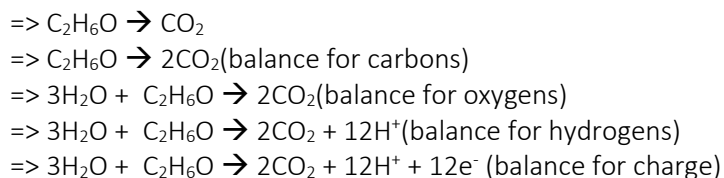


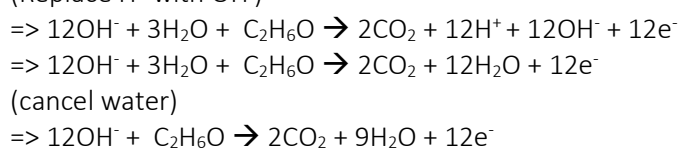
Writing half reactions for fuel cells. Writing half reactions for an alkaline or acidic fuel cell is identical to writing half equations for an alkaline or acidic galvanic cell. Keep in mind that the fuel always goes at the anode (-) of a fuel cell.

Write the half equations for an alkaline fuel cell that burns ethanol in oxygen gas to generate electrical energy.

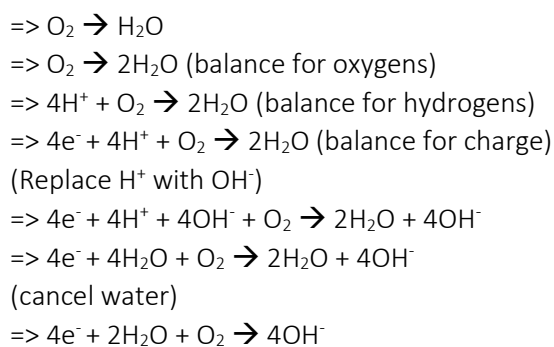
Anode



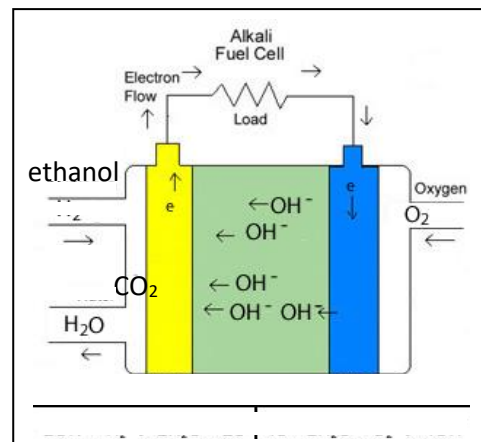
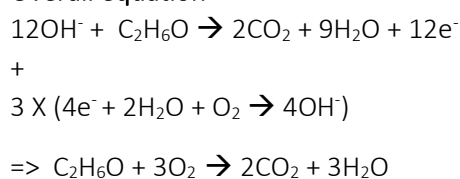
(Replace H^+ with OH^-)



Cathode

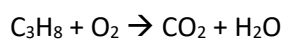
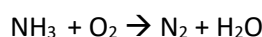
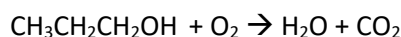


Overall equation



Try these

Give the anode and cathode half reactions when the following fuels undergo complete combustion with atmospheric oxygen in an alkaline fuel cell. The unbalanced chemical equation is given below.

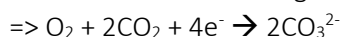


Write the half equations for a molten carbonate fuel cell that burns ethanol in oxygen gas to generate electrical energy.

Now the electrolyte is slightly different. Here liquid CO_3^{2-} ions migrate from the cathode to the anode. The O^{2-} ion is carried to the anode via CO_3^{2-} ions.

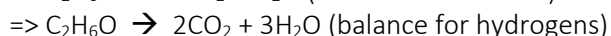
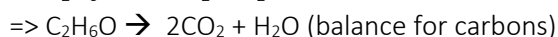
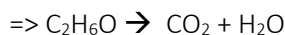
Cathode

Carbonate ions are formed at the cathode via the following reduction reaction. This reaction is the same for all molten carbonate fuel cells using atmospheric oxygen.

