Experimental Design

(b-d) A small piece of clean sodium metal is added to pure water. The following diagnostic tests are conducted first on pure water (as a control) and then on the final reaction mixture. If a flame is inserted into a sample of the gas above the water, and a squeal or "pop" sound is heard, then hydrogen is likely present. If pieces of red and blue litmus paper are immersed in the solution, and the red paper turns blue, then hydroxide ions are likely present. If a flame test is conducted on the liquid, and the flame is bright yellow, then sodium ions are likely present.

Evidence

(e) **Reaction of Sodium with Water**

Diagnostic test	Pure water control	Reaction mixture
hydrogen test	no sound heard	high, squeaky "pop" heard
litmus test	no colour change	red litmus turned blue
flame test	pale yellow flame	bright yellow flame

Analysis

(f) According to the evidence from the diagnostic tests, hydrogen gas, sodium ions, and hydroxide ions were produced in the reaction of sodium metal with water.

Evaluation

(g) The prediction is verified because it clearly agrees with the evidence obtained.
(h) Because the prediction is verified, the method of writing redox reactions appears to be acceptable for this reaction.
(i) One test cannot be sufficient to provide a reliable evaluation. Many other reactions should be predicted and then tested.

ACTIVITY 9.4.1 DEVELOPING AN ELECTRIC CELL

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Evidence

(a) Testing of several cells showed that the aluminum can must always be the negative (black) electrode in order to obtain a positive voltage reading. Scraping the coating to expose the aluminum metal gave better results. However, the voltages were often erratic and slowly changed. In all cases, the voltages slowly increased the longer the cell was assembled.

(b) **Developing an Electric Cell Using Different Electrodes and Electrolytes**

	Initial voltages (V)			Final voltages (V)		
Electrode	$NaCl_{(aq)}$	$NaOH_{(aq)}$	$HCl_{(aq)}$	$NaCl_{(aq)}$	$NaOH_{(aq)}$	$HCl_{(aq)}$
copper	0.5	0.4	0.6	1.1	2.4	1.2
carbon	0.4	1.5	0.9	1.5	3.8	2.4

Analysis

(c) According to the evidence collected, the largest voltage of an aluminum-can cell is 3.8 V. This voltage is obtained with a carbon electrode as the positive electrode in a 0.5 mol/L sodium hydroxide electrolyte left sitting in the aluminum can (negative electrode) for a long period of time.

Evaluation

(d) Overall, the quality of the evidence was not very high if accurate and reliable voltages are desired. The evidence did clearly show that some cell designs were better than others. Sources of experimental error or uncertainty include the electrical connection between the clip and the aluminum can, the influence of the coating on the inside of the can on the operation of the cell, the purity of the electrodes and solutions, and the time the electrolyte is left in contact with the components of the cell.
(e) The aluminum can would be cleaned or scraped down to the bare metal, both inside and outside where the wire is connected. Electrolytes would be left sitting in the can for a period of time before measuring the voltage. Finally, other electrodes and electrolytes would be tested.
(f) The $C_{(s)}$ | $NaOH_{(aq)}$ | $Al_{(s)}$ electric cell is judged according to these criteria: reliability, economy, and simplicity. The cell appears reliable since it produced a voltage immediately. However, if a constant voltage is required, this cell may

not function reliably. More trials are required to investigate long-term reliability and the time it takes the thin wall of the aluminum can to disintegrate. The economics of the cell would depend largely on the cost of aluminum and the cell's ability to be recharged. Recycled aluminum would be a significant economic advantage. Certainly, there does not appear to be a shortage of empty aluminum cans. The cell is simple as it does not have any complex parts or technical design. Further trials are needed using a moist, basic electrolyte paste to obtain a cell that will not easily leak its contents.

LAB EXERCISE 9.4.1 CHARACTERISTICS OF A HYDROGEN FUEL CELL

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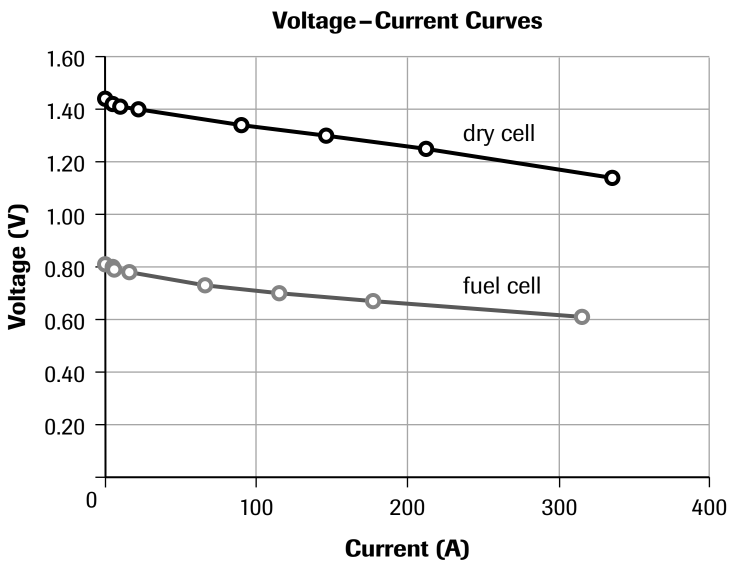
Analysis

(a)



(b) For both cells, the voltage of the cell slowly decreases as the current increases. The behaviour of the hydrogen fuel cell appears similar, although it starts at a lower initial voltage.

(c)

Power Curve Comparison

Dry cell			Hydrogen fuel cell		
Voltage (V)	Current (mA)	Power (mW)	Voltage (V)	Current (mA)	Power (mW)
1.44	0	0	0.81	0	0
1.42	5	7	0.80	5	4
1.41	10	14	0.79	6	5
1.40	22	31	0.78	16	12
1.34	90	120	0.73	66	48
1.30	146	190	0.70	115	80
1.25	212	265	0.67	177	120
1.14	335	382	0.61	315	190