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Laboratory Safety

DISCLAIMER

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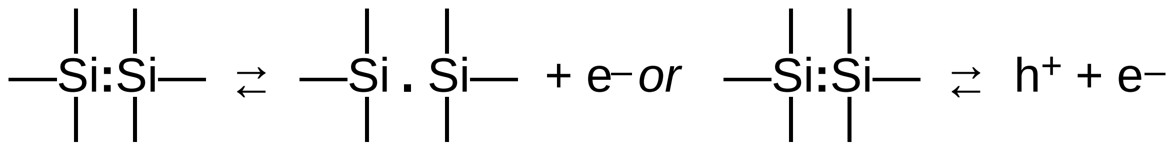
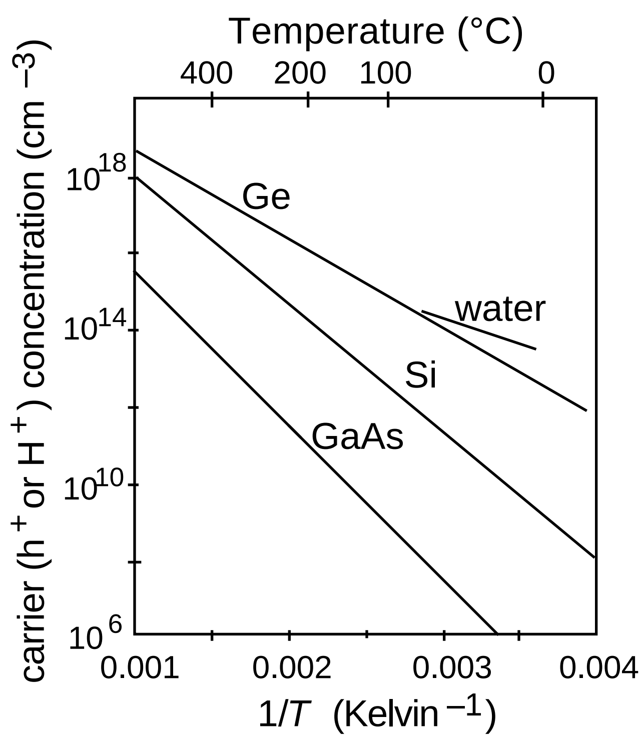
Autoionization Equilibria

