Lawrence Livermore Laboratory

INVESTIGATION OF THE KINETICS OF THE $\text{Li}/\text{LiOH}(\text{aq})$ ELECTRODE:
COULOMBIC EFFICIENCY, ELECTRODE POLARIZATION

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13 January 1977

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Prepared for U.S. Energy Research & Development Administration under contract No. W-7405-Eng-48.

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ABSTRACT

Experimental techniques and data from the investigation of electrode polarization and coulombic efficiency of the lithium/aqueous lithium hydroxide electrode are reported.

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INTRODUCTION

The kinetics of the $\text{Li}/\text{LiOH}(\text{aq})$ electrode have been investigated at this laboratory as part of the Lithium Battery Program.¹ Initial studies were directed toward the measurement of electrode polarization and coulombic efficiency of lithium dissolution* under the controlled parameters of electrolyte concentration, hydrodynamics, current density, and temperature. The purpose of this paper is to consolidate details of our experimental techniques and to report our experimental results in their entirety. The data reported here vary in the degree of accuracy due to progressive refinements in our experimental technique. Nonetheless, all data are included for the sake of completeness. Interpretation of the results will appear in a separate publication.²

ELECTRODE POLARIZATION

The polarization characteristics of the lithium electrode were measured with the use of the flow channel schematically shown in Figure 1. Electrodes of lithium³ and platinum, 10 mm square, were placed opposite each other, flush with the horizontal walls of a rectangular duct. The electrode separation was 3.16 mm with a channel width of 10.3 mm. The channel length, 650 mm, was chosen to assure fully developed laminar-flow profiles in the vicinity of the electrodes. Constant flow rates of lithium hydroxide⁴ solution were provided by a single stroke piston pump with a capacity of 2.3 litres and a velocity range of 3-60 ml/s. The channel and pump were constructed of lucite with interconnecting tubes of nylon-reinforced polyvinyl chloride. No metal or glass parts were allowed to contact the electrolyte.

The removable section of the flow channel floor, containing the lithium electrode, was equipped with a 0.3 mm reference electrode capillary opening just 0.3 mm upstream from the electrode's leading edge. The capillary opening was connected to a lucite vessel containing the reference electrode by tygon tubing. The lithium electrodes were prepared by extruding the metal into

*Coulombic efficiency of lithium dissolution is defined as the ratio of equivalents of charge delivered to the external circuit to the moles of lithium dissolved.

the rectangular cavity in the removable section of the channel floor. The lithium surface was then gently ground flat on methanol wetted 280 grit SiC paper.

During preparation of the lithium anodes dark reddish brown granules were occasionally observed on the lithium surface. X-ray diffraction indicated these granules to be Li_3N . Experimental anodes were free of these impurities. Other contaminants in the lithium itself, as detected by spectrochemical analysis, are indicated in Table 1.

In these experiments current was either held constant or programmed as a linear ramp with a scan rate of 20 mA/s. The electronic equipment consisted of a Princeton Applied Research Galvanostat/Potentiostat and Programmer.⁵ Electrode potential was measured relative to a Hg/HgO, 1 M LiOH reference electrode.⁶ Current and potential were recorded on a 1 mega-ohm x-y recorder.⁷

Polarization curves at various flow rates indicated a low potential polarization region and a rapid rise to a high potential region at a critical current density, i_K , as shown in Figure 2. For purposes of analysis the critical current density was defined as the current density where the electrode polarization, relative to the open circuit voltage, exceeded that extrapolated from the linear region by 30%. The polarization data as a function of flow rate and electrolyte concentration are listed in Table 2. The physiochemical properties of aqueous lithium hydroxide necessary to calculate the theoretical limiting current densities in Table 2 are given in Table 3. Reynolds numbers corresponding to the electrolyte concentrations and flow rates employed are presented in Table 4.

COULOMBIC EFFICIENCY

Coulombic efficiency was determined with a hydrogen gas coulometer schematically shown in Figure 3. The volume of hydrogen evolved was determined from the volume of electrolyte displaced into the pipette. By connecting the

pipette to the coulometer with tygon tubing, the pressure of the confined gas could be adjusted to approximately that of the atmosphere by moving the pipette vertically.

The coulometer consisted of a sealed lucite chamber equipped with an internal electrolyte circulation system. The lithium anode was contained in a removable polypropylene^{*} plug which fits into the chamber top above a flow tube. Electrolyte flow through this tube was produced by a polypropylene stirring rod coupled to an external motor with a ferromagnetic feed-through.⁸ The electrolyte flow rate was altered with a series of pulley wheels which were attached to the Bodine 1800 or 5000 rpm motor.

Two sizes of flow tubes were employed in the experiment. When the large tube, 31.25 mm I.D., was used, the potential was measured via a capillary which opened 8.5 mm from the lithium surface in the wall of the flow tube. The smaller flow tube, 12.7 mm I.D., had a corresponding anode holder which had been modified to include a capillary opening 0.5 mm from the lithium surface, and was similar in design to the anode holder used in the polarization measurements.

Prior to each experiment, the electrolyte was purged with hydrogen gas⁹ for a minimum of ten minutes. After purging, the anode assembly was introduced into the chamber and the gas evolution rate was measured at a series of galvanostatic currents. In an improved technique, which produced the most accurate efficiency data, the steady-state rate of hydrogen evolution was measured. Steady-state measurements thereby discounted an initial lag period where internal pressures increased (by about 49 Pa) to overcome viscous drag in the tubing and pipette. Since the liquid levels in the pipette and chamber were kept equal, the internal pressures therefore exceeded the atmospheric pressure by approximately 49 Pa.

The external current was galvanostatically controlled as before. The potential was also measured and recorded as in the electrode polarization experiments.

^{*} Polypropylene was chosen for its flexibility and its effect on reducing corrosion of the lithium around the sides of the holder.

Efficiency data* as a function of current for different flow rates and concentration of lithium hydroxide is listed in Table 5. Additional observations made during the experiment are also recorded in the table. Where available, the critical current density and resistance are also included.

The temperature and atmospheric pressure were determined just prior or immediately following each experiment. The partial pressure of water over lithium hydroxide solutions¹⁰ must be used to correct the atmospheric pressure to the partial pressure of hydrogen. Table 6 lists the partial pressure of water over lithium hydroxide for the temperature range from 20 to 25°C.

