(d)

Power Curve
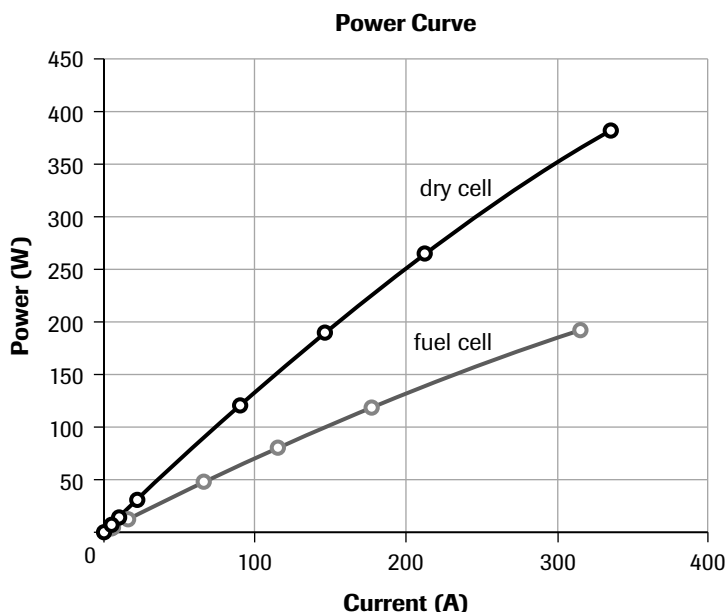

The power curve for the hydrogen fuel cell follows a similar pattern to that of the dry cell. However, the slope of the curve is noticeably less steep for the fuel cell. This means that, as the current increases, the power output of the fuel cell increases less rapidly than that of the dry cell.

(e) Based on the evidence collected, the trends of the voltage–current and power–current graphs are very similar for a hydrogen fuel cell compared to a typical dry cell.

Synthesis

(f) Both cells have two electrodes, an electrolyte, and chemicals that are consumed as the cell operates. In the case of the dry cell, there is a limited amount of reactant present and the cell will eventually stop producing electricity when the reactants are used up. In the fuel cell, the reactants are continuously supplied to the cell and the cell would only stop operating if the fuel is no longer provided.

(g) A fuel cell is like a gasoline motor; both operate using a continuous supply of fuel. As long as you keep fuel "in the tank," you can drive the car. Primary or even secondary cells have a limited quantity of "fuel" sealed inside their containers. The car can only travel a limited distance before the cell has to be recharged. (With present-day cells, this is not a very great distance unless a large battery — with unreasonable size and weight — of cells is present.)

ACTIVITY 9.5.1 GALVANIC CELL DESIGN

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(a) The first design with the single electrolyte is most like Volta's invention. All three designs have the same two metal electrodes and at least one electrolyte. Two of the cells have separate half-cells with the metal immersed in an electrolyte of its own ion and the half-cells separated by some porous boundary. The difference between these two designs is in the nature of the porous boundary. One has a salt bridge containing an inert electrolyte separating the two half-cell electrolytes and the other has a porous (porcelain) cup separating the electrolytes.

(b) In all cells, the silver metal is the cathode (positive electrode) and the copper metal is the anode (negative electrode). (Cell (a) had a voltage of 0.15 V; cell (b) was 0.45 V; and cell (c) was 0.46 V.)

(c) Each metal in contact with an electrolyte has a different electric potential determined by the nature of the metal atoms. As shown by a redox table, silver and copper have different strengths as reducing agents. Therefore, the answer to (a) should be the same if the two metals are the same.

(d) The two cells comprised of half-cells both contain the same oxidized and reduced species: e.g., $Cu_{(s)} \mid Cu^{2+}_{(aq)}$. The single electrolyte cell contains only an inert electrolyte.

(e) Removing one of the parts of the cell interrupts or breaks the electrical circuit. (Removing either electrode from the solution, removing the salt bridge, or removing the porous cup immediately produced a zero volt reading. Replacing the removed part restored the original voltmeter reading.)

(f) A common light switch also breaks or disconnects the electrical circuit.

- No evidence of reaction was visible after several minutes. After several days, long silvery crystals formed on the silver electrode in cells (b) and (c), the copper solution appeared darker, and some blue-coloured solution had moved toward the silver side of the cell. The voltage of the cell slowly decreased until, after several weeks, the voltage of the cell was almost zero volts.