$$H\!:\!O\!:\!H \rightleftarrows H^+ + OH^-$$

$$K_W = [H^+]\,[OH^-]$$

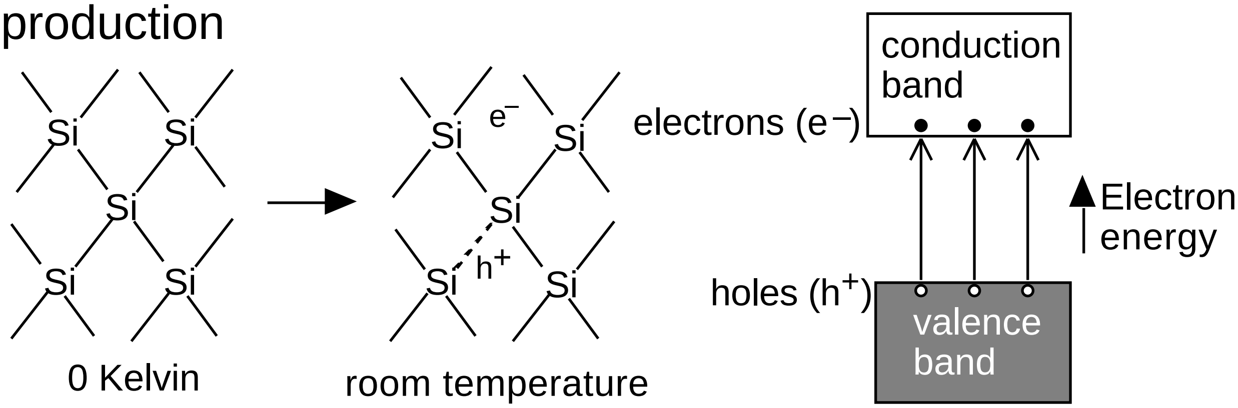


$$K = [h^+]\,[e^-] = p \times n$$

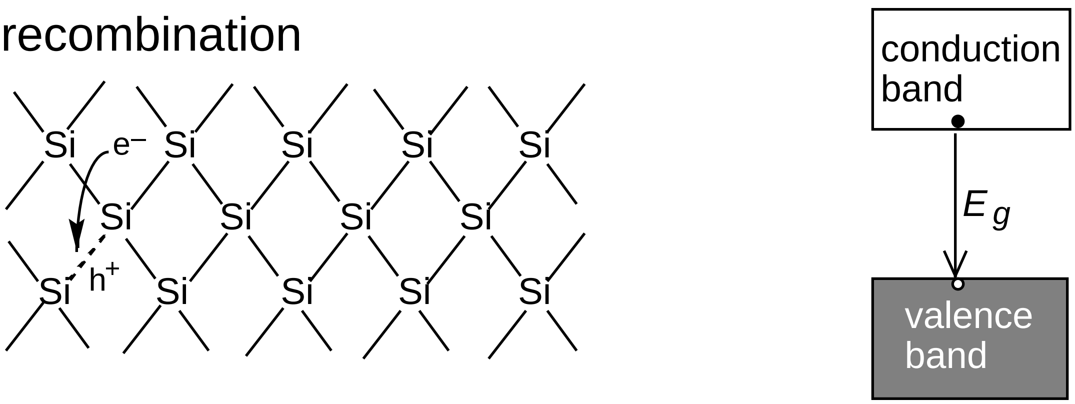


e- and h+ in Semiconductors

production

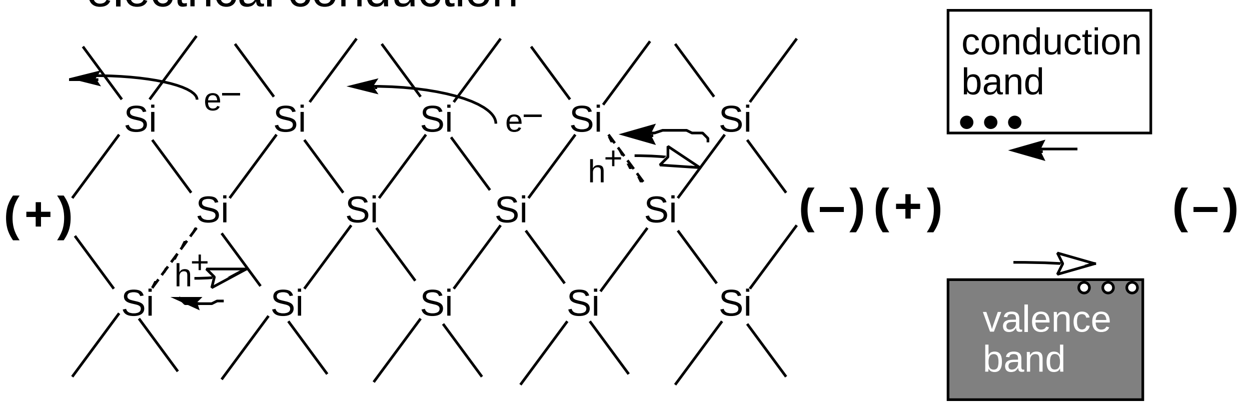


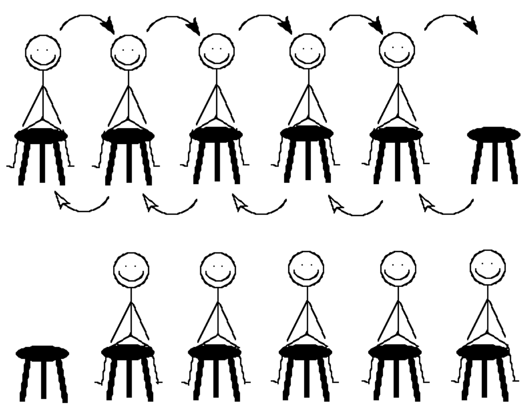
recombination

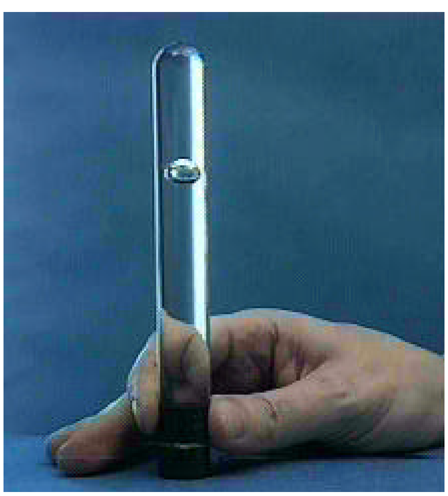


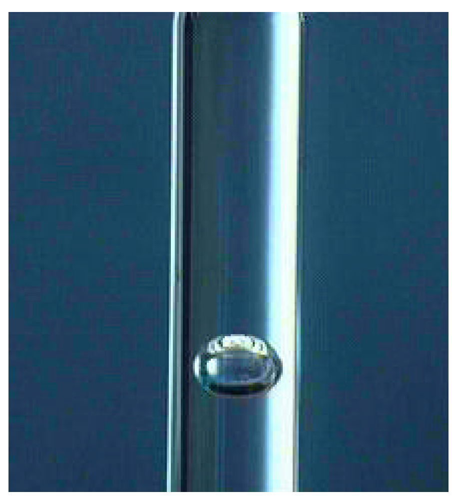