* By combining Faraday's Law with the ideal gas law, the total moles of water reduced may be related to gas volume change through the equation

$$\text{Coulombic Efficiency} = \frac{I \epsilon \Delta t / 2F}{P_{H_2} \Delta V / RT}$$

TABLE 1. Lithium Impurities. (Contaminants found by spectrochemical analysis. Values are approximate p.p.m. as LiOH by weight for the elements listed.)

Si	10	<p>The following elements were not detected.</p> <p><30 Cd, Na, Sb, Zn</p> <p><10 Nb</p> <p><3 B, Ba, Bi, Mo, Ni, Pb, Sn, Ti</p> <p><1 Co, Cr, Fe, Mn, Sr, V, Zn</p>
Ca	4	
Cu	4	
Ag	3	
Be	3	
Al	1	
Mg	1	

TABLE 2. ELECTRICAL CHARACTERISTICS OF THE LITHIUM ANODE

Experimental conditions: flow channel; $A = 92 \text{ mm}^2$; $h = 3.16 \text{ mm}$; $L = 9.8 \text{ mm}$; channel width = 10.3 mm ; $dI/dt = 0.010 \text{ A/s}$; $T = 21 \pm 1^\circ\text{C}$
 Values for σ , i_k represent the average of three experiments.

Concentration c_b , (mol/l)	Flow rate ^a $\langle v \rangle$, (m/s)	Resistance ^b $\sigma \times 10^5$ ($\text{V}\cdot\text{m}^2/\text{A}$)	Critical Current Density i_k , (kA/m^2)	Limiting Current Density $\langle i_l \rangle$, (kA/m^2)
2.94	0.092	5.8	2.88	4.0
	0.135	6.4	3.12	4.5
	0.240	6.3	3.55	5.4
	0.375	6.4	4.06	6.3
	0.568	5.9	4.54	7.2
	0.906 ± 0.03	6.7	4.79	8.5
3.91	0.092	8.9	1.29	1.9
	0.135	7.9	1.47	2.2
	0.240	7.4	1.76	2.7
	0.375	6.4	2.08	3.1
	0.906 ± 0.03	5.5	2.69	4.1
4.25	0.092	12.4	0.71	1.4
	0.369	9.6	1.21	2.2
	0.553	11.0	1.47	2.5
	0.922 ± 0.03	18.3	1.61	3.0
4.44	0.135	9.8	0.35	1.2
	0.240	9.2	0.39	1.5
	0.375	8.5/9.7	0.45/0.95	1.7
	0.568	11.7	1.16	2.0
	0.906 ± 0.03	9.0	1.36	2.3
	1.22 ± 0.03	8.5	1.49	2.5
4.70	0.092	13.0	0.31	0.7
	0.369	10.0	0.31	1.1
	0.553	16.0	0.31	1.3
	0.922 ± 0.03	17.0	0.33	1.5
4.90	0.374	8.9	0.27	0.7
	0.568	11.0	0.30	0.8
	0.906 ± 0.03	12.0	0.28	1.0
	1.22 ± 0.03	16.0	0.30	1.1
5.10	0.568	6.8	0.33	0.4

^aPrecision $\pm 0.015 \text{ m/s}$ unless otherwise noted

^bPrecision $\pm 5\%$

TABLE 3. DATA USED IN THE CALCULATION OF LIMITING CURRENT DENSITY

$T = 21^{\circ}\text{C}$; $h = 3.16 \text{ mm}$; $L = 9.8 \text{ mm}$; $c_s = 5.29 \text{ mol/l}$

c (mol/l)	$D \times 10^{10}$ (m^2/s)	t_+ ^a	$F(c)$ ^b ($\text{kA s}^{7/3}/\text{m}^{7/3}$)	μ/μ_0
2.94	6.4	0.101	8.7(5)	2.1(6)
3.91	4.9	0.096	4.2(7)	2.8(6)
4.25	4.5	0.095	3.0(4)	3.1(3)
4.44	4.2	0.095	2.3(7)	3.3(0)
4.70	4.0	0.095	1.5(9)	3.5(4)
4.90	3.8	0.094	1.0(2)	3.7(2)
5.10	3.7	0.094	0.4(9)	3.9(1)

^aValues estimated at $T = 18^{\circ}\text{C}$.

^bThe coefficient $F(c)$ is defined by the equations:

$$\langle i_l \rangle = F(c) \langle v \rangle^{1/3}$$

$$F(c) = \frac{1.467 n F (c_s - c) D^{2/3}}{(1 - t_+) (h L)^{1/3}}$$

TABLE 4 Reynolds Numbers Investigated in Electrode Polarization Studies

Q ml./s	<V> m/s	ν mm ² /s	2.04	2.67	2.81	2.88	2.98	3.18	3.31	3.45
		C_3 molar	2.94	3.91	4.15	4.25	4.40	4.70	4.90	5.10
3	0.092		290	220	210	200	200	180	180	170
4.4	0.135		420	320	300	300	290	270	260	250
7.8	0.240		740	570	540	530	510	480	460	440
12.2	0.375		1160	890	840	820	790	740	720	690
18.0	0.553		1710	1310	1240	1210	1170	1100	1060	1010
18.5	0.568		1760	1350	1280	1130	1210	1130	1090	1040
29.5	0.906		2810	2150	2040	1990	1920	1800	1730	1660
30.0	0.922		2860	2180	2070	2020	1950	1830	1760	1690
39.7	1.22		3780	2890	2740	2680	2590	2420	2330	2230

Assuming: $H = 3.16$ mm

$W = 10.3$ mm

$$Re = \frac{2H\langle V \rangle}{\mu} = \frac{2Q}{W\mu}$$

$T = 19^\circ C \pm 1^\circ C$; kinematic viscosity extrapolated from data reported by Honey¹¹.

