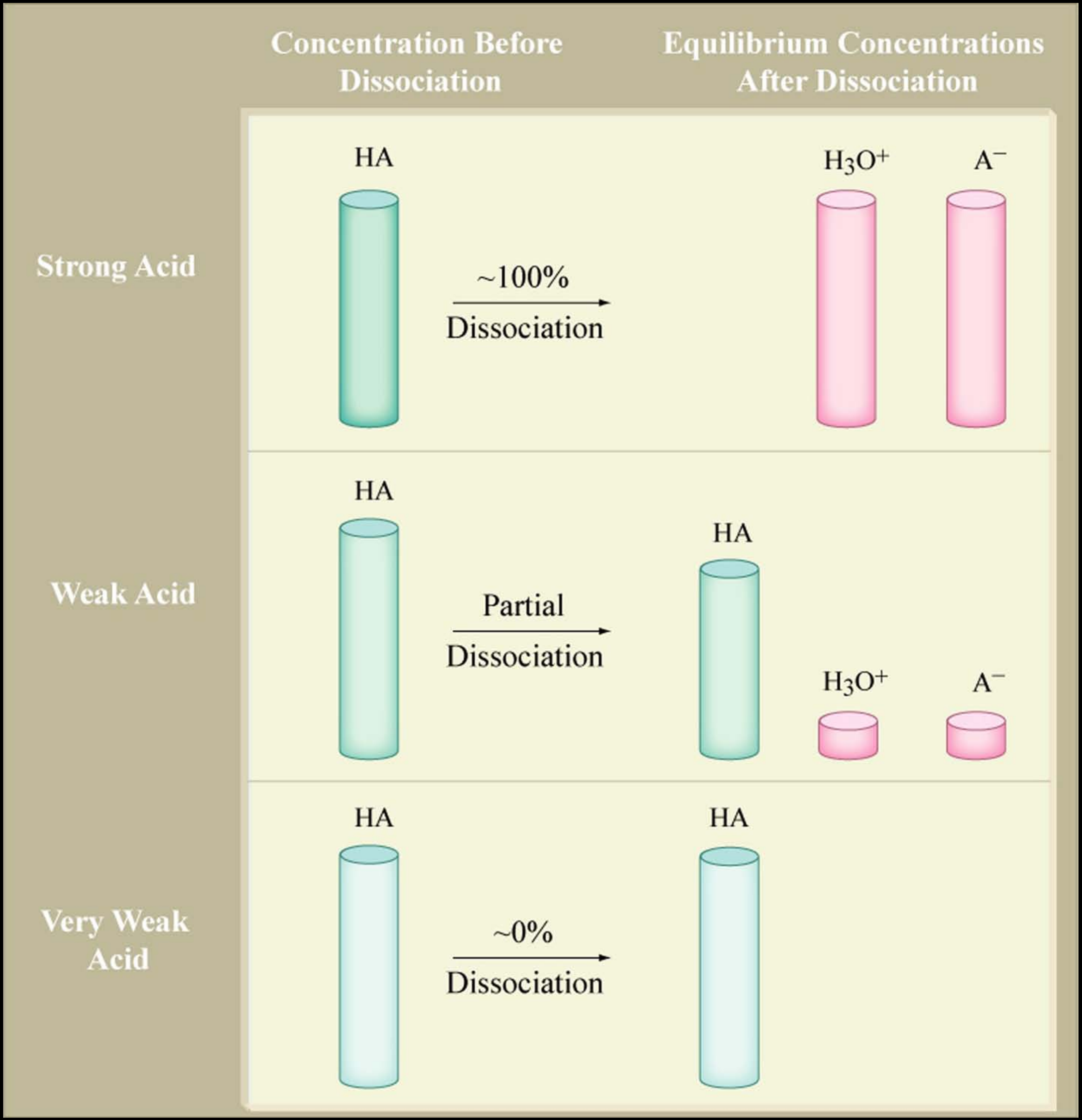


Averill, B., and P. Eldredge. *Chemistry: Principles, Patterns, and Applications*. Flat World Knowledge, 2011. ISBN: 9781453331224.