e- and h+ in Semiconductors

electrical conduction



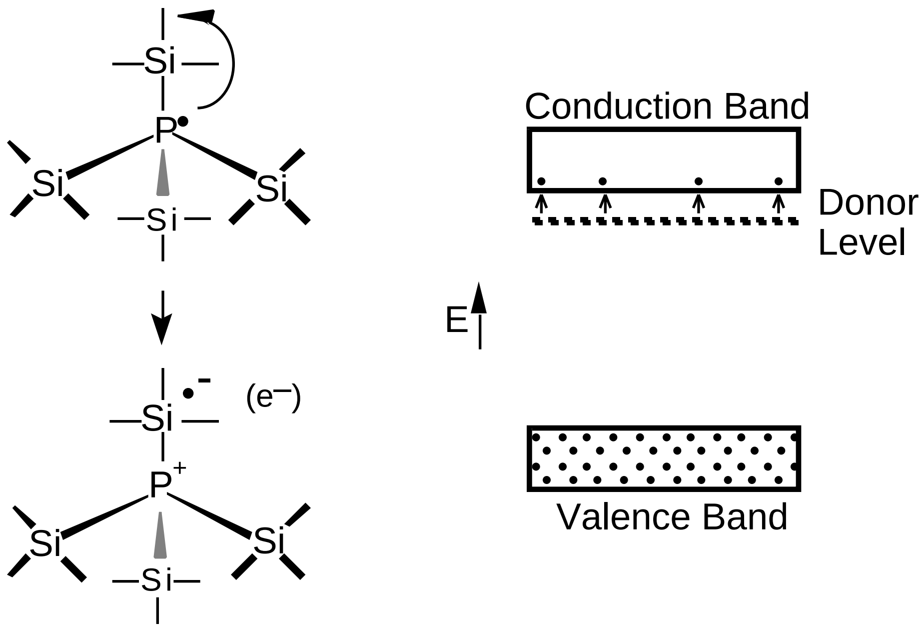




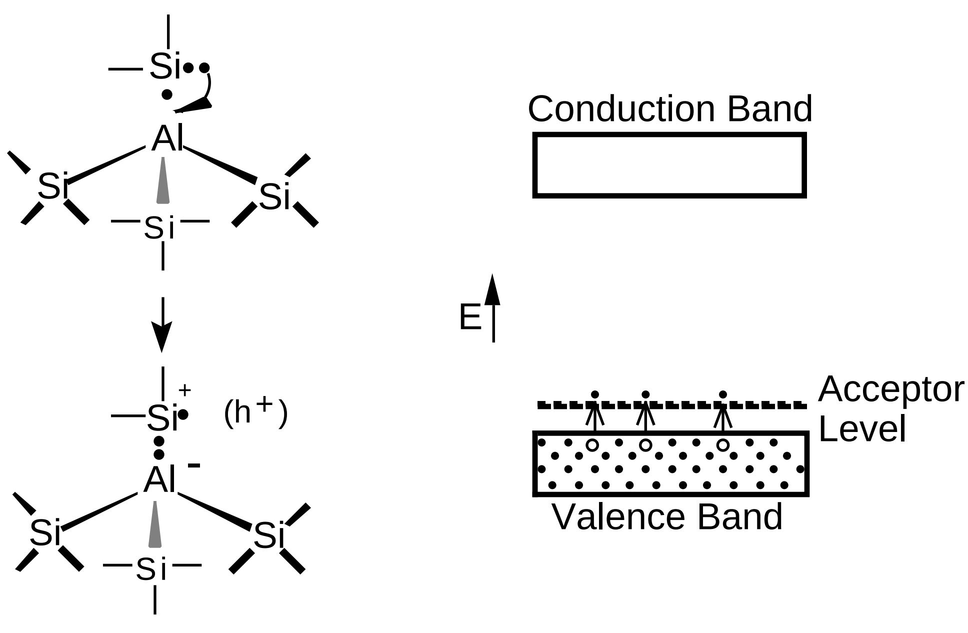


Doping

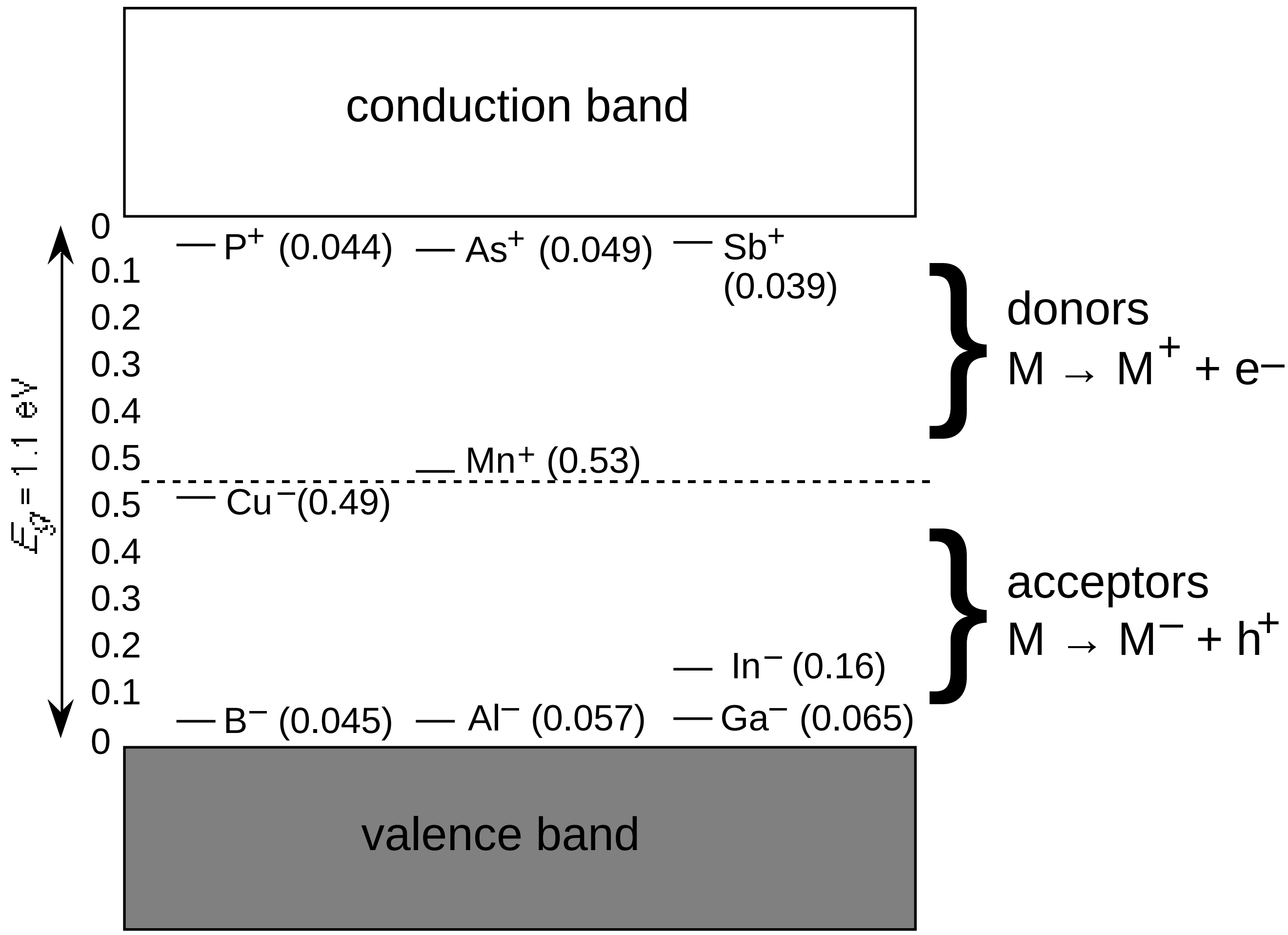
Addition of P to Si



Addition of Al to Si



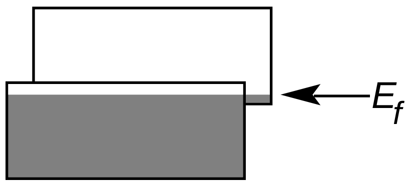
Donors and Acceptors in Silicon



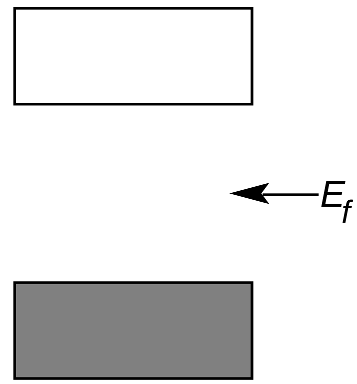
Ionization energy in parentheses (eV), measured from nearest band edge.