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 3.92 \text{ M}$$

Revolution Rate = 580 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2)		
					i_e	i_a	i_c
$T = 295^\circ\text{K}$	0.000	47.1	-2.88	0.000	0.00	3.62	3.62
$P_{\text{atm}} = 99.36$ kPa	0.048	44.2	-2.85	0.142	0.48	3.39	2.91
$P_{\text{H}_2\text{O}} = 2.346$ kPa	0.098	43.7	-2.82	0.294	0.98	3.35	2.37
$P_{\text{H}_2} = 97.01$ kPa	0.146	41.3	-2.78	0.463	1.47	3.17	1.70
$A = 99.40$ mm^2	0.195	40.2	-2.74	0.635	1.96	3.09	1.13
	0.244	40.0	-2.66	0.799	2.45	3.07	0.62
Additional Data	0.293	40.1	-2.25	0.957	2.95	3.08	0.13
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$ $= 131.0 \mu\text{l/sA}$	0.341	44.7	+5	1.000	3.43	3.43	0.00
Tube diameter $= 12.7 \text{ mm}$							
Gas volume change $= 2020 \mu\text{l}$							
Experiment date 12 November '76							

Comment: Most accurate experimental technique employed.

$$\text{Scan (10 mA/s), } i_{\text{lim}} = 0.262 \text{ kA/m}^2$$

$$h_c = 89.5 \text{ } \Omega \cdot \text{mm}^2$$

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TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 3.96 \text{ M}$$

Revolution Rate = 580 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2)		
					i_e	i_a	i_c
$T = 294^\circ \text{K}$	0.000	39.4	-2.87	0.000	0.00	3.02	3.02
$P_{\text{atm}} = 99.50$ kPa	0.073	39.7	-2.83	0.240	0.73	3.06	2.33
$P_{\text{H}_2\text{O}} = 2.35$ kPa	0.146	39.6	-2.78	0.481	1.47	3.06	1.59
$P_{\text{H}_2} = 97.15$ kPa	0.219	38.1	-2.72	0.750	2.20	2.93	0.73
$A = 99.40$ mm^2	0.292	37.5	-2.55	1.016	2.94	2.89	-0.05
	0.317	38.0	-1.00	1.088	3.19	2.93	-0.26
Additional Data	0.341	40.4	+2.00	1.101	3.43	3.12	-0.31
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$ $= 130.5 \mu\text{l/sA}$							
Tube diameter $= 12.7 \text{ mm}$							
Gas volume change $= 1010 \mu\text{l}$							
Experiment date 11 October '76							

Comment: Most accurate experimental technique employed.

No polarization scan.

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TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 4.15 \text{ M}$$

Revolution Rate = 1280 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2)		
					i_e	i_a	i_c
$T = 294^\circ \text{K}$	0.000	192.3	-----	0.000	0.00	2.68	2.68
$P_{\text{atm}} = 99.59$ kPa	0.098	151.3	-2.83	0.084	0.18	2.12	1.94
$P_{\text{H}_2\text{O}} = 2.186$ kPa	0.195	129.1	-2.79	0.196	0.35	1.80	1.44
$P_{\text{H}_2} = 97.41$ kPa	0.292	123.5	-2.75	0.307	0.53	1.72	1.19
$A = 552 \text{ mm}^2$	0.390	125.1	-2.70	0.405	0.71	1.74	1.04
	0.488	126.2	-2.66	0.503	0.88	1.76	0.87
Additional Data	0.585	118.3	-2.62	0.643	1.06	1.65	0.59
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$	0.682	118.3	-2.57	0.749	1.24	1.65	0.41
$= 130.0 \mu\text{l/sA}$	0.780	119.4	-2.52	0.849	1.41	1.66	0.25
Tube diameter	0.878	119.4	-2.45	0.956	1.59	1.66	0.07
$= 31.25 \text{ mm}$	0.975	121.1	-2.25	1.047	1.77	1.68	-0.08
Gas volume change							
$= 5050 \mu\text{l}$							
Experiment date							
22 July '76							

Comment: Small, undetermined errors due to original experimental technique.

$$\text{Scan (manual), } i_{\text{lim}} = 1.85 \text{ kA/m}^2$$

$$h_c = 331 \text{ .mm}^2$$

P. Hosmer, L. Koons

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 4.15 \text{ M}$$

Revolution Rate = 580 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2) i_e i_a i_c		
$T = 294^\circ \text{K}$	0.000	167.9	-2.87	0.000	0.00	2.37	2.37
$P_{\text{atm}} = 99.56$ kPa	0.000	169.4	-2.87	0.000	0.00	2.39	2.39
$P_{\text{H}_2\text{O}} = 2.160$ kPa	0.000	171.7	-2.87	0.000	0.00	2.42	2.42
$P_{\text{H}_2} = 97.40$ kPa $A = 545 \text{ mm}^2$	0.000	170.9	-2.87	0.000	0.00	2.41	2.41
Additional Data							
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$							
$= 130.1 \mu\text{l/sA}$							
Tube diameter							
$= 31.25 \text{ mm}$							
Gas volume change							
$= 37774 \mu\text{l}$							
Experiment date							
15 July 1976							

Comment: Small, undetermined errors due to original experimental technique.

No polarization scan.

Anode left in air the night prior to the experiment.

Lucite cell.

L. Koons

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 4.15 \text{ M}$$

Revolution Rate = 580 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2) i_e i_a i_c		
$T = 294^\circ \text{K}$ $P_{\text{atm}} = 99.55$ kPa $P_{\text{H}_2\text{O}} = 2.226$ kPa $P_{\text{H}_2} = 97.32$ kPa $A = 545 \text{ mm}^2$ Additional Data $RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$ $= 195.2 \mu\text{l/sA}$ Tube diameter $= 31.25 \text{ mm}$ Gas volume change $= 37774 \mu\text{l}$ Experiment date 15 July '76	-0.594	415.1	----	0.279	-1.09	-3.91	-2.82

Comment: Small, undetermined errors due to original experimental technique.

No polarization scan.

Anode left in air the night prior to the experiment.

Lucite cell.

L. Koons

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 4.15 \text{ M}$$

Revolution Rate = 580 RPM

Experimental Parameters	External Current I_c , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2)		
					i_e	i_a	i_c
$T = 295^\circ \text{K}$	0.000	170.1	-2.87	0.000	0.00	2.43	2.43
$P_{\text{atm}} = 99.32 \text{ kPa}$	0.098	178.4	-2.83	0.072	0.18	2.54	2.36
$P_{\text{H}_2\text{O}} = 2.333 \text{ kPa}$	0.195	115.3	-2.76	0.222	0.36	1.64	1.28
$P_{\text{H}_2} = 96.99 \text{ kPa}$	0.292	93.0	-2.71	0.411	0.55	1.33	0.78
$A = 535 \text{ mm}^2$	0.390	86.6	-2.67	0.590	0.73	1.24	0.51
	0.488	85.2	-2.60	0.823	0.91	1.11	0.20
Additional Data	0.585	77.7	-2.30	0.986	1.09	1.11	0.02
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$ $= 131.0 \mu\text{l/sA}$							
Tube diameter $= 31.25 \text{ mm}$							
Gas volume change $= 5050 \mu\text{l}$							
Experiment date 26 July '76							

Comment: Small undetermined error due to original experimental technique.