Concentration Before Dissociation

Equilibrium Concentrations After Dissociation

Strong Acid

HA $\xrightarrow[\text{Dissociation}]{\sim 100\%}$ H_3O^+ A^-

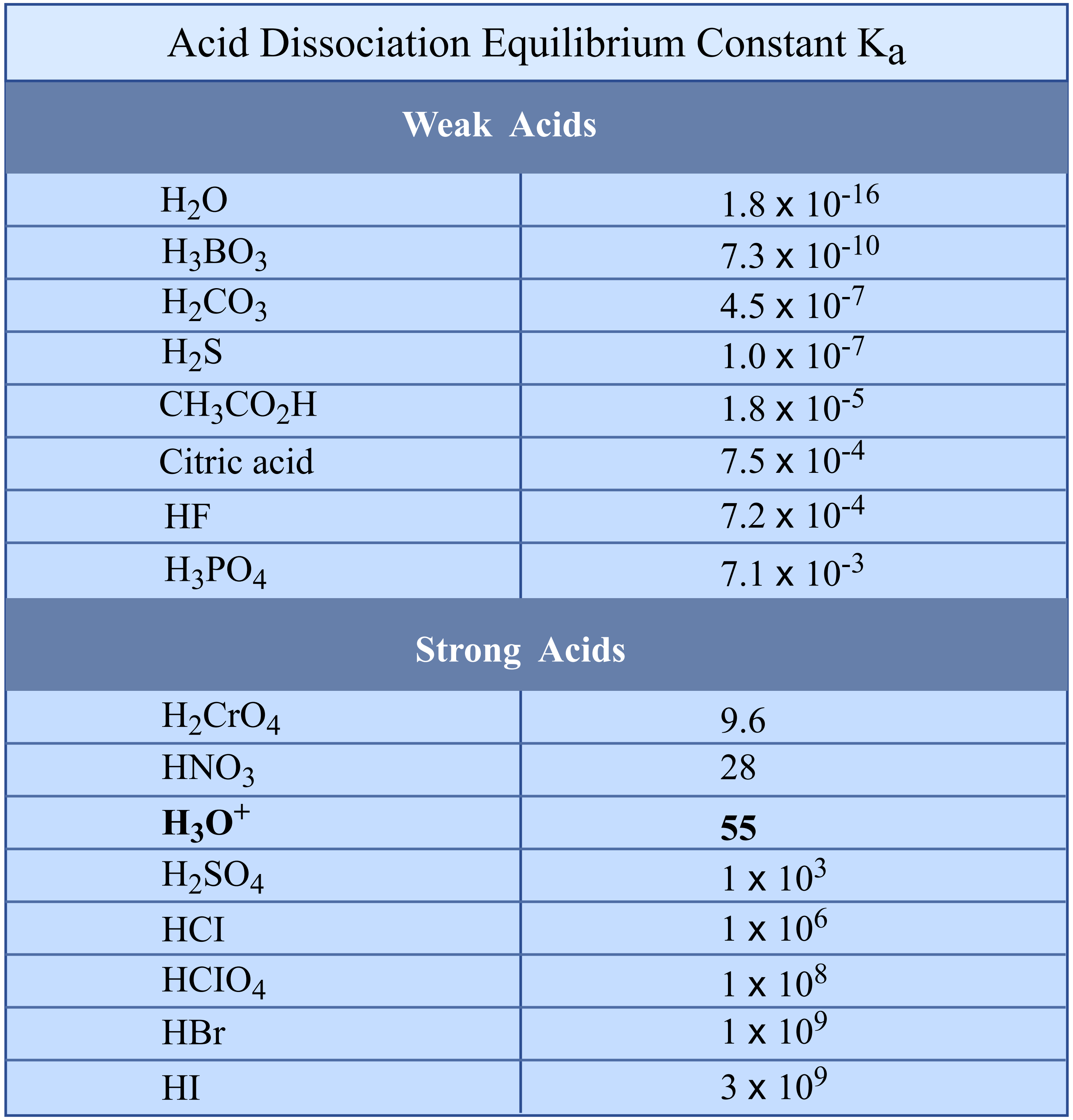
Weak Acid

HA $\xrightarrow[\text{Dissociation}]{\text{Partial}}$ HA H_3O^+ A^-

Very Weak Acid

HA $\xrightarrow[\text{Dissociation}]{\sim 0\%}$ HA

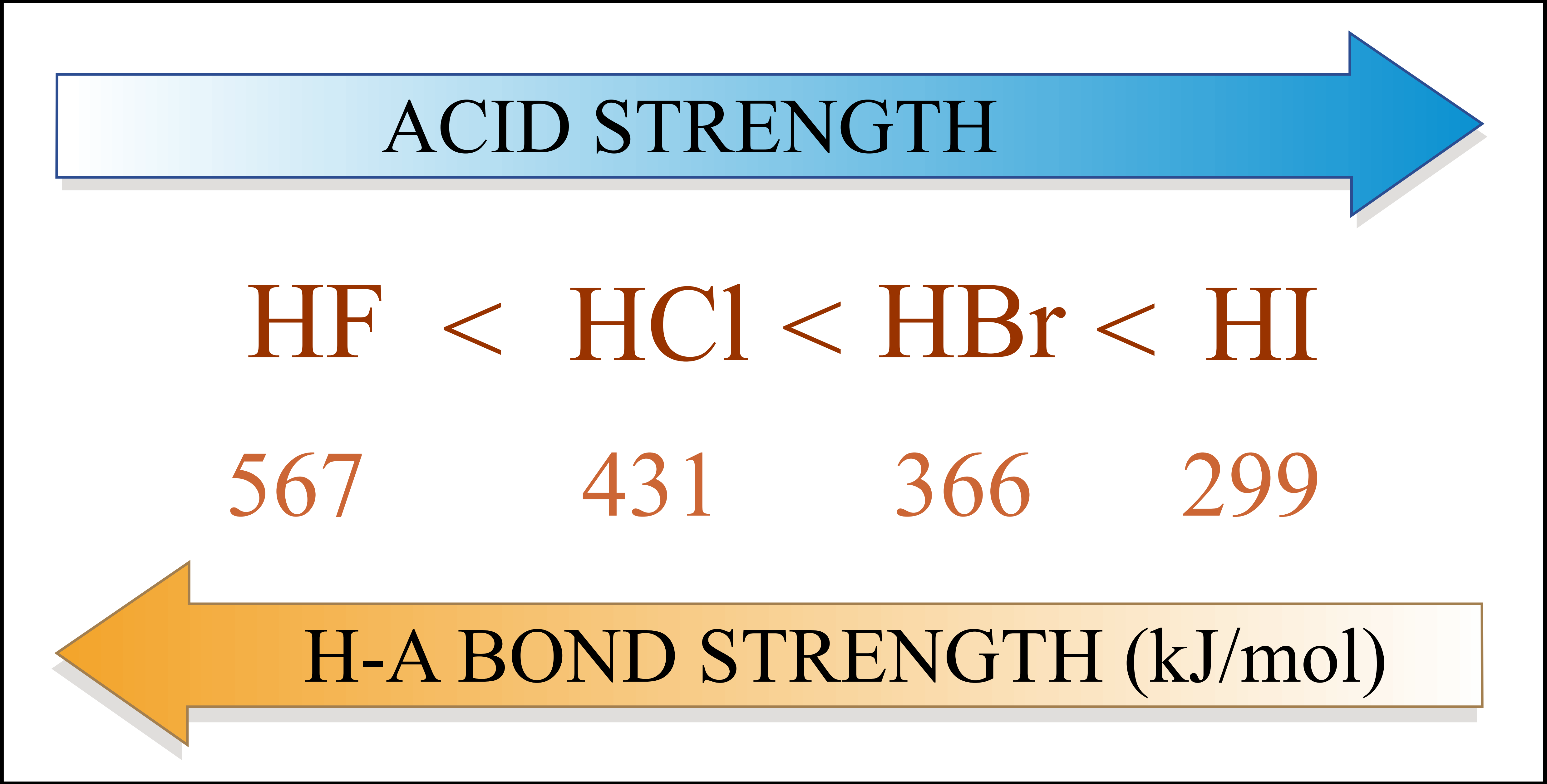
Image by MIT OpenCourseWare.



Acid Dissociation Equilibrium Constant K_a	
Weak Acids	
H_2O	1.8×10^{-16}
H_3BO_3	7.3×10^{-10}
H_2CO_3	4.5×10^{-7}
H_2S	1.0×10^{-7}
CH_3CO_2H	1.8×10^{-5}
Citric acid	7.5×10^{-4}
HF	7.2×10^{-4}
H_3PO_4	7.1×10^{-3}
Strong Acids	
H_2CrO_4	9.6
HNO_3	28
H_3O^+	**55**
H_2SO_4	1×10^{3}
HCl	1×10^{6}
$HClO_4$	1×10^{8}
HBr	1×10^{9}
HI	3×10^{9}

Common acids and their acid dissociation equilibrium constants for the loss of one proton

Image by MIT OpenCourseWare. After Spencer, Bodner, and Rickard, *Chemistry: Structure and Dynamics* (Wiley, 2003).