Fermi Level

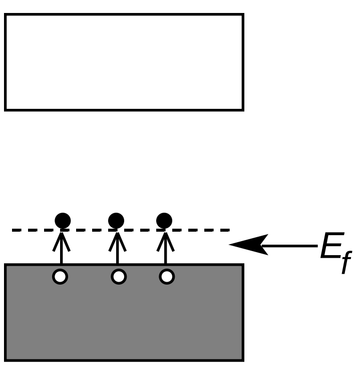
metal



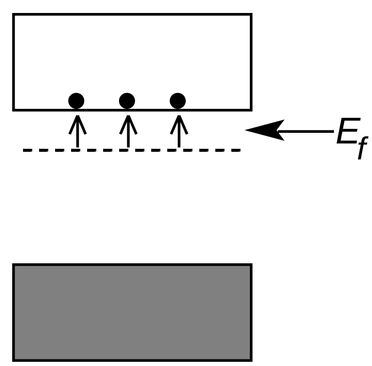
undoped Semiconductor



p-type semiconductor

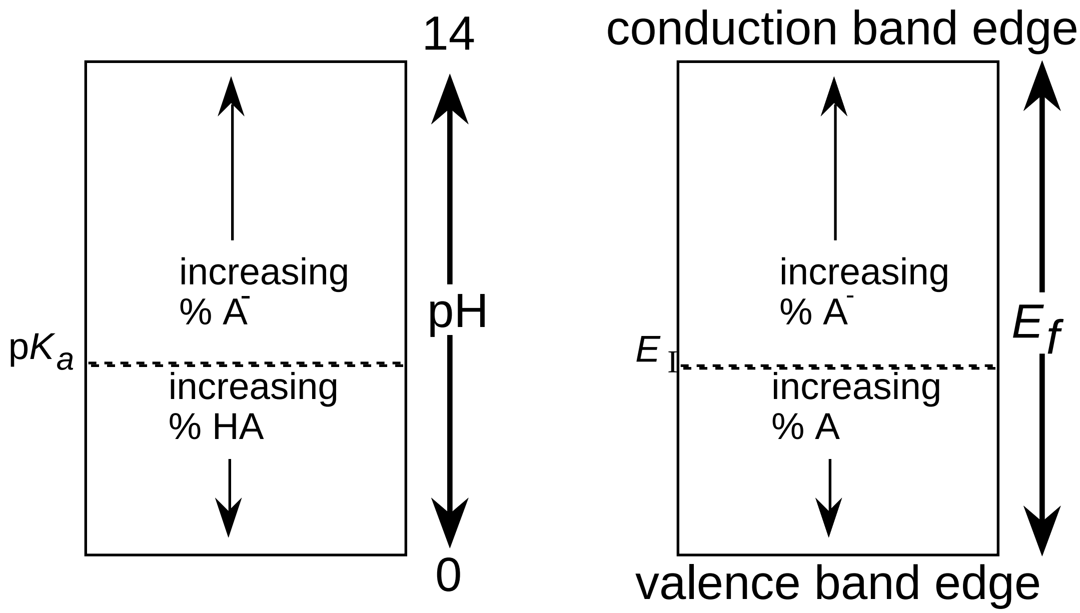


n-type semiconductor

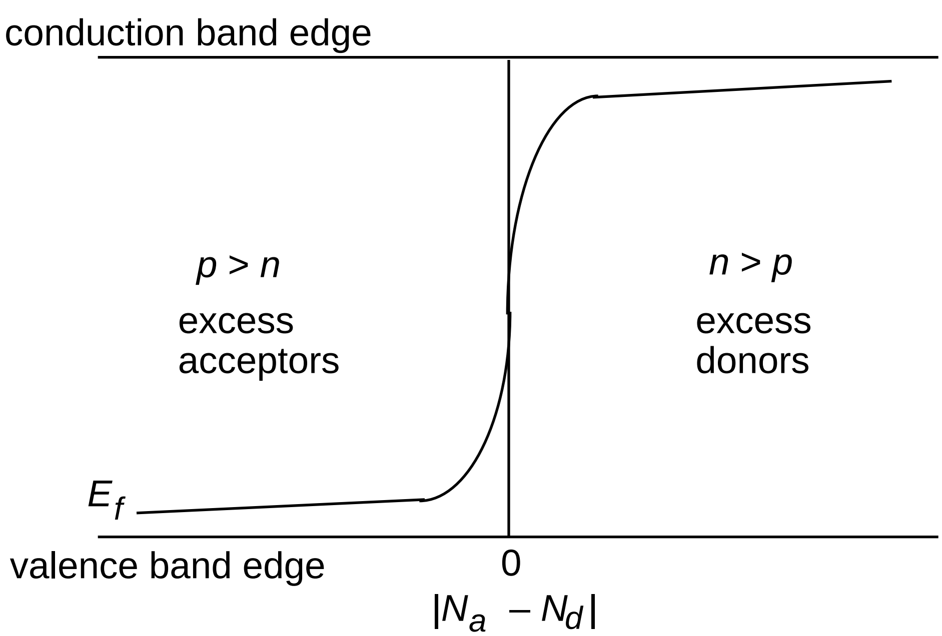


The Fermi level is the energy at which the probability of finding an electron is 50%; below the Fermi level it is more likely that the electronic states are occupied with electrons and above the Fermi level it is more likely they are not occupied.