Scan indicates $i_{\text{lim}} = 1.09 \text{ kA/m}^2$, $h_o = 214 \Omega \cdot \text{mm}^2$

Transient passivation observed at $.37 \text{ kA/m}^2$.

P. Hosmer, L. Koons

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 4.15 \text{ M}$$

Revolution Rate = 580 RPM

Experimental Parameters	External Current I_c , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2) i_e i_a i_c		
$T = 293^\circ\text{K}$	0.122	121.4	-2.83	0.130	0.23	1.74	1.51
$P_{\text{atm}} = 99.59$ kPa	0.195	115.3	-2.80	0.219	0.36	1.65	1.29
$P_{\text{H}_2\text{O}} = 2.040$ kPa	0.390	109.8	-2.72	0.459	0.72	1.57	0.85
$P_{\text{H}_2} = 97.56$ kPa	0.634	99.6	-2.55	0.823	1.17	1.43	0.25
$A = 540 \text{ mm}^2$	0.673	83.2	-0.8	1.046	1.25	1.19	-0.06
Additional Data							
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$							
$= 129.4 \mu\text{l/sA}$							
Tube diameter							
$= 31.25 \text{ mm}$							
Gas volume change							
$= 5050 \mu\text{l}$							
Experiment date							
22 July '76							

Comment: Small, undetermined error due to original experimental technique.

Scan indicates $i_{\text{lim}} = 1.15 \text{ kA/m}^2$, $h_c = 216 \Omega \cdot \text{mm}^2$.

Transient passivation observed at $.37 \text{ kA/m}^2$.

After the experiment, the side erosion and surface dissolution depths were approximately 0.5 mm. Good surface condition.

P. Hosmer, L. Koons

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 4.15 \text{ M}$$

Revolution Rate = 430 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2) i_e i_a i_c		
$T = 294^\circ \text{K}$	0.098	130.2	-2.83	0.098	0.18	1.84	1.66
$P_{\text{atm}} = 99.59$ kPa	0.195	101.6	-2.78	0.250	0.36	1.43	1.07
$P_{\text{H}_2\text{O}} = 2.186$ kPa	0.292	90.2	-2.76	0.421	0.54	1.27	0.74
$P_{\text{H}_2} = 97.41$ kPa	0.390	83.7	-2.69	0.606	0.72	1.18	0.47
$A = 545 \text{ mm}^2$	0.480	81.5	-2.63	0.766	0.90	1.17	0.27
	0.575	71.4	-1.0	1.047	1.06	1.01	-0.05
Additional Data							
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$							
$= 130.0 \mu\text{l/sA}$							
Tube diameter							
$= 31.25 \text{ mm}$							
Gas volume change							
$= 5050 \mu\text{l}$							
Experiment date							
22 July '76							

Comment: Small, undetermined error due to original experimental technique.

Scan indicates $i_{\text{lim}} = 1.11 \text{ kA/m}^2$, $n_c = 218 \Omega \cdot \text{mm}^2$.

Transient passivation observed at $.37 \text{ kA/m}^2$.

P. Hosmer, L. Koons

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 4.24 \text{ M}$$

Revolution Rate = 2480 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2)		
					i_e	i_a	i_c
$T = 294^\circ \text{K}$	0.000	66.7	-2.87	0.000	0.00	5.19	5.19
$P_{\text{atm}} = 99.8 \text{ kPa}$	0.098	64.3	-2.80	0.201*	1.00	5.00	4.00
$P_{\text{H}_2\text{O}} = 2.6 \text{ kPa}$	0.195	65.2	-2.78	0.394	2.00	5.07	3.07
$P_{\text{H}_2} = 97.2 \text{ kPa}$	0.293	64.2	-2.76	0.601	3.00	5.00	2.00
$A = 97.64 \text{ mm}^2$	0.390	65.6	-2.71	0.782	3.99	5.11	1.11
	0.507	71.4	+2	0.935	5.19	5.53	0.36
Additional Data	0.468	64.6	+5	0.954	4.79	5.03	0.23
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$ $= 131.7 \mu\text{l/sA}$							
Tube diameter $= 12.7 \text{ mm}$							
Gas volume change $= 3030 \mu\text{l}$							
Experiment date 6 October '76							
* Compensated for 0.19 cm recession at end of experiment.							

Comment: Small, undetermined error due to original experimental technique.

No scan taken.

Experiment performed with bad bearings.

J. Cooper, P. Hosmer

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 4.24 \text{ M}$$

Revolution Rate = 1620 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2)		
					i_e	i_a	i_c
$T = 296^\circ \text{K}$	0.000	61.2	-2.85	0.000	0.00	4.81	4.81
$P_{\text{atm}} = 99.39$ kPa	0.098	58.6	-2.81	0.220	1.01	4.59	3.58
$P_{\text{H}_2\text{O}} = 2.45$ kPa	0.195	57.4	-2.75	0.438	2.02	4.61	2.59
$P_{\text{H}_2} = 96.94$ kPa	0.292	55.6	-2.69	0.669	3.03	4.53	1.50
$A = 96.8$ mm^2	0.390	56.4	-2.5	0.910	4.03	4.43	0.40
	0.414	57.2	-1.5	0.952	4.28	4.50	0.22
Additional Data	0.458	62.2	+5	0.969	4.73	4.88	0.15
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$ $= 131.6 \mu\text{l/sA}$	-----						
	CATHODIC						
Tube diameter	0.000	52.3	-2.85	0.000	0.00	4.11	4.11
$= 12.7 \text{ mm}$	-0.098	73.5	-2.93	0.263	-1.01	-3.84	-2.83
Gas volume change	-0.244	124.	-3.03	0.388	-2.52	-6.49	-3.97
	-0.488	217	-3.16	0.444	-5.04	-11.4	-6.31
$= 2020 \mu\text{l}$	-0.731	340	-3.37	0.424	-7.55	-17.8	-10.3
Experiment date	-0.975	430	-3.63	0.447	-10.0	-22.4	-12.4
7 October '76							

Comment: Data acquired with most accurate experimental technique.

