Blue bottle reaction

CH102 General Chemistry, Spring 2009

BOSTON UNIVERSITY

Metabolism is powered by food "burning" in O_2

Metabolic pathways ***harness*** the ***spontaneous flow of electrons*** to ***power the life processes***.

Metabolic pathways are analogous to electrochemical ***external circuits.***

Dextrose "burns" in oxygen

A step in oxidation of dextrose is

$2\ RCHO + O_2 \rightarrow 2\ RCOO^- + 2\ H^+$, **$\Delta G^{o'} < 0$**

Evaluate $E^{o'}$ and $\Delta G^{o'}$ for this oxidation step.

$O_2 + 4\ H^+ + 4\ e^- \rightarrow 2\ H_2O$, $E^{o'} = +0.816$ V

$RCOO^- + 3\ H^+ + 2\ e^- \rightarrow RCHO + H_2O$, $E^{o'} = -0.44$ V

$2\ RCHO + O_2 \rightarrow 2\ RCOO^- + 2\ H^+$

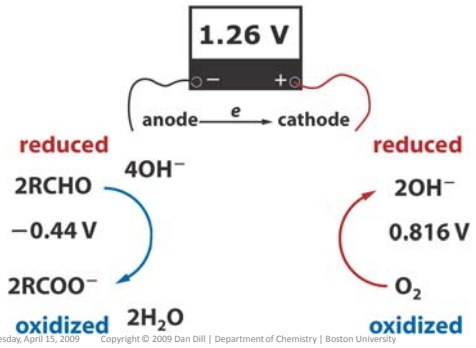
$E^{o'} = E^{o'}_{cathode} - E^{o'}_{anode}$

$= +0.816\ V - (-0.44\ V) =$ **+1.26 V**

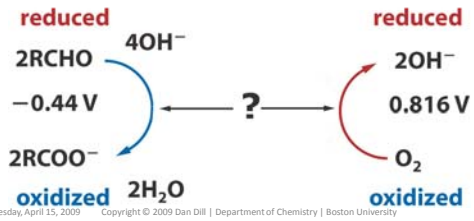
$\Delta G^{o'} = -n\ F\ E^{o'}$

$= -(4 \times 96{,}500\ C/mol \times 1.26\ J/C) =$ **–486 kJ/mol**

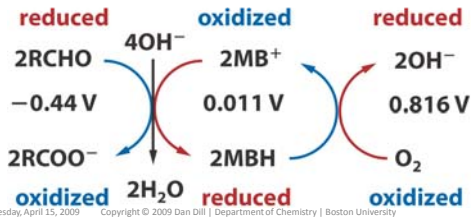
Dextrose "burns" in oxygen



How to harness the burning?



Metabolic pathways!



Couple dextrose oxidation to O_2

Methylene blue redox, $E^{o'}$ = +0.011 V,

(link) $MB^+ + H^+ + 2\ e^- \leftrightarrows MBH$

links the ***oxidation*** of dextrose, $E^{o'}$ = –0.44 V,

(ox) $2\ RCHO + 2\ H_2O \rightarrow 2\ RCOO^- + 6\ H^+ + 4\ e^-$

to ***reduction*** of oxygen, $E^{o'}$ = +0.816 V,

(red) $O_2 + 4\ H^+ + 4\ e^- \rightarrow 2\ H_2O$

The MB+|MBH process plays the role of an ***external circuit*** for the ***combustion of dextrose***,

$2\ RCHO + O_2 \rightarrow 2\ RCOO^- + 2\ H^+$, $E^{o'}$ = +1.26 V

Coupling dextrose oxidation to O_2

(ox) $RCHO + H_2O \rightarrow RCOO^- + 3\ H^+ + 2\ e^-$, $E^{o'}$ = –0.44 V

(link) $MB^+ + H^+ + 2\ e^- \leftrightarrows MBH$, $E^{o'}$ = +0.011 V

(red) $O_2 + 4\ H^+ + 4\ e^- \rightarrow 2\ H_2O$, $E^{o'}$ = +0.816 V

Blue bottle reaction demonstration:

(red) – (link) O_2 oxidizes MBH,

$E^{o'}$ = +0.816 V – 0.011 V = +0.805 V,

turning solution from **clear** (MBH) to **blue** (MB^+)

(link) – (ox) MB^+ oxidizes dextrose (RCHO),

$E^{o'}$ = +0.011 V – (– 0.44 V) = +0.45 V,

turning solution from **blue** (MB^+) to **clear** (MBH)

Coupling dextrose oxidation to O_2

Breathe in: (red) – (link): O_2 oxidizes MBH,

$O_2 + 2\ H^+ + 2\ MBH \rightarrow 2\ MB^+ + 2\ H_2O$

Breathe out: (link) – (ox): MB^+ oxidizes dextrose (RCHO),

$MB^+ + RCHO + H_2O \rightarrow MBH + RCOO^- + 2\ H^+$

Breathe in: (red) – (link): O_2 oxidizes MBH,

$O_2 + 2\ H^+ + 2\ MBH \rightarrow 2\ MB^+ + 2\ H_2O$

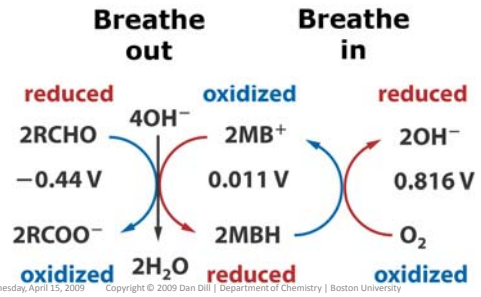
Breathe out: (link) – (ox): MB^+ oxidizes dextrose (RCHO),

$MB^+ + RCHO + H_2O \rightarrow MBH + RCOO^- + 2\ H^+$

etc., …

until the food runs out (**time to eat!**)

Coupling dextrose oxidation to O_2



Metabolism couples oxidation of "food" to reduction of O_2

Metabolic pathways ***harness*** the ***spontaneous flow of electrons*** to ***power the life processes***.

Metabolic pathways are analogous to electrochemical ***external circuits.***