Analogy of Fermi Level to pH



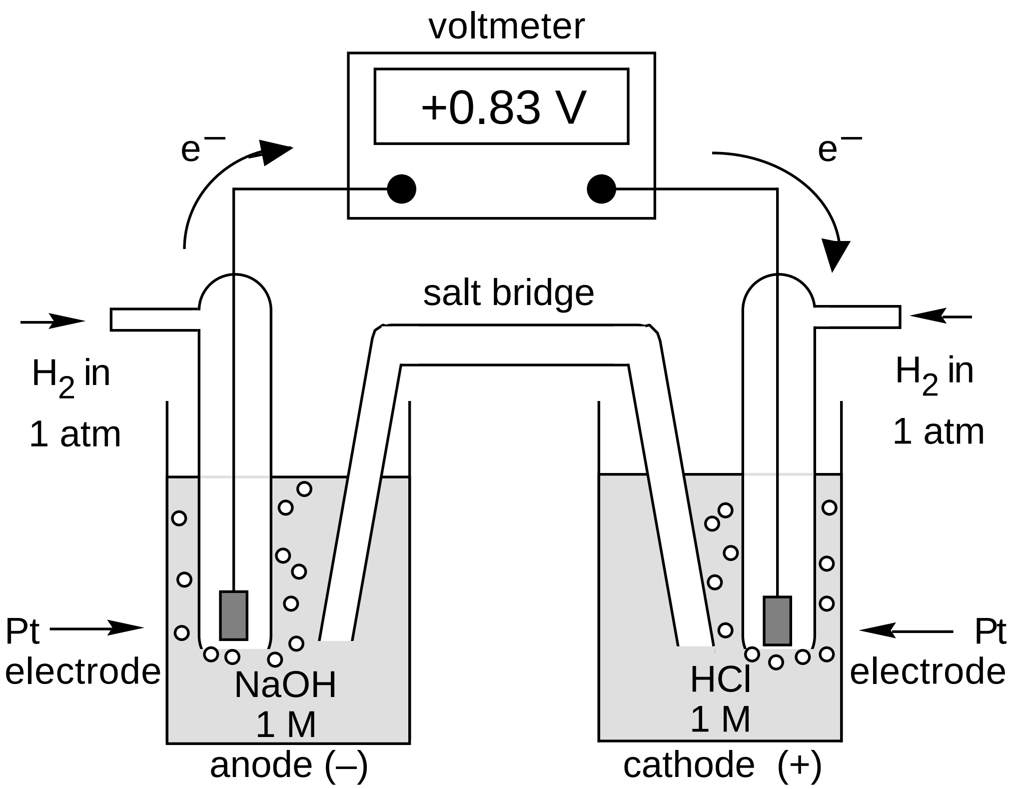
Neutralization Reaction



Nernst Equation

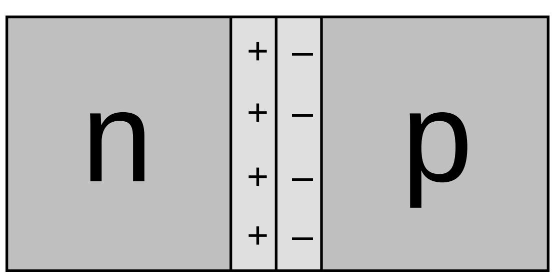
$$[H^+]_{\text{acid side}} \rightarrow [H^+]_{\text{base side}}$$

$$E = E^o - \frac{RT}{nF} \ln Q = \frac{-2.3\ RT}{F} \log \frac{[H^+]_{\text{base side}}}{[H^+]_{\text{acid side}}}$$

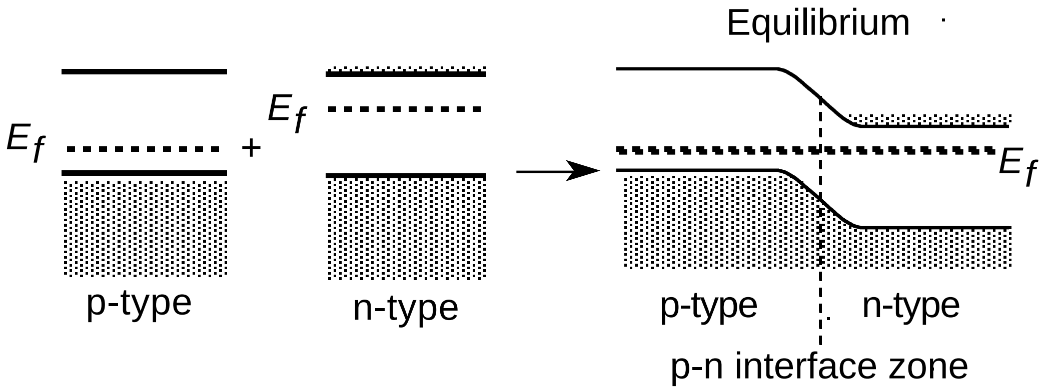


$$[h^+]_{\text{p-type side}} \rightarrow [h^+]_{\text{n-type side}}$$

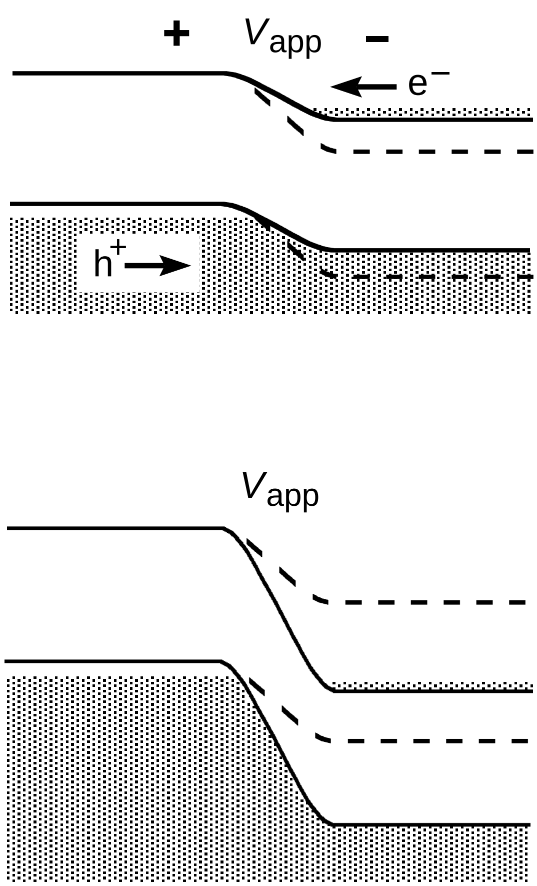
$$E \text{ (in volts)} = \frac{-2.3\ RT}{F} \log \frac{[h^+]_{\text{n-type side}}}{[h^+]_{\text{p-type side}}}$$