J. Cooper, P. Hosmer

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 4.24 \text{ M}$$

Revolution Rate = 1280 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2)		
					i_e	i_a	i_c
$T = 294^\circ \text{K}$	0.000	33.5	-2.86	0.000	0.00	2.49	2.49
$P_{\text{atm}} = 99.83$ kPa	0.049	31.9	-2.81	0.199	0.47	2.37	1.90
$P_{\text{H}_2\text{O}} = 2.173$ kPa	0.098	32.8	-2.75	0.388	0.94	2.43	1.49
$P_{\text{H}_2} = 97.66$ kPa	0.146	32.3	-2.72	0.586	1.41	2.40	0.99
$A = 103.9$ mm^2	0.195	32.0	-2.65	0.791	1.88	2.37	0.50
	0.219	31.9	-2.55	0.891	2.11	2.37	0.26
Additional Data	0.244	32.3	-1.5	0.980	2.35	2.40	0.05
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$ $= 129.7 \mu\text{l/sA}$							
Tube diameter $= 12.7 \text{ mm}$							
Gas volume change $= 2020 \mu\text{l}$							
Experiment date 5 October '76							

Comment: Small, undetermined error due to original experimental technique.

J. Cooper

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 4.24 \text{ M}$$

Revolution Rate = 580 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2)		
					i_e	i_a	i_c
$T = 295^\circ \text{K}$	0.000	206 ^a	-2.88	0.000	0.00	2.85	2.85
$P_{\text{atm}} = 99.9 \text{ kPa}$	0.098	167	-2.81	0.077	0.18	2.30	2.13
$P_{\text{H}_2\text{O}} = 2.23 \text{ kPa}$	0.195	118	-2.77	0.22	0.35	1.62	1.27
$P_{\text{H}_2} = 97.58 \text{ kPa}$	0.292	104	-2.73	0.37	0.53	1.43	0.91
$A = 555.7 \text{ mm}^2$	0.390	102	-2.67	0.50	0.70	1.40	0.70
	0.536	99	-2.58	0.70	0.96	1.37	0.41
Additional Data	0.634	97	-2.49	0.85	1.14	1.34	0.20
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$	0.731	96	-2.0	0.99	1.32	1.33	0.01
$= 130.3 \mu\text{l/sA}$	0.829	109	+5	0.99	1.49	1.50	0.01
Tube diameter							
$= 31.25 \text{ mm}$							
Gas volume change							
$= 5050 \mu\text{l}$							
Experiment date							
24 Sept. '76							
^a Data accurate to $\pm 3\%$							

Comment: Small undetermined error due to original experimental technique.

Scan indicates $i_{\text{lim}} = 1.21 \text{ kA/m}^2$, $h_c = 278 \Omega \cdot \text{mm}^2$.

P. Hosmer

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 4.24 \text{ M}$$

Revolution Rate = 580 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2) i_e i_a i_c		
$T = 295^\circ \text{K}$	0.000	33.5	-2.86	0.00	0.00	2.66	2.66
$P_{\text{atm}} = 99.9 \text{ kPa}$	0.049	26.2	-2.80	0.24	0.51	2.08	1.57
$P_{\text{H}_2\text{O}} = 2.3 \text{ kPa}$	0.098	26.2	-2.75	0.49	1.01	2.08	1.06
$P_{\text{H}_2} = 97.6 \text{ kPa}$	0.146	25.5	-2.70	0.75	1.51	2.02	0.52
$A = 96.8 \text{ mm}^2$	0.195	25.2	-2.25	1.01	2.01	2.00	-0.01
	0.266	35.4	(-1 to +5)	0.98	2.75	2.81	0.06
Additional Data	0.291	38.8	+5	0.98	3.00	3.08	0.07
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$ $= 130.2 \mu\text{l/sA}$							
Tube diameter $= 12.7 \text{ mm}$							
Gas volume change $= 2020 \mu\text{l}$							
Experiment date 4 October '76							

Comment: Small, undetermined error due to original experimental technique.

No polarization curves taken.

J. Cooper, P. Hosmer

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 4.24 \text{ M}$$

Revolution Rate = 430 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2) i_e i_a i_c		
$T = 293^\circ \text{K}$	0.000	29.5	-2.86	0.00	0.00	2.20	2.20
$P_{\text{atm}} = 99.8 \text{ kPa}$	0.049	26.9	-2.83	0.24	0.47	2.01	1.53
$P_{\text{H}_2\text{O}} = 2.1 \text{ kPa}$	0.098	26.6	-2.77	0.48	0.95	1.99	1.03
$P_{\text{H}_2} = 97.7 \text{ kPa}$	0.146	26.5	-2.72	0.71	1.41	1.98	0.57
$A = 103.4 \text{ mm}^2$	0.195	26.8	(-2.1 ± 0.4)	0.94	1.89	2.00	0.11
Additional Data							
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$							
$= 129.4 \mu\text{l/sA}$							
Tube diameter							
$= 12.7 \text{ mm}$							
Gas volume change							
$= \text{---} \mu\text{l}$							
Experiment date							
5 October '76							

Comment: Small, undetermined error due to original experimental technique.

Chart not available to provide further information.

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 4.40 \text{ M}$$

Revolution Rate = 1280 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2)		
					i_e	i_a	i_c
$T = 296^\circ\text{K}$	0.000	202.0	-2.86	0.000	0.00	2.74	2.74
$P_{\text{atm}} = 99.90$ kPa	0.098	170.0	-2.82	0.075	0.17	2.32	2.14
$P_{\text{H}_2\text{O}} = 2.453$ kPa	0.195	116.6	-2.78	0.219	0.35	1.58	1.23
$P_{\text{H}_2} = 97.45$ kPa	0.292	85.0	-2.75	0.446	0.52	1.16	0.64
$A = 564 \text{ mm}^2$	0.390	83.1	-2.68	0.614	0.69	1.12	0.43
	0.488	84.2	-2.62	0.758	0.86	1.14	0.28
Additional Data	0.585	83.7	-2.50	0.913	1.04	1.14	0.10
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$ $= 130.9 \mu\text{l/sA}$	0.634	82.8	-2.38	1.001	1.12	1.12	0.00
Tube diameter $= 31.25 \text{ mm}$							
Gas volume change $= 5050 \mu\text{l}$							
Experiment date 2 August '76							

Comment: Small, undetermined error due to original experimental technique.

Scan indicates $i_{\text{lim}} = 1.04 \text{ kA/m}^2$, $h_c = 395 \mu\text{mm}^2$.