ACID STRENGTH

$HF < HCl < HBr < HI$

567 431 366 299

H-A BOND STRENGTH (kJ/mol)

Image by MIT OpenCourseWare.

Reducing acid rain from burning coal

* 51% of our electrical energy is generated in coal-fired power plants (17% natural gas; 3% petroleum)

* industrial coal contains ~1% sulfur

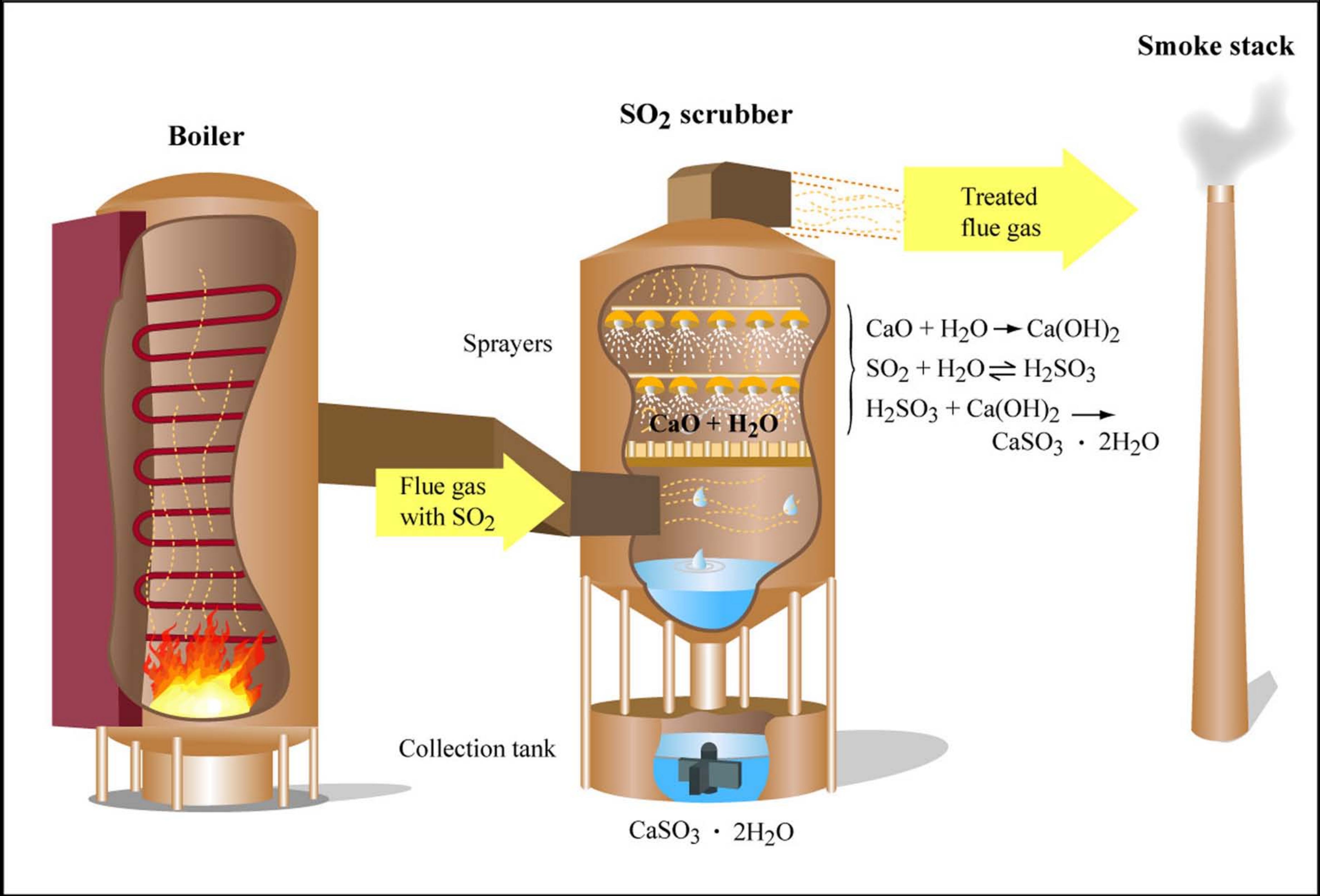
* 1 ton coal = 25×10^{6} BTU = 2.64×10^{10} J

