# Generated Exam Questions with Model Answers

## Essay Questions

### Question 1:

\*\*Exam Question:\*\*  
  
Explain the key differences between batteries and fuel cells in terms of how they generate electricity, and discuss the main material and design challenges that must be addressed to build efficient fuel cells according to the principles outlined in the lecture.  
  
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\*\*Model Answer:\*\*  
  
Batteries and fuel cells are both electrochemical devices used to generate electricity, but they differ fundamentally in how they operate. In batteries, the anodic and cathodic materials (the reactants) are contained within a closed system. This means that the chemical reactions and, hence, electricity generation are limited to the materials initially present inside the battery; once these are depleted, the battery stops producing electricity.  
  
In contrast, fuel cells function as open systems. They allow for the continuous supply of reactants—specifically, fuels such as hydrogen and oxygen—from external sources. As long as these fuels are provided, a fuel cell can continue to generate electricity. This fundamental difference allows fuel cells to potentially produce electricity for much longer periods than batteries.  
  
The operation of a fuel cell is based on the reverse of water electrolysis. In a typical setup, hydrogen is oxidized at the anode and oxygen is reduced at the cathode, both reactions forming water. Theoretically, this can generate a cell voltage of slightly over 1.2 volts, as predicted by the Pourbaix diagram and observed under open-circuit, laboratory conditions.  
  
However, several material and design challenges must be overcome to construct efficient and practical fuel cells. The main issues are:  
  
1. \*\*Reaction Kinetics and Triple-Phase Boundaries:\*\* The rates of the critical reactions—hydrogen oxidation and oxygen reduction—are limited by how fast oxygen can diffuse from the gas phase into the electrolyte and reach the electrode surface. The effective electrochemical reactions occur primarily at "triple-phase boundaries," where gas, electrolyte, and electrode are in contact. To enhance efficiency, materials must be engineered to maximize the area of these triple-phase boundaries, often by using porous structures that allow both gas and electrolyte to reach the electrode surface.  
  
2. \*\*Catalytic Activity:\*\* The electrode materials must act as effective catalysts for the hydrogen oxidation and oxygen reduction reactions. High catalytic activity ensures these reactions proceed rapidly and with minimal overpotential, which is important for maintaining cell efficiency. Platinum is often used in laboratory setups for this reason.  
  
3. \*\*Minimizing Overpotential:\*\* Excessive overpotential—extra voltage required to drive the reactions beyond the theoretical minimum—leads to energy losses. Thus, selecting materials and designs that minimize overpotential is critical.  
  
4. \*\*Electrolyte Resistance:\*\* The electrolyte must have low ohmic (electrical) resistance to avoid additional potential drops within the cell, which would further reduce net energy output.  
  
In summary, while fuel cells theoretically offer continuous electricity generation as long as fuel is supplied, practical implementation requires careful attention to maximizing reaction rates at triple-phase boundaries, selecting and engineering effective catalytic materials, minimizing overpotential, and reducing electrolyte resistance to optimize performance.

## Multiple Choice Questions

### Question 1:

\*\*1. Which of the following statements correctly distinguishes a fuel cell from a battery?\*\*   
A) Both are closed systems with reactants stored internally.   
B) Fuel cells are closed systems, while batteries are open systems.   
C) Fuel cells are open systems with continuous reactant supply, while batteries use only initially stored reactants. (Correct)   
D) Both fuel cells and batteries require an external voltage to generate electricity.  
  
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\*\*2. What is the primary reason the laboratory setup for water electrolysis is not practical for fuel cell applications?\*\*   
A) The theoretical voltage is too high to be useful.   
B) The hydrogen oxidation and oxygen reduction reactions proceed too quickly.   
C) The diffusion of oxygen to the electrode is too slow, resulting in very low current. (Correct)   
D) The electrolyte cannot conduct ions at all.  
  
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\*\*3. In a fuel cell, what is the significance of the triple-phase boundary?\*\*   
A) It is where the electrolyte and gas react without the electrode.   
B) It is the area where only the electrode and electrolyte meet.   
C) It is the region where gas, electrolyte, and metal electrode are all in contact, allowing efficient electrochemical reactions. (Correct)   
D) It is the point where the maximum overpotential is achieved.  
  
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\*\*4. Which of the following material properties is NOT essential for optimizing fuel cell performance?\*\*   
A) High porosity to support three-phase boundaries   
B) High catalytic activity for hydrogen oxidation and oxygen reduction   
C) High ohmic resistance in the electrolyte (Correct)   
D) Minimal overpotential for the electrochemical reactions