Transient passivation observed at 0.44 kA/m^2 .

P. Hosmer, L. Koons

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 4.40 \text{ M}$$

Revolution Rate = 1280 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2) i_e i_a i_c		
$T = 296^\circ \text{K}$	0.000	288.6	-2.85	0.000	0.00	3.93	3.93
$P_{\text{atm}} = 99.90$ kPa	-0.098	336.7	-2.90	0.057	0.17	3.05	2.88
$P_{\text{H}_2\text{O}} = 2.453$ kPa	-0.244	420.8	-2.95	0.114	0.43	3.81	3.38
$P_{\text{H}_2} = 97.45$ kPa	-0.488	505.0	-3.05	0.190	0.87	4.57	3.70
$A = 562 \text{ mm}^2$	-0.731	631	-3.15	0.227	1.30	5.73	4.43
	-0.975	721	-3.22	0.265	1.74	6.55	4.82
Additional Data							
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$ $= 130.9 \mu\text{l}/\epsilon\text{A}$	0.292	48.9	-2.60	0.802	0.52	0.65	0.13
Tube diameter $= 31.25 \text{ mm}$							
Gas volume change $= 5050 \mu\text{l}$							
Experiment date 2 August '76							

Comment: Small, undetermined error due to original experimental technique.

No polarization curves taken.

F. Hosmer, L. Koons

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 4.40 \text{ M}$$

Revolution Rate = 580 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2)		
					i_e	i_a	i_c
$T = 295^\circ \text{K}$	0.000	27.2	-2.88	0.000	0.00	2.12	2.12
$P_{\text{atm}} = 99.36$ kPa	0.049	25.9	-2.85	0.247	0.50	2.03	1.53
$P_{\text{H}_2\text{O}} = 2.346$ kPa	0.098	26.3	-2.79	0.488	1.00	2.06	1.05
$P_{\text{H}_2} = 97.01$ kPa	0.146	26.1	-2.74	0.734	1.50	2.04	0.54
$A = 97.64$ mm^2	0.195	26.0	-2.45	0.983	2.00	2.03	0.03
	0.244	30.5	+5	1.050	2.50	2.38	-0.12
Additional Data							
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$ $= 131.0 \mu\text{l/sA}$							
Tube diameter $= 12.7 \text{ mm}$							
Gas volume change $= 2020 \mu\text{l}$							
Experiment date 12 Nov. '76							

Comment: Data acquired with most accurate experimental technique.

Scan (10 mA/s) indicates $i_{\text{lim}} = 1.69 \text{ kA/m}^2$, $n_c = 107 \Omega \cdot \text{mm}^2$.

J. Cooper, P. Hosmer

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 4.40 \text{ M}$$

Revolution Rate = 580 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution ² dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2) i_e i_a i_c		
$T = 296^\circ \text{K}$	0.000	35.0	-2.88	0.000	0.00	2.66	2.66
$P_{\text{atm}} = 99.73$ kPa	0.039	28.3	-2.85	0.181	0.39	2.15	1.76
$P_{\text{H}_2\text{O}} = 2.453$ kPa	0.078	26.2	-2.82	0.391	0.78	1.99	1.21
$P_{\text{H}_2} = 97.28$ kPa	0.117	26.7	-2.78	0.575	1.17	2.03	0.86
$A = 100.3$ mm^2	0.156	26.6	-2.72	0.768	1.56	2.03	0.47
	0.186	26.6	-2.35	0.940	1.85	1.97	0.12
Additional Data	0.215	28.0	+5	1.006	2.14	2.13	-0.01
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$ $= 131.1 \mu\text{l/sA}$	0.234	31.5	+10	0.975	2.33	2.39	0.06
Tube diameter $= 12.7 \text{ mm}$							
Gas volume change $= 2020 \mu\text{l}$							
Experiment date 11 Nov. '76							

Comment: Data acquired with most accurate experimental technique.

The i_{lim} was approximately 2.00 kA/m^2 . (not scanned)

F. Hosmer, J. Cooper

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 4.40 \text{ M}$$

Revolution Rate = 430 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution ² dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2)		
					i_e	i_a	i_c
$T = 296^\circ \text{K}$	0.000	297.1	-2.87	0.000	0.00	4.10	4.10
$P_{\text{atm}} = 99.90$ kPa	0.073	252.5	-2.85	0.038	0.13	3.47	3.34
$P_{\text{H}_2\text{O}} = 2.453$ kPa	0.146	213.1	-2.82	0.090	0.26	2.73	2.47
$P_{\text{H}_2} = 97.45$ kPa	0.195	161.3	-2.80	0.158	0.35	2.23	1.88
$A = 554 \text{ mm}^2$	0.244	136.5	-2.75	0.234	0.44	1.88	1.44
	0.292	55.8	-2.68	0.684	0.53	0.77	0.24
Additional Data	0.341	53.8	-2.58	0.850	0.62	0.73	0.11
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})^F$ $= 130.9 \mu\text{l/sA}$	0.375	52.6	-1.5	0.932	0.68	0.73	0.05
Tube diameter $= 31.25 \text{ mm}$							
Gas volume change $= 5050 \mu\text{l}$							
Experiment date 2 August '76							

Comment: Small, undetermined error due to original experimental technique.

Scan indicates $i_{\text{lim}} = 0.43 \text{ kA/m}^2$, $h_c = 277 \Omega \cdot \text{mm}^2$.

Limiting current acts like transient passivation with "teasing" to achieve currents greater than i_{lim} without passivation.

P. Hosmer, L. Koons

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 4.51 \text{ M}$$

Revolution Rate = 580 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2) i_e i_a i_c		
$T = 295^\circ \text{K}$	0.000	30.1	-2.87	0.000	0.00	2.42	2.42
$P_{\text{atm}} = 99.50$ kPa	0.049	21.8	-2.83	0.294	0.52	1.77	1.25
$P_{\text{H}_2\text{O}} = 2.31$ kPa	0.098	19.6	-2.77	0.653	1.03	1.58	0.55
$P_{\text{H}_2} = 97.19$ kPa	0.146	19.0	-2.58	1.004	1.54	1.53	-0.01
$A = 95.0$ mm^2	0.166	19.8	+2	1.093	1.75	1.60	-0.15
	0.195	23.3	+14	1.095	2.05	1.87	-0.18
Additional Data							
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$							
$= 130.8 \mu\text{l/sA}$							
Tube diameter							
$= 12.7 \text{ mm}$							
Gas volume change							
$= 1010 \mu\text{l}$							
Experiment date							
11 Oct. '76							

Comment: Data acquired with most accurate experimental technique.

