

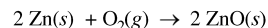
AP® CHEMISTRY
2015 SCORING GUIDELINES

Question 1

Metal-air cells are a relatively new type of portable energy source consisting of a metal anode, an alkaline electrolyte paste that contains water, and a porous cathode membrane that lets in oxygen from the air. A schematic of the cell is shown above. Reduction potentials for the cathode and three possible metal anodes are given in the table below.

Half Reaction	E at pH 11 and 298 K (V)
$\text{O}_2(g) + 2 \text{H}_2\text{O}(l) + 4 e^- \rightarrow 4 \text{OH}^-(aq)$	+0.34
$\text{ZnO}(s) + \text{H}_2\text{O}(l) + 2 e^- \rightarrow \text{Zn}(s) + 2 \text{OH}^-(aq)$	−1.31
$\text{Na}_2\text{O}(s) + \text{H}_2\text{O}(l) + 2 e^- \rightarrow 2 \text{Na}(s) + 2 \text{OH}^-(aq)$	−1.60
$\text{CaO}(s) + \text{H}_2\text{O}(l) + 2 e^- \rightarrow \text{Ca}(s) + 2 \text{OH}^-(aq)$	−2.78

- (a) Early forms of metal-air cells used zinc as the anode. Zinc oxide is produced as the cell operates according to the overall equation below.



- (i) Using the data in the table above, calculate the cell potential for the zinc-air cell.

$E_{\text{cell}} = 0.34 \text{ V} - (-1.31 \text{ V}) = 1.65 \text{ V}$	1 point is earned for the correct cell potential.
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- (ii) The electrolyte paste contains OH^- ions. On the diagram of the cell above, draw an arrow to indicate the direction of migration of OH^- ions through the electrolyte as the cell operates.

(The arrow should point to the left.)	1 point is earned for indicating the movement of OH^- ions from right to left in the cell.
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- (b) A fresh zinc-air cell is weighed on an analytical balance before being placed in a hearing aid for use.

- (i) As the cell operates, does the mass of the cell increase, decrease, or remain the same?

The mass increases.	1 point is earned for indicating an increase in cell mass.
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- (ii) Justify your answer to part (b)(i) in terms of the equation for the overall cell reaction.

Oxygen gas from the air reacts with $\text{Zn}(s)$ in the cell, producing $\text{ZnO}(s)$, which has more mass than the original $\text{Zn}(s)$.	1 point is earned for the justification.
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Question 1 (continued)

- (c) The zinc-air cell is taken to the top of a mountain where the air pressure is lower.

- (i) Will the cell potential be higher, lower, or the same as the cell potential at the lower elevation?

The cell potential will be lower.	1 point is earned for indicating a lower cell potential.
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- (ii) Justify your answer to part (c)(i) based on the equation for the overall cell reaction and the information above.

$\text{O}_2(g)$, a reactant in the cell reaction, will be at a lower partial pressure at the higher elevation; thus the reaction has a greater value of Q (closer to K). Deviations in partial pressure that take the cell closer to equilibrium will decrease the magnitude of the cell potential.	1 point is earned for a justification that relates a lower pressure (or concentration) of $\text{O}_2(g)$ to Q , or a qualitative approach using the Nernst equation.
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- (d) Metal-air cells need to be lightweight for many applications. In order to transfer more electrons with a smaller mass, Na and Ca are investigated as potential anodes. A 1.0 g anode of which of these metals would transfer more electrons, assuming that the anode is totally consumed during the lifetime of a cell? Justify your answer with calculations.

For Na, $1.0 \text{ g Na} \times \frac{1.0 \text{ mol Na}}{22.99 \text{ g Na}} \times \frac{1.0 \text{ mol } e^-}{1.0 \text{ mol Na}} = 0.043 \text{ mol } e^-$	1 point is earned for the correct calculation of moles for Na and Ca.
For Ca, $1.0 \text{ g Ca} \times \frac{1.0 \text{ mol Ca}}{40.08 \text{ g Ca}} \times \frac{2.0 \text{ mol } e^-}{1.0 \text{ mol Ca}} = 0.050 \text{ mol } e^-$	1 point is earned for taking 1 vs. 2 moles of electrons into account and the correct answer.
The cell with the Ca anode would transfer more electrons.	

- (e) The only common oxide of zinc has the formula ZnO .

- (i) Write the electron configuration for a Zn atom in the ground state.

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10}$ or $[\text{Ar}] 4s^2 3d^{10}$	1 point is earned for a correct configuration.
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- (ii) From which sublevel are electrons removed when a Zn atom in the ground state is oxidized?

4s sublevel	1 point is earned for the correct answer.
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