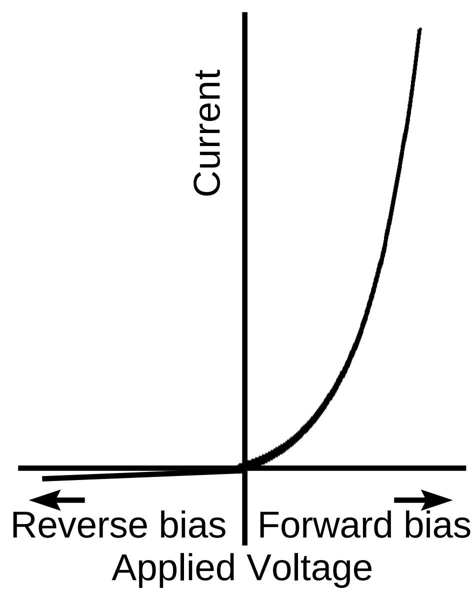


p-n Junction

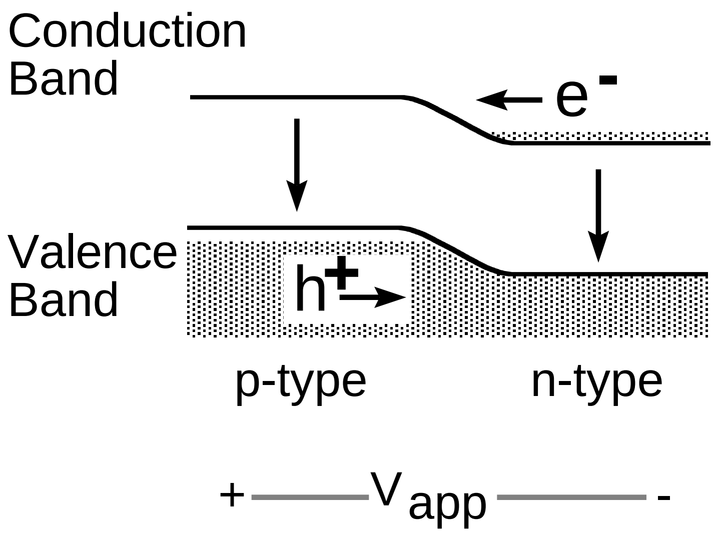


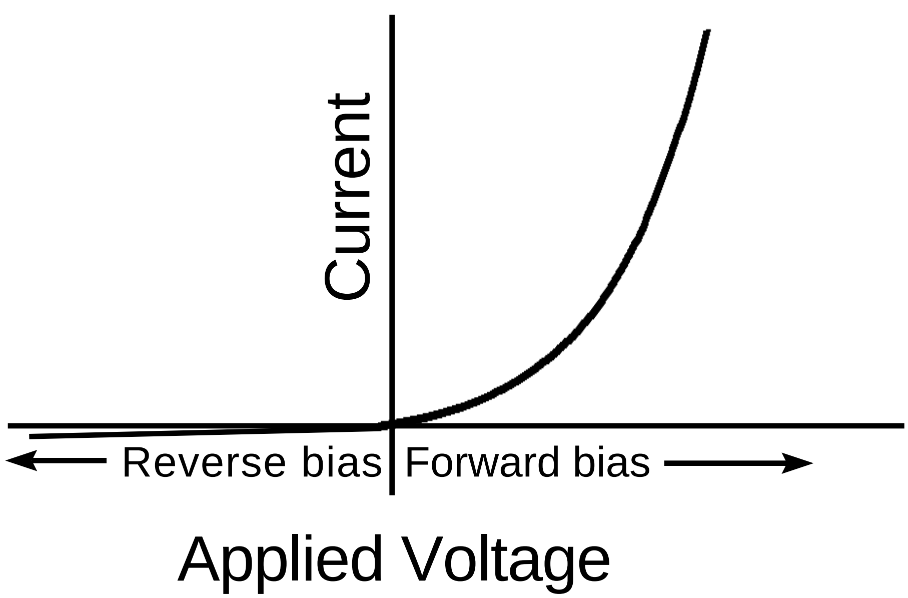
Applied Voltage

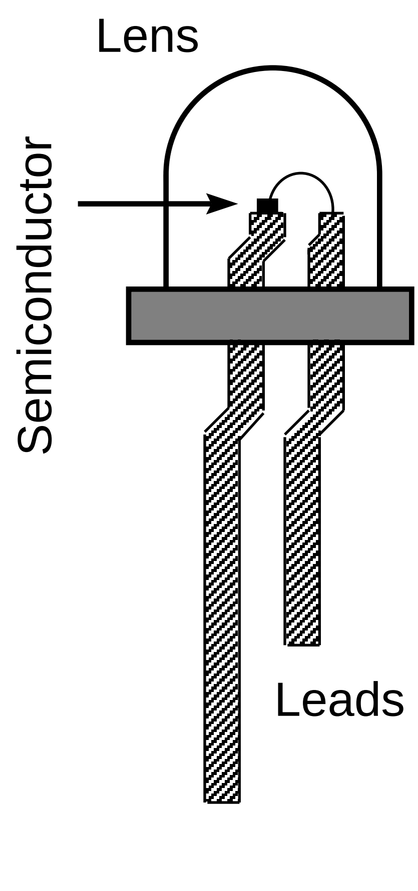




Light Emitting Diodes (LEDS)

