Analysis

(d) The evidence obtained is consistent with spontaneous, single displacement reactions for only the combinations of:

- copper metal and silver ions;
- lead metal and copper(II) ions;
- lead metal and silver ions; and
- zinc metal and each of copper(II), silver, and lead(II) ions.

Evaluation

(e) The experimental design was adequate to answer the problem since only evidence for a reaction (not the identity of the product) was required. The materials and procedure were adequate, although the short observation time did create a little uncertainty for those combinations that did not appear to react.

(f) Two aspects of this experiment could be improved. The combinations that did not appear to react could be left longer in case there was a slow reaction. Some diagnostic tests could be done to determine the identity of any products produced.

(g) Overall, the prediction is judged to be falsified since six out of the twelve predicted spontaneous reactions did not give any evidence of a chemical change. The mixture of a metal and a solution of its own ion was predicted to be nonspontaneous and this was verified with the possible exception of the copper system, which would require further testing.

(h) The assumption of spontaneous reactions is judged to be unacceptable since the prediction was clearly falsified. The assumption will need to be restricted, revised, or discarded.

LAB EXERCISE 9.3.1 BUILDING A REDOX TABLE

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Analysis

(a) SOA $Br_{2(aq)} + 2\,e^- \rightleftharpoons 2\,Br^-_{(aq)}$

$Ag^+_{(aq)} + e^- \rightleftharpoons Ag_{(s)}$

$I_{2(aq)} + 2\,e^- \rightleftharpoons 2\,I^-_{(aq)}$

$Cu^{2+}_{(aq)} + 2\,e^- \rightleftharpoons Cu_{(s)}$ SRA

Synthesis

(b) SOA $Cl_{2(aq)} + 2\,e^- \rightleftharpoons 2\,Cl^-_{(aq)}$

$Br_{2(aq)} + 2\,e^- \rightleftharpoons 2\,Br^-_{(aq)}$

$Ag^+_{(aq)} + e^- \rightleftharpoons Ag_{(s)}$

$I_{2(aq)} + 2\,e^- \rightleftharpoons 2\,I^-_{(aq)}$

$Cu^{2+}_{(aq)} + 2\,e^- \rightleftharpoons Cu_{(s)}$

$Pb^{2+}_{(aq)} + 2\,e^- \rightleftharpoons Pb_{(s)}$

$Zn^{2+}_{(aq)} + 2\,e^- \rightleftharpoons Zn_{(s)}$ SRA

INVESTIGATION 9.3.2 THE REACTION OF SODIUM WITH WATER

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Prediction

(a) According to the method for predicting redox reactions, the products of the reaction are hydrogen gas and aqueous sodium hydroxide as shown below.

	SOA
$Na_{(s)}$	$H_2O_{(l)}$
SRA	RA

$$2\,H_2O_{(l)} + 2\,e^- \rightarrow H_{2(g)} + 2\,OH^-_{(aq)}$$

$$2\,[Na_{(s)} \rightarrow Na^+_{(aq)} + e^-]$$

$$2\,H_2O_{(l)} + 2\,Na_{(s)} \xrightarrow{\text{spont.}} H_{2(g)} + 2\,OH^-_{(aq)} + 2\,Na^+_{(aq)}$$

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**

Electrode	Initial voltages (V)			Final voltages (V)		
	$NaCl_{(aq)}$	$NaOH_{(aq)}$	$HCl_{(aq)}$	$NaCl_{(aq)}$	$NaOH_{(aq)}$	$HCl_{(aq)}$
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 $C_{(s)} \mid NaOH_{(aq)} \mid Al_{(s)}$ 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