Chart not available to provide further information.

P. Hosmer

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 4.70 \text{ M}$$

Revolution Rate = 1280 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2)		
					i_e	i_a	i_c
$T = 294^\circ \text{K}$	0.122	102.5	-2.82	0.154	0.22	1.45	1.23
$P_{\text{atm}} = 100.07 \text{ kPa}$	0.219	37.3	-2.57	0.780	0.40	0.52	0.11
$P_{\text{H}_2\text{O}} = 2.146 \text{ kPa}$	0.239	37.5	-2.48	0.823	0.44	0.53	0.09
$P_{\text{H}_2} = 97.93 \text{ kPa}$	0.268	38.5	-2.25	0.900	0.49	0.55	0.06
$A = 545 \text{ mm}^2$	0.287	38.7	-1.1	0.959	0.53	0.55	0.02
Additional Data							
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$							
$= 129.4 \mu\text{l/sA}$							
Tube diameter							
$= 31.25 \text{ mm}$							
Gas volume change							
$= 2020 \mu\text{l}$							
Experiment date							
20 July '76							

Comment: Small, undetermined error due to original experimental technique.

Scan indicates $i_{\text{lim}} = 0.34 \text{ kA/m}^2$, $h_c = 382 \Omega \cdot \text{mm}^2$.

Transient passivation like I_{lim} , with teasing to achieve the unpassivated higher currents.

P. Hosmer, L. Koons

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 4.70 \text{ M}$$

Revolution Rate = 580 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2)		
					i_e	i_a	i_c
$T = 294^\circ \text{K}$	0.000	176.8	-2.87	0.000	0.00	2.51	2.51
$P_{\text{atm}} = 100.07$ kPa	0.024	168.3	-2.86	0.018	0.04	2.45	2.41
$P_{\text{H}_2\text{O}} = 2.146$ kPa	0.049	147.3	-2.85	0.043	0.09	2.09	2.00
$P_{\text{H}_2} = 97.93$ kPa	0.073	133.4	-2.83	0.071	0.13	1.89	1.76
$A = 545 \text{ mm}^2$	0.098	126.9	-2.82	0.100	0.18	1.80	1.62
	0.122	120.4	-2.80	0.131	0.22	1.71	1.49
Additional Data	0.146	108.8	-2.79	0.173	0.27	1.55	1.28
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$	0.171	90.7	-2.78	0.244	0.31	1.29	0.98
$= 122.6 \mu\text{l/sA}$	0.219	30.6	-2.3	0.923	0.40	0.44	0.03
Tube diameter	0.229	30.1	-1.9	0.985	0.42	0.43	0.00
$= 31.25 \text{ mm}$	0.239	29.2	-0.0	1.058	0.44	0.42	-0.02
Gas volume change							
$= 7070 \mu\text{l}$							
Experiment date							
20 July '76							

Comment: Small, undetermined error due to original experimental technique.

Scan indicates $i_{\text{lim}} = .28 \text{ kA/m}^2$, $h_c = 218 \mu\text{mm}^2$.

Transient passivation like I_{lim} , with teasing to achieve the unpassivated higher currents.

P. Hosmer, L. Koons

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 4.70 \text{ M}$$

Revolution Rate = 580 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2)		
					i_e	i_a	i_c
$T = 295^\circ \text{K}$	0.000	181.7	-2.88	0.000	0.00	2.50	2.50
$P_{\text{atm}} = 99.50$ kPa	0.034	167.2	-2.87	0.027	0.61	2.26	2.20
$P_{\text{H}_2\text{O}} = 2.280$ kPa	0.073	154.0	-2.85	0.062	0.13	2.11	1.98
$P_{\text{H}_2} = 97.22$ kPa	0.122	131.9	-2.82	0.121	0.22	1.81	1.59
$A = 556 \text{ mm}^2$	0.146	119.1	-2.80	0.160	0.26	1.64	1.38
	0.184	92.7	-2.72	0.259	0.33	1.28	0.95
Additional Data							
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$							
$= 130.7 \mu\text{l/sA}$							
Tube diameter							
$= 31.25 \text{ mm}$							
Gas volume change							
$= 5050 \mu\text{l}$							
Experiment date							
22 Sept. '76							

Comment: Small, undetermined error due to original experimental technique.

Chart not available to provide further information.

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 4.70 \text{ M}$$

Revolution Rate = 580 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2) i_e i_a i_c		
$T = 294^\circ \text{K}$	0.000	25.8	-2.88	0.000	0.00	2.05	2.05
$P_{\text{atm}} = 99.64$ kPa	0.010	21.9	-2.87	0.059	0.10	1.75	1.65
$P_{\text{H}_2\text{O}} = 2.16$ kPa	0.029	14.6	-2.85	0.258	0.30	1.16	0.86
$P_{\text{H}_2} = 97.48$ kPa	0.044	10.9	-2.72	0.525	0.46	0.87	0.41
$A = 96.8$ mm^2	0.059	9.05	-2.62	0.848	0.61	0.72	0.11
	0.068	8.88	-2.1	0.996	0.70	0.71	0.00
Additional Data	0.078	9.98	+6	1.016	0.81	0.79	-0.01
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$ $= 130.0 \mu\text{l/sA}$							
Tube diameter $= 12.7 \text{ mm}$							
Gas volume change $= 1010 \mu\text{l}$							
Experiment date 8 Oct. '76							

Comment: Data acquired with most accurate experimental technique.

No polarization data.

P. Hosmer

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 5.10 \text{ M}$$

Revolution Rate = 580 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2) i_e i_a i_c		
$T = 295^\circ \text{K}$	-0.098	34.6	-22	0.55	-1.01	-1.84	-0.83
$P_{\text{atm}} = 99.64$ kPa	-0.244	88.2	-40	0.54	-2.52	-4.65	-2.13
$P_{\text{H}_2\text{O}} = 2.24$ kPa	-0.488	98.1	-23	0.97	-5.04	-5.17	-0.13
$P_{\text{H}_2} = 97.41$ kPa	-0.731	153.0	-22	0.94	-7.55	-8.04	-0.49
$A = 96.77$ mm^2	-0.975	212.6	-25	0.90	-10.08	-11.19	-1.11
Additional Data							
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$							
$= 130.5 \mu\text{l/sA}$							
Tube diameter							
$= 12.7 \text{ mm}$							
Gas volume change							
$= \text{---} \mu\text{l}$							
Experiment date							
8 Oct. '76							

Comment: Data acquired with most accurate experimental technique.