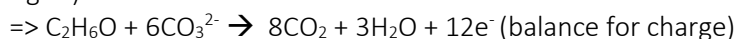
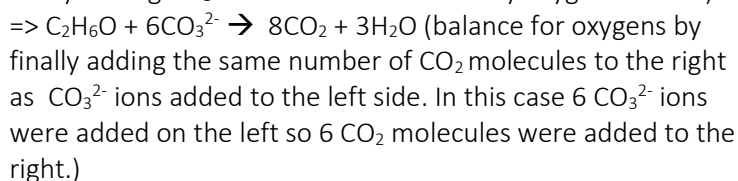
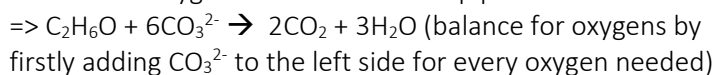


Anode

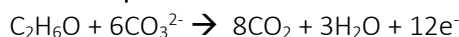
At the anode the fuel reacts with the carbonate ions to form water and carbon dioxide as shown in the schematic. Always refer to the diagram for information on the products formed.



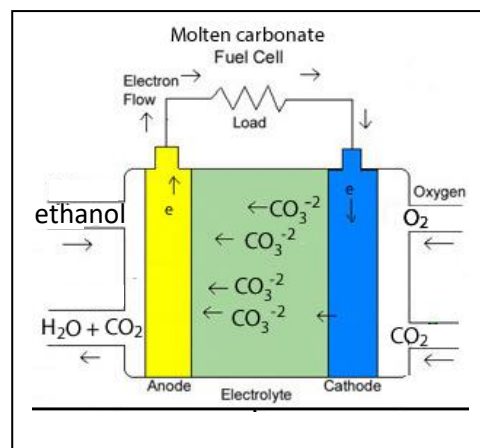
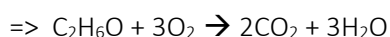
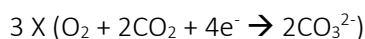
Balance for oxygen atoms in a two-step process.



Overall equation

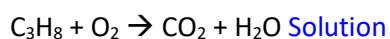
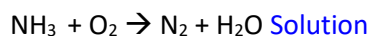
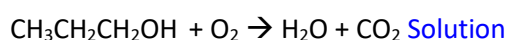


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Try these

Give the anode and cathode half reactions when the following fuels undergo complete combustion with atmospheric oxygen in a molten carbonate fuel cell. The unbalanced chemical equation is given below.



Write the half equations for a solid oxide fuel cell that burns ethanol in oxygen gas to generate electrical energy.

Once again, the electrolyte is different. Here a solid ceramic electrolyte allows for the movement of O^{2-} from the cathode to the anode.

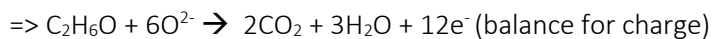
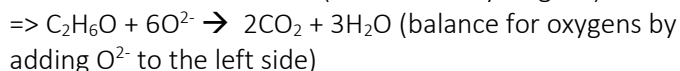
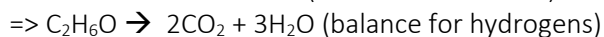
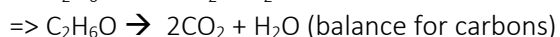
Cathode

Oxide ions (O^{2-}) are formed at the cathode. This reaction is the same for all solid oxide fuel cells using atmospheric oxygen.