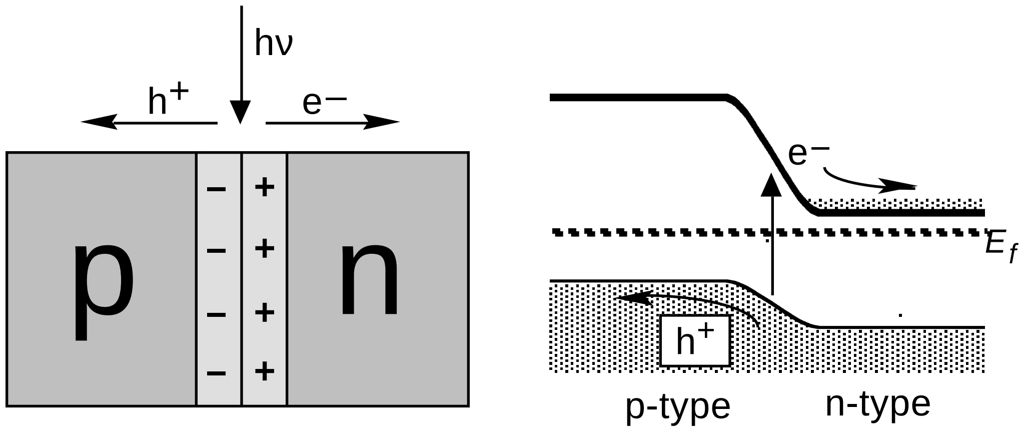




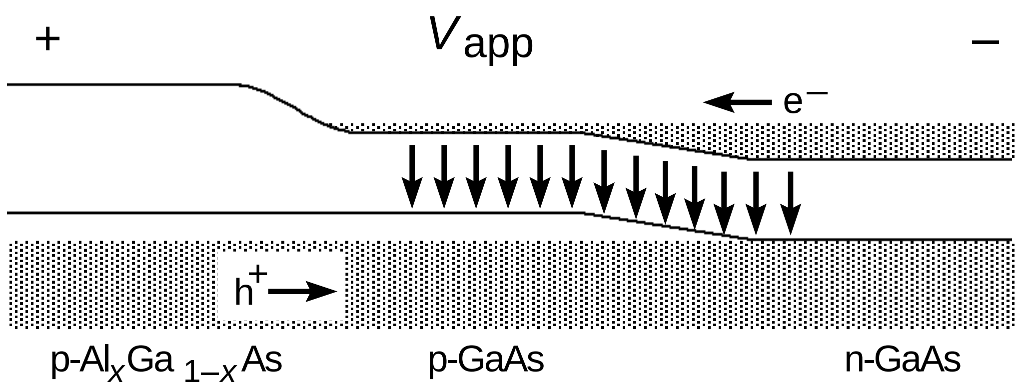


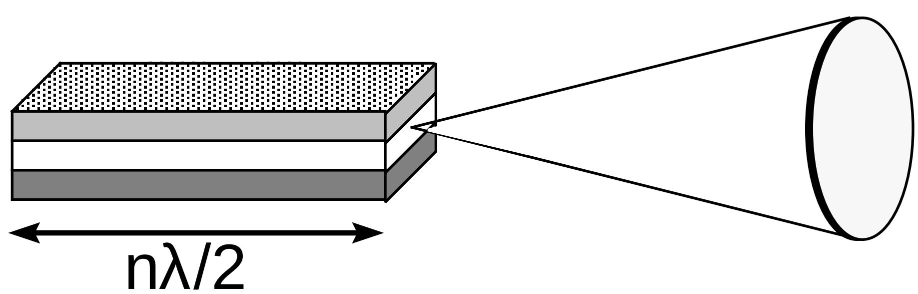
Applications of p-n Junctions

Photovoltaic Cell



Diode Laser





$$K = [h^+][e^-] = p \times n$$

Values of K at 300 K for Semiconductors

Semiconductor	K (cm^{-6})	Band Gap
GaAs	4.0×10^{12}	138 kJ/mol (1.43 eV)
Si	2.2×10^{20}	107 kJ/mol (1.11 eV)
Ge	6.2×10^{26}	66 kJ/mol (0.68 eV)

Parallels Between Aqueous Solution Chemistry and Semiconductors

Chemical Reaction	Aqueous Example	Silicon Example
Solvent autoionization	$H_2O \rightarrow H^+ + OH^-$ $K_W = [H^+][OH^-]$ $[H^+] \approx 10^{14}$ ions/cm^3	Si (crystal) $\rightarrow h^+ + e^-$ $K = [h^+][e^-] = p \times n$ $[h^+] \approx 1.5 \times 10^{10}$ cm^{-3}
Strong acid–acceptor, strong base–donor	$HCl \rightarrow H^+ + Cl^-$ $NaOH \rightarrow Na^+ + OH^-$	$Ga \rightarrow h^+ + Ga^-$ $As \rightarrow As^+ + e^-$
Weak acid–acceptor; weak base–donor	$CH_3COOH \rightleftarrows H^+ + CH_3COO^-$ $NH_3 + H_2O \rightleftarrows NH_4^+ + OH^-$	$Cu \rightleftarrows h^+ + Cu^-$ $Mn \rightleftarrows Mn^+ + e^-$
Common ion effect	adding base (acid) suppresses the concentration of H^+ (OH^-)	adding a donor (acceptor) suppresses the concentration of h^+ (e^-)
Concentration cell[a]	H_2 ½NaOH½½HCl ½H_2 $E = \frac{-2.3RT}{F} \log \frac{[H^+]_{\text{base side}}}{[H^+]_{\text{acid side}}}$	— n-type | p-type — $E = \frac{-2.3RT}{F} \log \frac{[h^+]_{\text{n-side}}}{[h^+]_{\text{p-side}}}$

[a]Cell is treated as a concentration cell $[H^+]_{\text{acid side}} \rightarrow [H^+]_{\text{basic side}}$.

