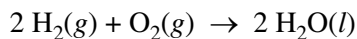


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**Question 3**

Hydrogen gas burns in air according to the equation below.



- (a) Calculate the standard enthalpy change,  $\Delta H_{298}^\circ$ , for the reaction represented by the equation above.  
(The molar enthalpy of formation,  $\Delta H_f^\circ$ , for  $\text{H}_2\text{O}(l)$  is  $-285.8 \text{ kJ mol}^{-1}$  at 298 K.)

$\Delta H_{298}^\circ = [2(-285.8)] - [2(0) + 1(0)] = -571.6 \text{ kJ mol}^{-1}$	1 point is earned for the correct answer.
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- (b) Calculate the amount of heat, in kJ, that is released when 10.0 g of  $\text{H}_2(g)$  is burned in air.

$q = 10 \text{ g H}_2 \times \frac{1 \text{ mol H}_2}{2.016 \text{ g H}_2} \times \frac{285.8 \text{ kJ}}{1 \text{ mol H}_2} = 1.42 \times 10^3 \text{ kJ}$	1 point is earned for the correct setup. 1 point is earned for the correct answer.
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- (c) Given that the molar enthalpy of vaporization,  $\Delta H_{vap}^\circ$ , for  $\text{H}_2\text{O}(l)$  is  $44.0 \text{ kJ mol}^{-1}$  at 298 K, what is the standard enthalpy change,  $\Delta H_{298}^\circ$ , for the reaction  $2 \text{H}_2(g) + \text{O}_2(g) \rightarrow 2 \text{H}_2\text{O}(g)$  ?

$2 \text{H}_2(g) + \text{O}_2(g) \rightarrow 2 \text{H}_2\text{O}(l) \quad -571.6 \text{ kJ}$ $2 \text{H}_2\text{O}(l) \rightarrow 2 \text{H}_2\text{O}(g) \quad +2(44.0) \text{ kJ}$ <hr style="width: 50%; margin-left: 0;"/> $2 \text{H}_2(g) + \text{O}_2(g) \rightarrow 2 \text{H}_2\text{O}(g) \quad -483.6 \text{ kJ}$	1 point is earned for the correct answer.
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A fuel cell is an electrochemical cell that converts the chemical energy stored in a fuel into electrical energy. A cell that uses  $\text{H}_2$  as the fuel can be constructed based on the following half-reactions.

Half-reaction	$E^\circ$ (298 K)
$2 \text{H}_2\text{O}(l) + \text{O}_2(g) + 4 e^- \rightarrow 4 \text{OH}^-(aq)$	0.40 V
$2 \text{H}_2\text{O}(l) + 2 e^- \rightarrow \text{H}_2(g) + 2 \text{OH}^-(aq)$	-0.83 V

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**Question 3 (continued)**

(d) Write the equation for the overall cell reaction.

$2 \text{H}_2\text{O}(l) + \text{O}_2(g) + 4 e^- \rightarrow 4 \text{OH}^-(aq)$ $2 \text{H}_2(g) + 4 \text{OH}^-(aq) \rightarrow 4 \text{H}_2\text{O}(l) + 4 e^-$ <hr style="width: 50%; margin: 10px auto;"/> $2 \text{H}_2(g) + \text{O}_2(g) \rightarrow 2 \text{H}_2\text{O}(l)$	<p style="text-align: center;">1 point is earned for the correct equation.</p>
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(e) Calculate the standard potential for the cell at 298 K.

$E^\circ = 0.40 \text{ V} - (-0.83 \text{ V}) = 1.23 \text{ V}$	<p style="text-align: center;">1 point is earned for the correct answer.</p>
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(f) Assume that 0.93 mol of  $\text{H}_2(g)$  is consumed as the cell operates for 600. seconds.

(i) Calculate the number of moles of electrons that pass through the cell.

$0.93 \text{ mol H}_2 \times \frac{2 \text{ mol } e^-}{1 \text{ mol H}_2} = 1.9 \text{ mol } e^-$	<p style="text-align: center;">1 point is earned for the correct answer.</p>
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(ii) Calculate the average current, in amperes, that passes through the cell.

$1.9 \text{ mol } e^- \times \frac{96,500 \text{ C}}{1 \text{ mol } e^-} = 1.8 \times 10^5 \text{ C}$ $I = \frac{q}{t} = \frac{1.8 \times 10^5 \text{ C}}{600. \text{ s}} = 3.0 \times 10^2 \text{ amps}$	<p style="text-align: center;">1 point is earned for calculation of the charge in coulombs.</p> <p style="text-align: center;">1 point is earned for calculation of the current in amperes.</p>
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(g) Some fuel cells use butane gas,  $\text{C}_4\text{H}_{10}$ , rather than hydrogen gas. The overall reaction that occurs in a butane fuel cell is  $2 \text{C}_4\text{H}_{10}(g) + 13 \text{O}_2(g) \rightarrow 8 \text{CO}_2(g) + 10 \text{H}_2\text{O}(l)$ . What is one environmental advantage of using fuel cells that are based on hydrogen rather than on hydrocarbons such as butane?

<p>Hydrogen fuel cells produce only water as a product, unlike fuel cells that use hydrocarbons, which release carbon dioxide. Carbon dioxide contributes to global warming via the enhanced atmospheric greenhouse effect.</p>	<p style="text-align: center;">1 point is earned for an acceptable environmental advantage.</p>
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