∴ ~3 tons coal ⇨ 1 MW day (c.f. 1 g U / MW day)

∴ 10 MW plant burns ~30 tons coal/day ctg ~⅓ ton S which makes ~⅔ ton SO_2

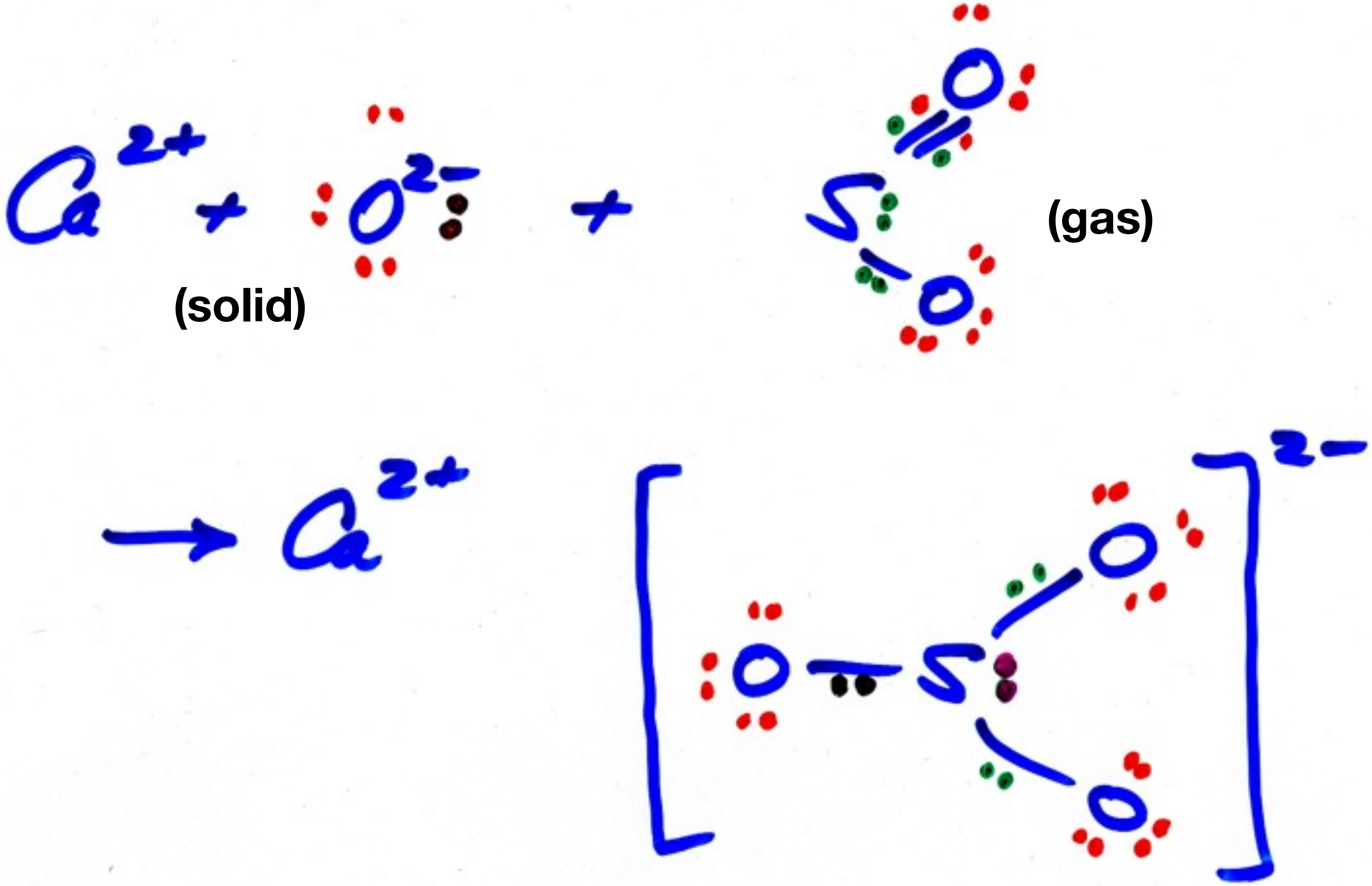
* reduce SO_2 emissions by reacting with lime (CaO) according to