(g) A suitable control would be an identical cell with no electrical connection (wire) between the electrodes.

(h) Silver half-cell: Test the concentration of silver ions several times by removing a known volume of the solution and precipitating the silver ions as silver chloride. Measure the mass of the silver electrode at the beginning and at the end. Copper half-cell: Using colour standards (or a spectrophotometer), determine the concentration of copper ions several times using a sample of the solution. (Alternatively, the concentration of copper ions could be determined by precipitation.) Measure the mass of the copper electrode at the beginning and at the end.
Salt bridge: Note the colour changes in the solution.

(i) Nitrates are spectator ions and should be the same for all cells as a control.

INVESTIGATION 9.5.1 INVESTIGATING GALVANIC CELLS

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Prediction

(a) According to redox concepts and the table of redox half-reactions ...

Cathode (+)				Anode (–)			Cell potential (V)
$Cu_{(s)}$	|	$Cu^{2+}_{(aq)}$	||	$Pb^{2+}_{(aq)}$	|	$Pb_{(s)}$	+0.47
$Ag_{(s)}$	|	$Ag^+_{(aq)}$	||	$Cu^{2+}_{(aq)}$	|	$Cu_{(s)}$	+0.46
$Cu_{(s)}$	|	$Cu^{2+}_{(aq)}$	||	$Zn^{2+}_{(aq)}$	|	$Zn_{(s)}$	+1.10
$Ag_{(s)}$	|	$Ag^+_{(aq)}$	||	$Pb^{2+}_{(aq)}$	|	$Pb_{(s)}$	+0.93
$Pb_{(s)}$	|	$Pb^{2+}_{(aq)}$	||	$Zn^{2+}_{(aq)}$	|	$Zn_{(s)}$	+0.63
$Ag_{(s)}$	|	$Ag^+_{(aq)}$	||	$Zn^{2+}_{(aq)}$	|	$Zn_{(s)}$	+1.56

Experimental Design

(b) Individual metal–metal ion half-cells are constructed. Different combinations are connected with a salt bridge and the electrodes, and the cell potentials are determined. The independent variable is the combination of half-cells and the dependent variable is the cell potential. Controlled variables are temperature and electrolyte concentration.

Procedure

(c) 1. Clean metal strips with steel wool and rinse with distilled water.
2. Assemble two of the four metal–metal ion half-cells, for example, copper and lead.
3. Connect the copper half-cell with the lead half-cell using the salt bridge.
4. Use the voltmeter and connecting wires to determine the cathode and anode of the cell.
5. With the voltmeter connected to the cell, measure the initial voltmeter reading.
6. Remove and rinse the salt bridge.
7. Repeat steps 1 to 5 for the remaining combinations of half-cells.
8. Clean and return the metal strips and recycle the electrolyte solutions.

Evidence/Analysis

(d)

Cathode (+)				Anode (–)			Predicted potential (V)	Measured potential (V)	Percent diff. (%)
$Cu_{(s)}$	|	$Cu^{2+}_{(aq)}$	||	$Pb^{2+}_{(aq)}$	|	$Pb_{(s)}$	+0.47	+0.46	2
$Ag_{(s)}$	|	$Ag^+_{(aq)}$	||	$Cu^{2+}_{(aq)}$	|	$Cu_{(s)}$	+0.46	+0.45	2
$Cu_{(s)}$	|	$Cu^{2+}_{(aq)}$	||	$Zn^{2+}_{(aq)}$	|	$Zn_{(s)}$	+1.10	+1.06	4
$Ag_{(s)}$	|	$Ag^+_{(aq)}$	||	$Pb^{2+}_{(aq)}$	|	$Pb_{(s)}$	+0.93	+0.88	5
$Pb_{(s)}$	|	$Pb^{2+}_{(aq)}$	||	$Zn^{2+}_{(aq)}$	|	$Zn_{(s)}$	+0.63	+0.59	6
$Ag_{(s)}$	|	$Ag^+_{(aq)}$	||	$Zn^{2+}_{(aq)}$	|	$Zn_{(s)}$	+1.56	+1.47	6