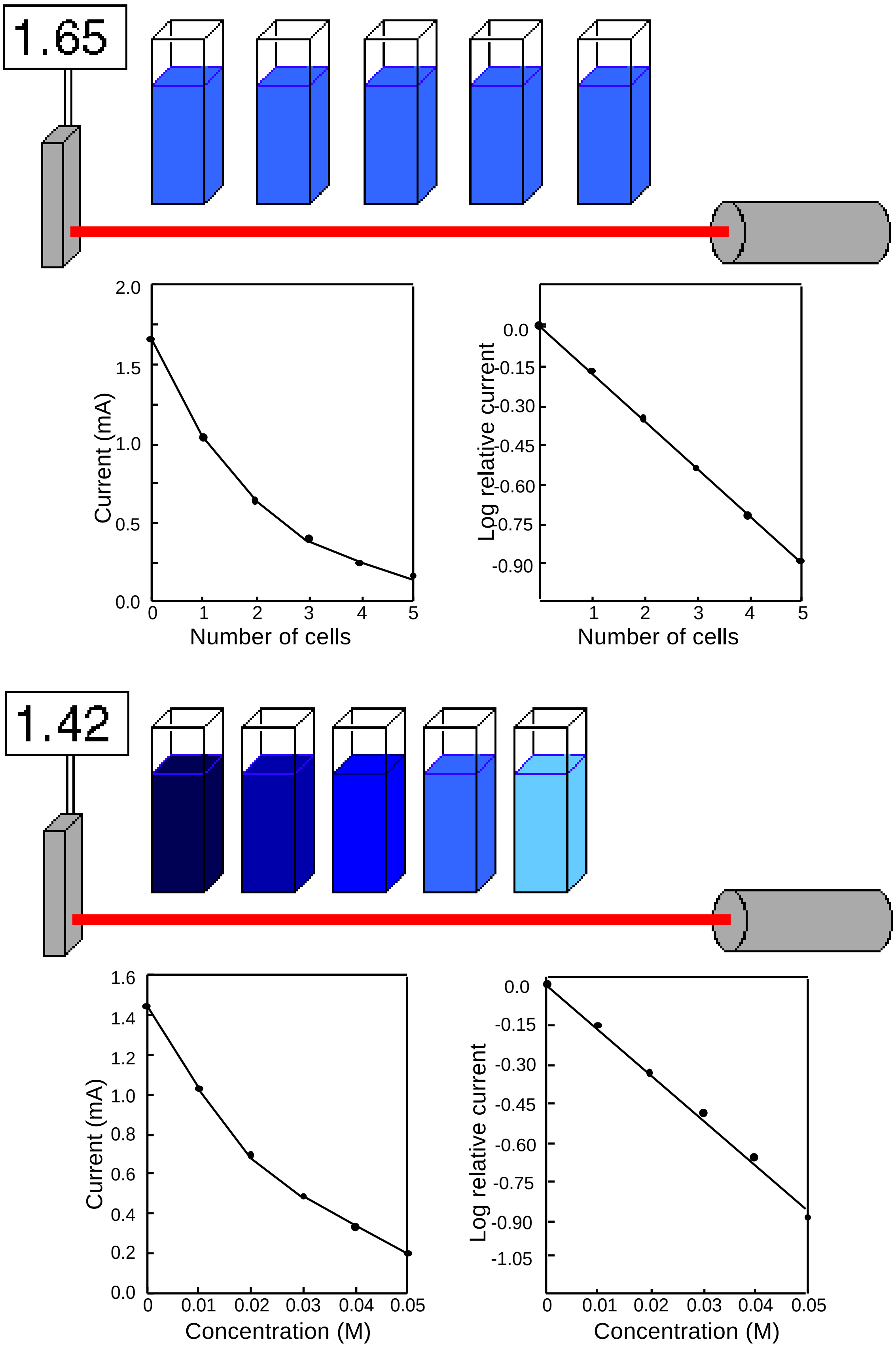
Oxygen Sensor

in air

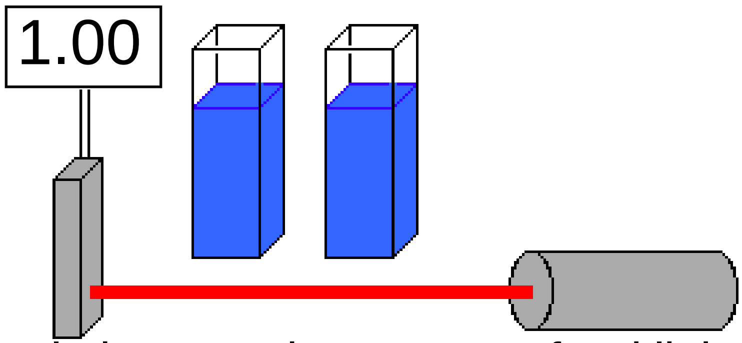
deplete oxygen in bottle

in depleted oxygen

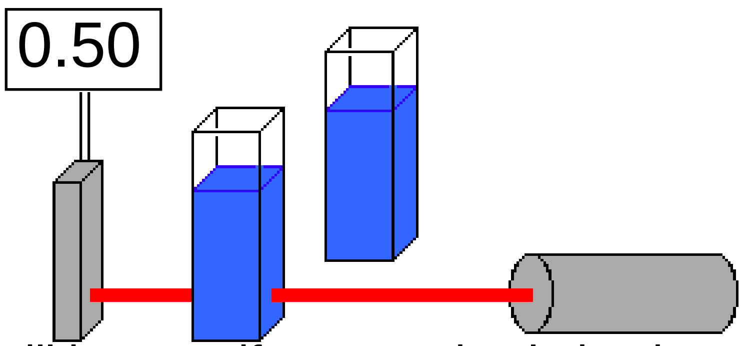
Beer's Law


1.65
Current (mA)
2.0
1.5
1.0
0.5
0.0
0
1
2
3
4
5
Number of cells
Log relative current
0.0
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
1
2
3
4
5
Number of cells
1.42
Current (mA)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
0.01
0.02
0.03
0.04
0.05
Concentration (M)
Log relative current
0.0
-0.15
-0.30
-0.45
-0.60
-0.75
-0.90
-1.05
0
0.01
0.02
0.03
0.04
0.05
Concentration (M)

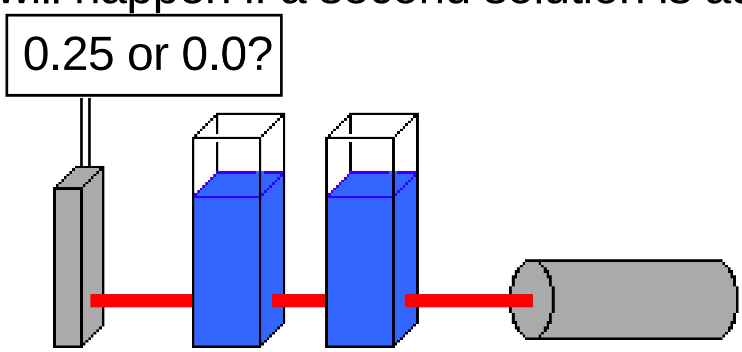
ConcepTest



If a blue solution cuts the amount of red light in half...



what will happen if a second solution is added?



Will the red or blue solution absorb more red light?