Introduction to the Materials Science of

Rechargeable Batteries

Week 1: Basic Concepts, Fundamentals, and Definitions

Lecture 1.1: The Battery Potential

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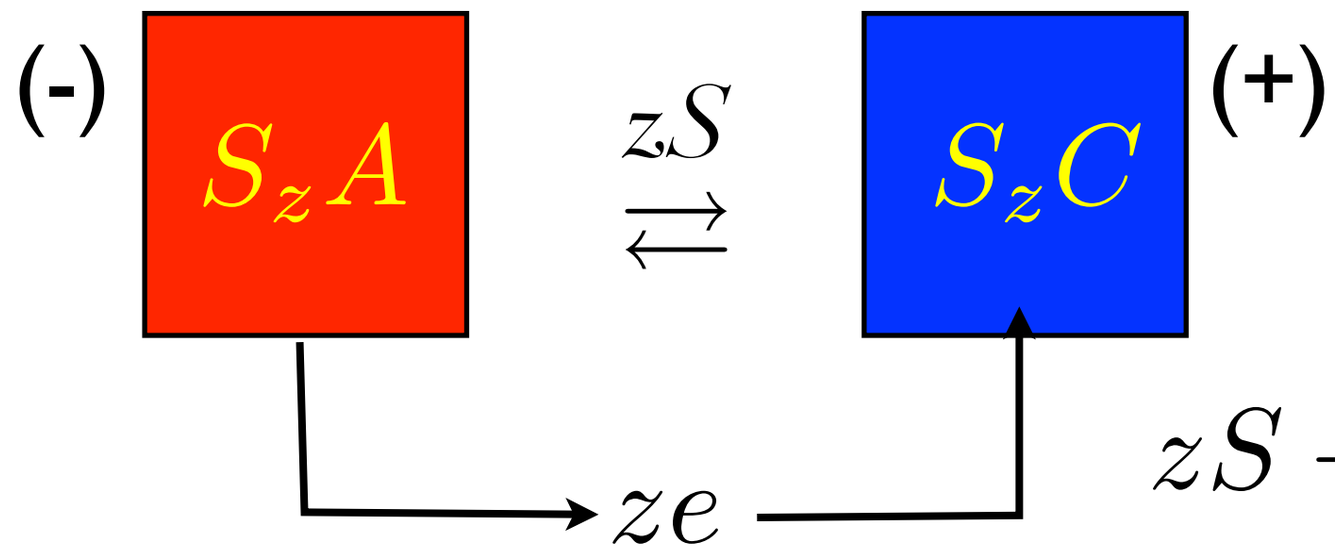
A Sketch of a Rechargeable Battery

$$S_zA \rightleftarrows zS^+ + A + ze^-$$

$$S_zA \rightleftarrows zS + A$$

(electrolyte)



$$zS + C \rightleftarrows S_zC$$

$$zS^+ + C + ze^- \rightleftarrows S_zC$$

The Electrolyte Intervening Medium

- Dissolves component S
- Possesses high diffusivity
- Possesses high ionic conductivity
- Electronically Insulating
- Should be stable in the presence of the electrodes (large voltages)

Potential of Electrodes

Anode Potential:

$$S_z A \rightleftarrows z S^+ + A + z e^-$$

$\varphi_A = \dfrac{\Delta G_f^A}{zF}$: voltage of anode

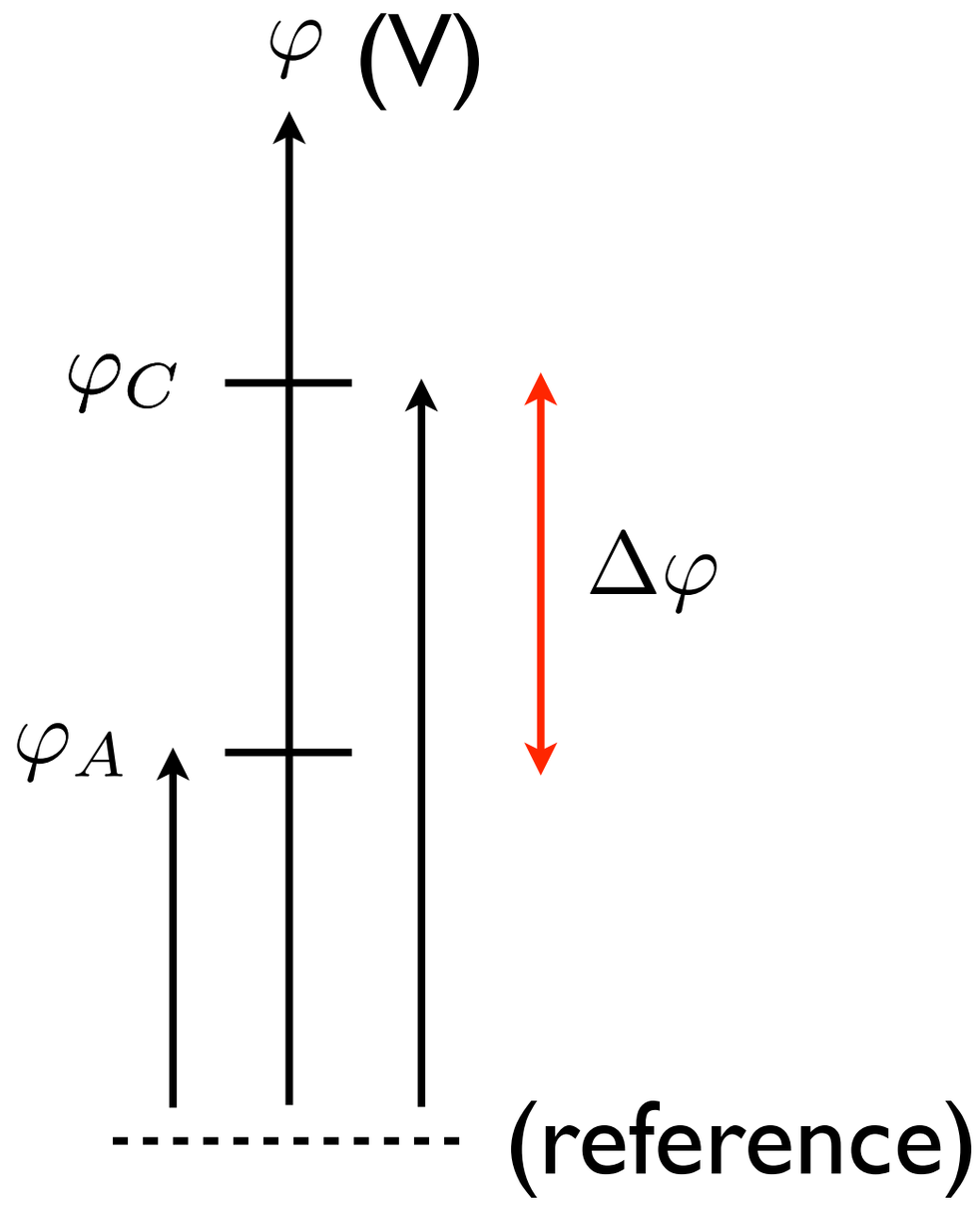
Cathode Potential:

$$z S^+ + C + z e^- \rightleftarrows S_z C$$

φ_C : voltage of cathode

Cell Potential:

$$\Delta\varphi = \varphi_C - \varphi_A$$

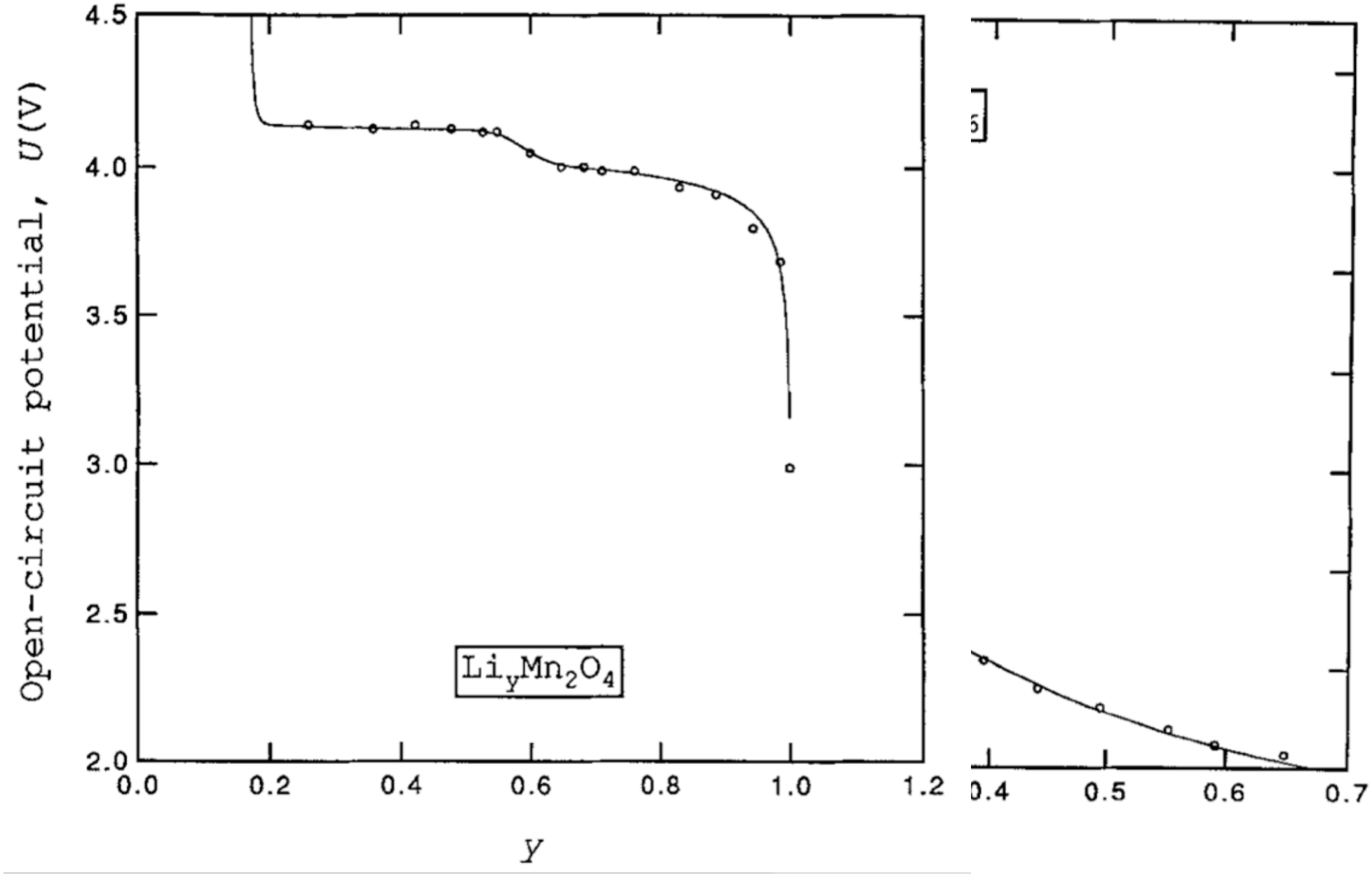


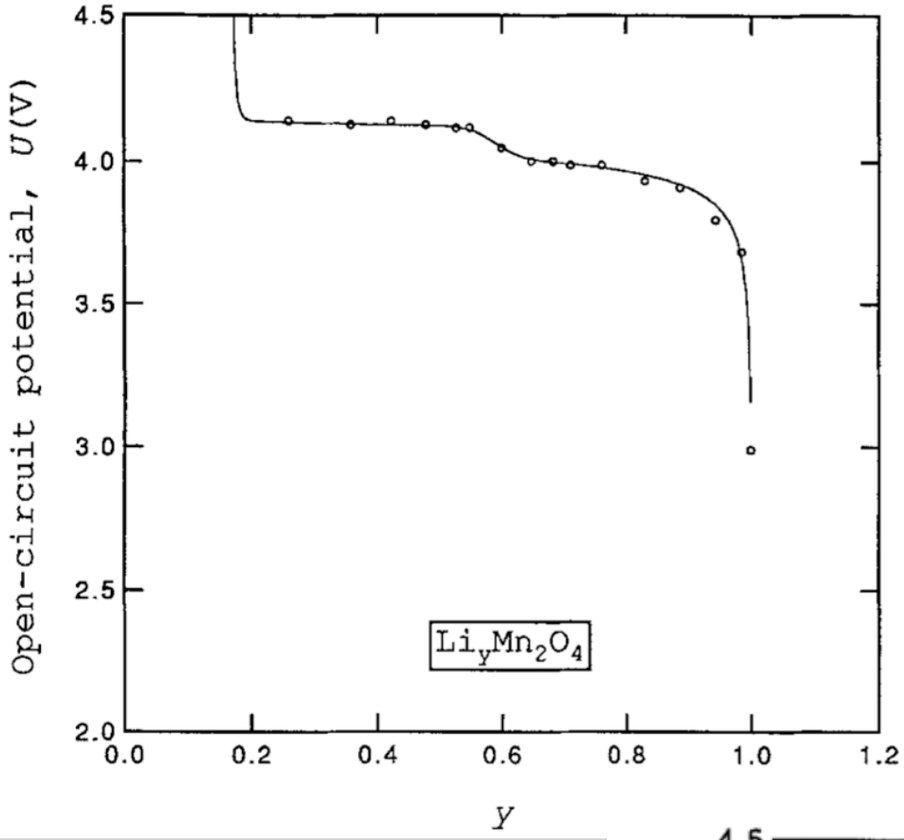
Example Reactions

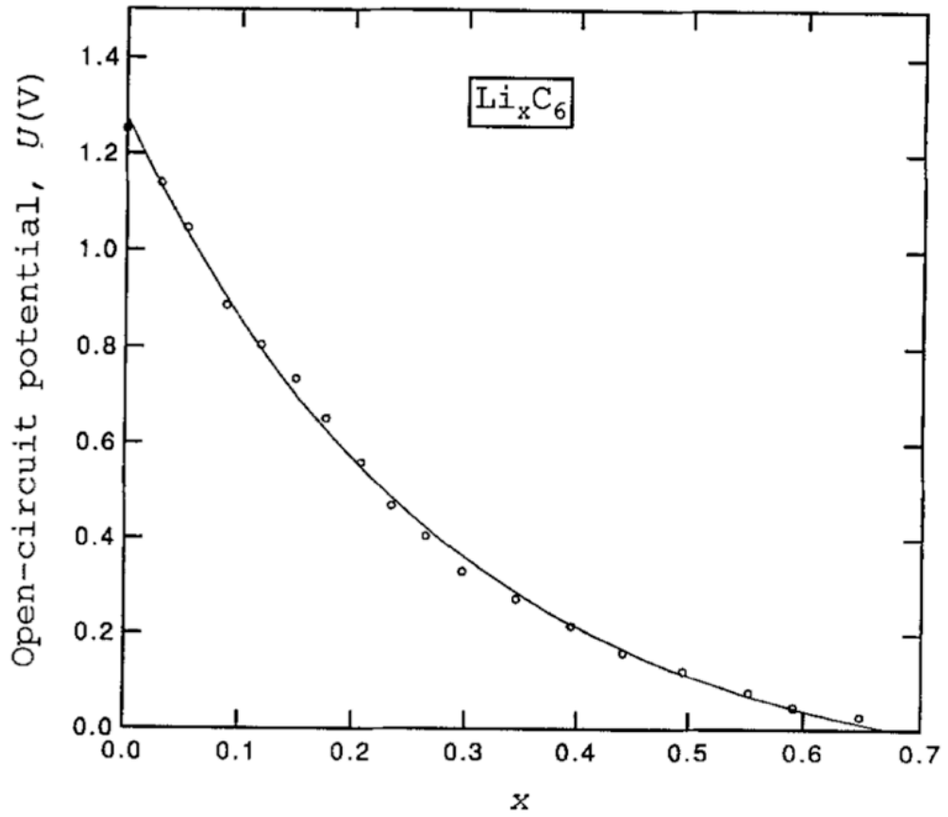
	(–) $Li_xC \longrightarrow C + xLi^+ + xe$	$\varphi^\circ = -2.90$ V	(1)
Li-ion	(+) $Li_{1-x}CoO_2 + xLi^+ + xe \longrightarrow LiCoO_2$	$\varphi^\circ = 1.20$ V	(2)
	(o) $Li_xC + Li_{1-x}CoO_2 \longrightarrow C + LiCoO_2$	$E^\circ = 4.10$ V	(3)