No observable gas evolution at open circuit, where the potential reached 80 V.

Circuit overloaded at open circuit and with any anodic current.

P. Hosmer

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 5.10 \text{ M}$$

Revolution Rate = 580 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2)		
					i_e	i_a	i_c
$T = 294^\circ \text{K}$	0.000	220.9	-2.88	0.000	0.00	3.05	3.05
$P_{\text{atm}} = 99.90$ kPa	-0.244	307.4	-3.00	0.154	-0.44	-2.83	-2.39
$P_{\text{H}_2\text{O}} = 2.106$ kPa	-0.488	386.3	-3.10	0.245	-0.87	-3.56	-2.69
$P_{\text{H}_2} = 97.79$ kPa	-0.731	411.0	-3.40	0.345	-1.31	-3.78	-2.48
$A = 560 \text{ mm}^2$	-0.975	425.9	-3.85	0.456	-1.74	-3.82	-2.08
Additional Data							
$RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$							
$= 129.5 \mu\text{l/sA}$							
Tube diameter							
$= 31.25 \text{ mm}$							
Gas volume change							
$= 7070 \mu\text{l}$							
Experiment date							
30 August '76							

Comment: Small, undetermined error due to original experimental technique.

No polarization data.

P. Hošmer

TABLE 5. COULOMBIC EFFICIENCY DATA

$$[\text{LiOH}] = 5.10 \text{ M}$$

Revolution Rate = 580 RPM

Experimental Parameters	External Current I_e , (A)	Rate of H_2 Evolution dV/dt , ($\mu\text{l/s}$)	Electrode Potential E_{Li} , (V)	Coulombic Efficiency ϵ	Current Densities (kA/m^2) i_e i_a i_c		
$T = 294^\circ\text{K}$ $P_{\text{atm}} = 99.90$ kPa $P_{\text{H}_2\text{O}} = 2.106$ kPa $P_{\text{H}_2} = 97.79$ kPa $A = 560 \text{ mm}^2$ Additional Data $RT/2(P_{\text{atm}} - P_{\text{H}_2\text{O}})F$ $= 129.5 \mu\text{l/sA}$ Tube diameter $= 31.25 \text{ mm}$ Gas volume change $= 7070 \mu\text{l}$ Experiment date 30 August '76	0.000	220.9	-2.88	0.000	0.00	3.05	3.05

Comment: Small, undetermined error due to original experimental technique.

No polarization data.

P. Hosmer

TABLE 6. Partial Pressure of Water Over Aqueous Lithium Hydroxide⁵, kPa

Temperature °K	Concentration of Lithium Hydroxide					
	3.96 M	4.15 M	4.24 M	4.40 M	4.70 M	5.10 M
293	2.053	2.040	2.026	2.013	2.000	1.960
294	2.200	2.186	2.173	2.160	2.146	2.106
295	2.333	2.333	2.320	2.306	2.280	2.240
296	2.480	2.466	2.453	2.453	2.426	2.386
297	2.626	2.613	2.600	2.586	2.560	2.520
298	2.760	2.760	2.746	2.733	2.706	2.626

At 293°K $P = (17.158 - 0.2931m - 0.03676 m^2) \cdot 133.322$ $m \geq 3 \pm 0.003$ kPa

At 298°K $P = (24.087 - 0.868 m + 0.0133 m^2) \cdot 133.322$ $m \geq 3 \pm 0.001$ kPa

Where P is the pressure in kPa

m is the molal concentration of lithium hydroxide

Figure 1. Flow Channel Apparatus (Schematic). A, piston pump; B, fresh electrolyte reservoir; C, valve; D, flow channel; E, platinum cathode; F, lithium anode; G, Hg/HgO, 1M LiOH reference electrode; H, used electrolyte reservoir; I, current-measuring resistor.

Figure 2. Typical Polarization Curves for Lithium Dissolution at Various Flow Rates. Critical current density, i_k determined from extrapolation of the linear polarization region, a-b.

Figure 3. Hydrogen Gas Coulometer (Schematic). A, reference electrode; B, lithium electrode lead; C, lithium electrode holder; D, lithium anode; E, platinum counter electrode; F, counter electrode lead; G, thermometer; H, magnetic feed-through; I, variable speed motor; J, valve; K, hydrogen gas bottle; L, exhaust port; M, flexible tubing; N, pipette; O, Lucite vessel; P, flow channel; Q, electrolyte.

ACKNOWLEDGMENTS

We would like to acknowledge Lawrence Koons for his participation in the experiments on coulombic efficiency.

Particular thanks to Earl Kelly for designing and constructing all the apparatus used in both the polarization and coulombic efficiency experiments.

We also wish to thank Hal Wiesner and Bill Frey for the use of their laboratory in the polarization study.

SYMBOLS

A	Projected anode area
C	Concentration of LiOH
c_b, c_s, c_{sat}	Bulk electrolyte concentration, surface concentration, saturation concentration
D	Diffusion coefficient of LiOH(aq)
ϵ	Coulombic efficiency
E_{Li}	Lithium electrode surface potential
F	Faradays constant, 96 480 coulombs/equivalent
F(c)	Coefficient of concentration, $= \frac{1.467 n F (C_s - C_b) D^{2/3}}{(1 - t^+) (h L)^{1/3}}$
H, h	Electrode separation
h_c	Resistance of lithium surface film
i_a	Anodic current density
i_c	Corrosion current density
i_e	External current density
I_e	External current
i_k	Critical current density
i_l, i_{lim}	Limiting current density
L	Electrode length in direction of flow
n	Number of electrons transferred per unit reaction
P_{atm}	Atmospheric pressure
P_{H_2}	Partial pressure of hydrogen
P_{H_2O}	Partial pressure of water
Q	Electrolyte flow velocity, ml/s

R	Gas constant
Re	Reynolds number
T	Temperature
t_+	Transference number of Li^+
Δt	Change in time
ν	Kinematic viscosity
$\langle v \rangle$	Electrolyte linear flow rate, m/s
Δv	Volume change
W	Channel width

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