$$CaO_{(s)} + SO_{2(g)} \Rightarrow CaSO_{3(s)}$$



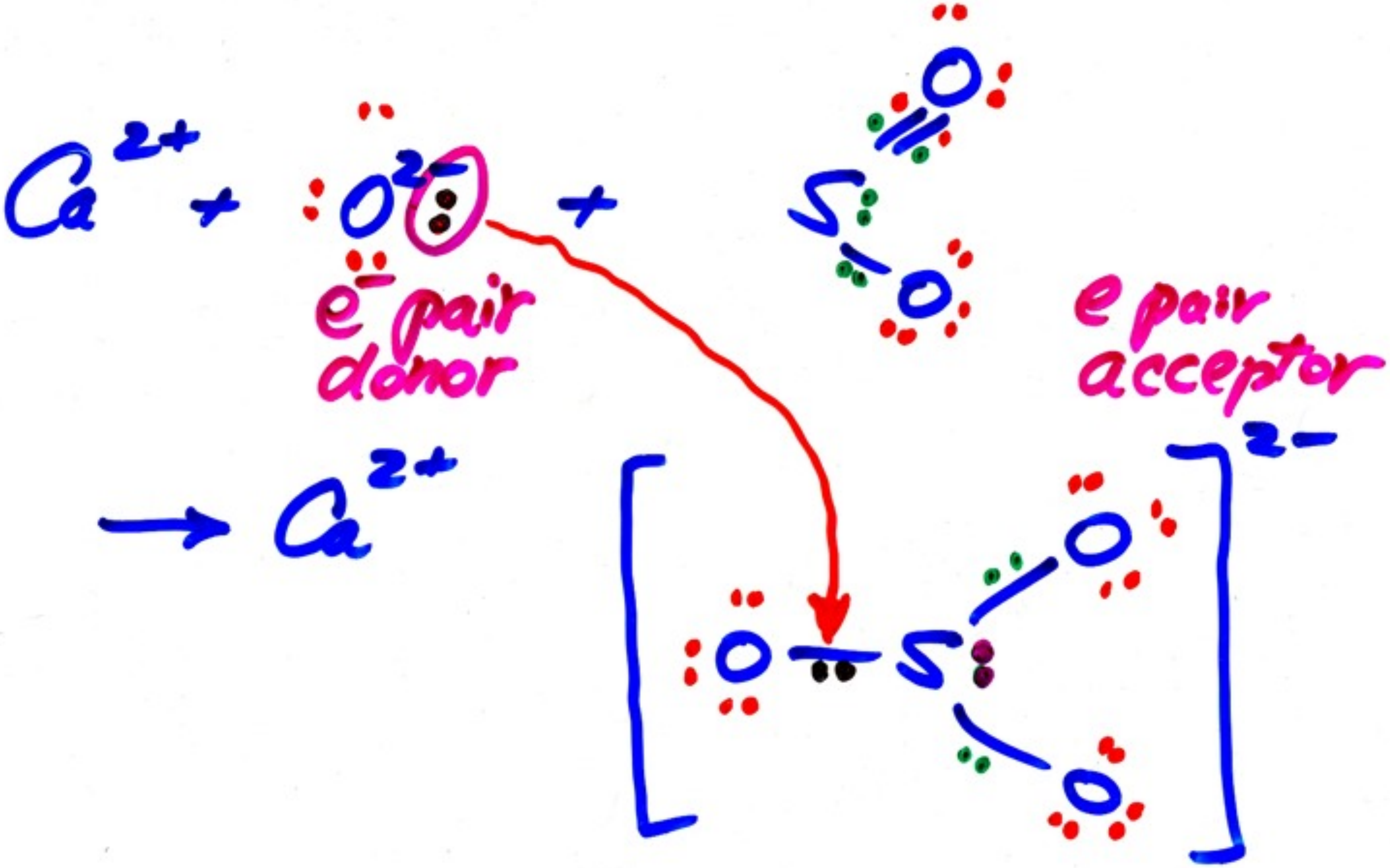
$$\left.\begin{array}{l} CaO + H_2O \rightarrow Ca(OH)_2 \\ SO_2 + H_2O \rightleftharpoons H_2SO_3 \\ H_2SO_3 + Ca(OH)_2 \rightarrow CaSO_3 \cdot 2H_2O \end{array}\right.$$

Image by MIT OpenCourseWare.