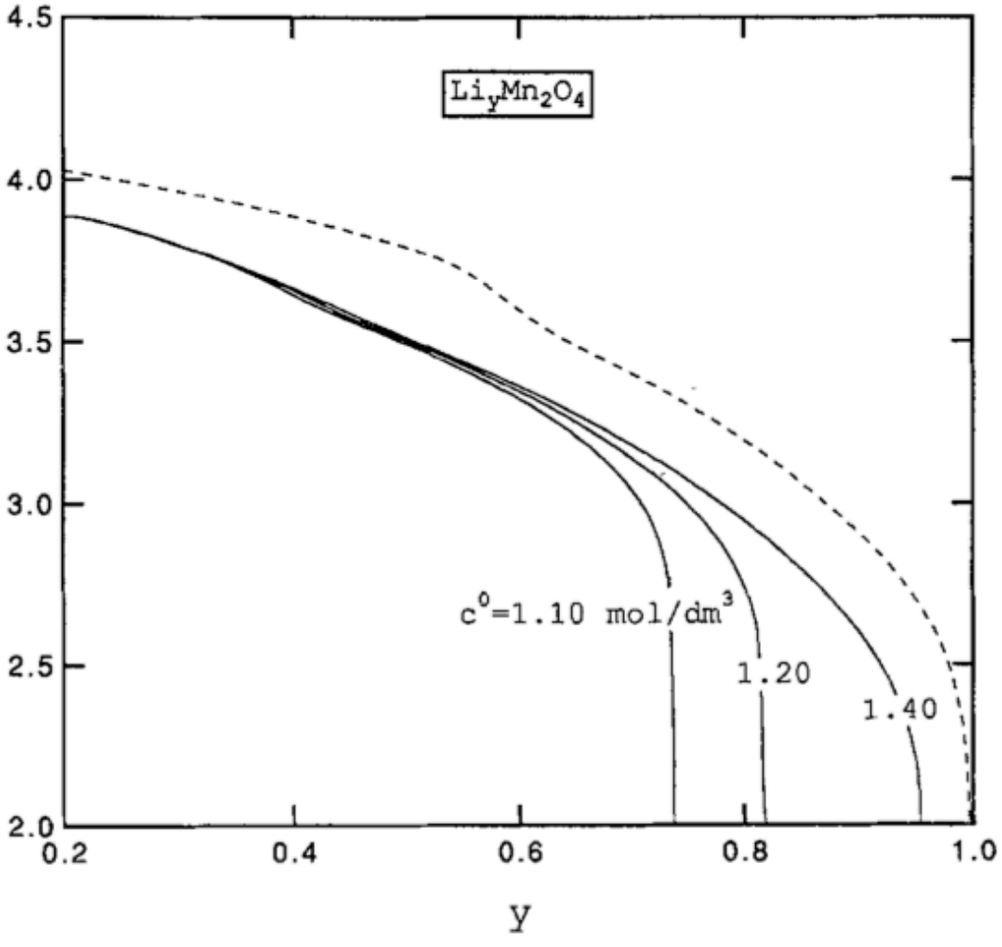
F. Cheng, J. Liang, Z. Tao, and J. Chen "*Functional Materials for Rechargeable Batteries*." Adv. Mater. 2011, 23, 1695–1715.

Battery Voltage




Open-circuit potential, U(V)
4.5
4.0
3.5
3.0
2.5
2.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
y
Li$_y$Mn$_2$O$_4$


Open-circuit potential, U(V)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
x
Li$_x$C$_6$


Li$_y$Mn$_2$O$_4$
Cell Potential (V)
4.5
4.0
3.5
3.0
2.5
2.0
0.2
0.4
0.6
0.8
1.0
y
c^0=1.10 mol/dm^3
1.20
1.40