(solid)

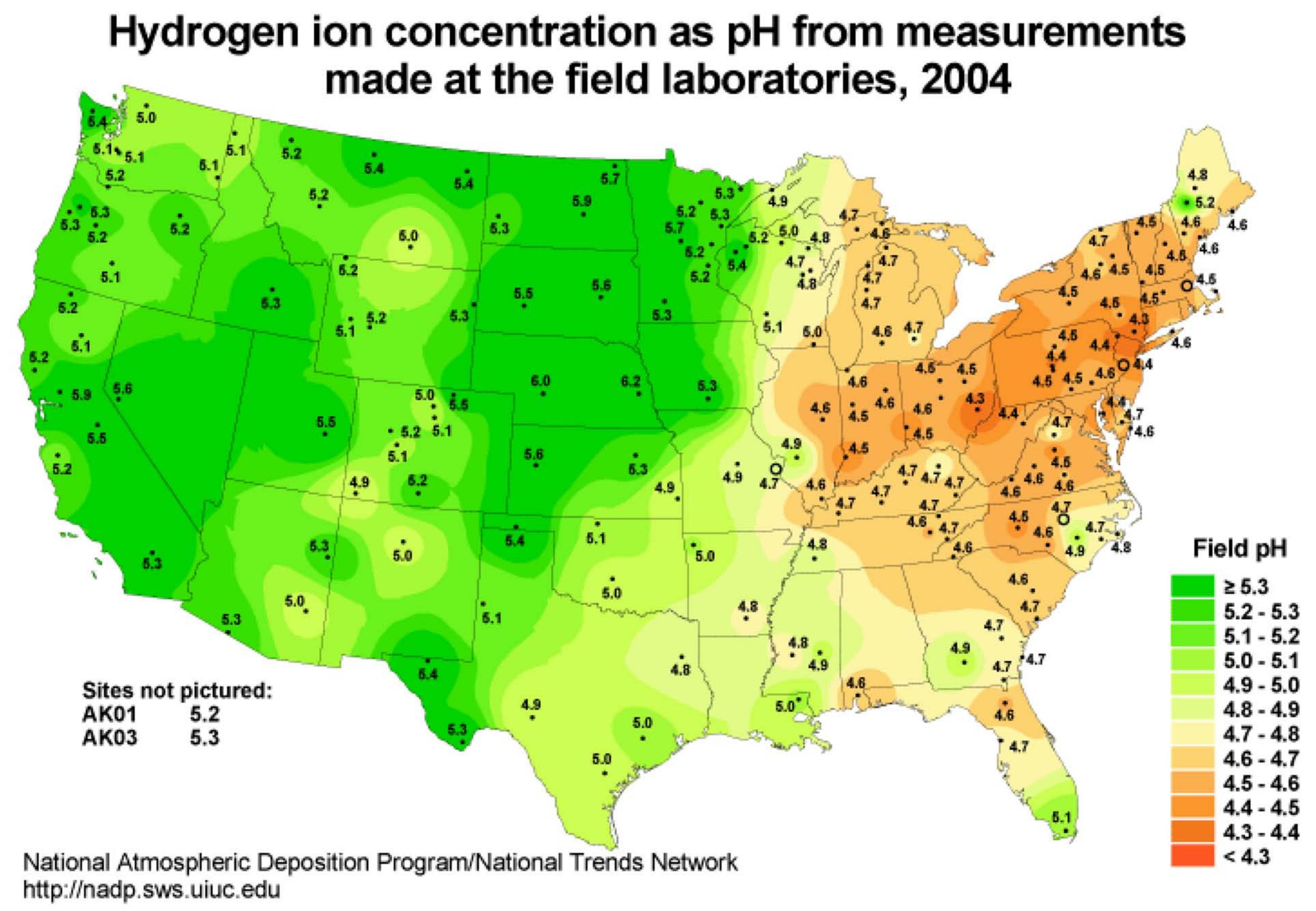
(gas)



CaO is Lewis base (O^{2-} is Lewis base)

SO_2 is Lewis acid

acid/base concept applied to gas-solid rxn



Hydrogen ion concentration as pH from measurements made at the field laboratories, 2004

Sites not pictured:
AK01 5.2
AK03 5.3

National Atmospheric Deposition Program/National Trends Network
http://nadp.sws.uiuc.edu

Public domain image, from National Atmospheric Deposition Program (NADP).

Image removed due to copyright restrictions. Promotional poster for Djerassi, C., and R. Hoffman. *Oxygen: A Play in 2 Acts*. Wiley-VCH, 2001. ISBN: 9783527304134.

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