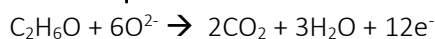


Anode

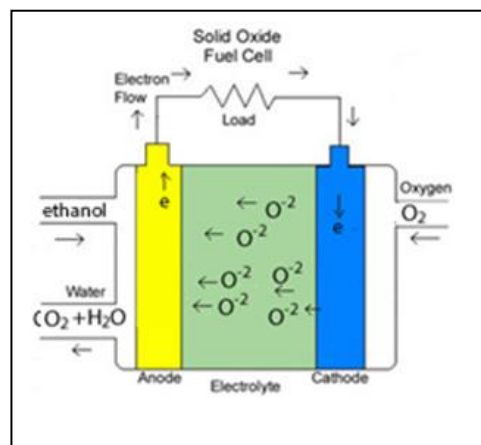
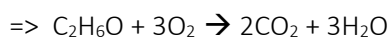
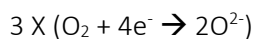
At the anode the fuel reacts with the oxide ions to form water and carbon dioxide as shown in the schematic. Always refer to the diagram for information on the products formed.



Overall equation

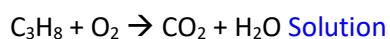
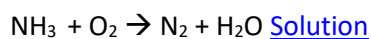
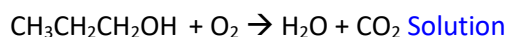


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Try these

Give the anode and cathode half reactions when the following fuels undergo complete combustion with atmospheric oxygen in a solid oxide fuel cell. The unbalanced chemical equation is given below.

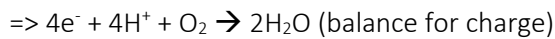
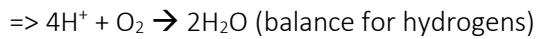
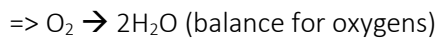
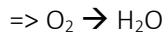


Write the half equations for an acidic electrolyte fuel cell or proton exchange membrane cell that burns ethanol in oxygen gas to generate electrical energy.

Once again, the electrolyte is different. Here an acidic electrolyte or proton exchange membrane allows for the movement of H^+ ions from the cathode to the anode.

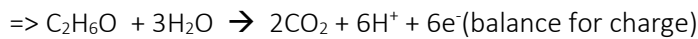
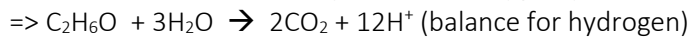
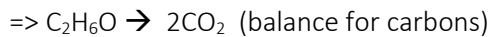
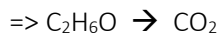
Cathode

From the schematic on the right we can write the following reaction.

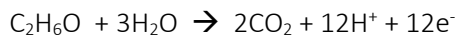


Anode

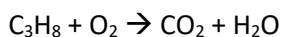
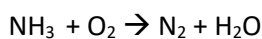
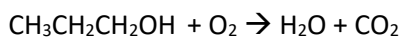
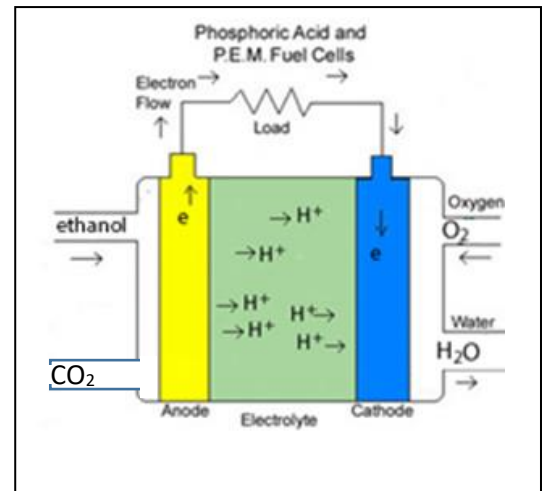
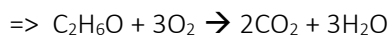
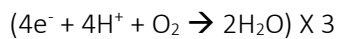
At the anode the fuel reacts with the oxide ions to form water and carbon dioxide as shown in the schematic. Always refer to the diagram for information on the products formed.



Overall equation

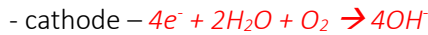
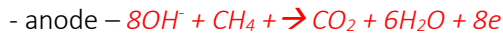


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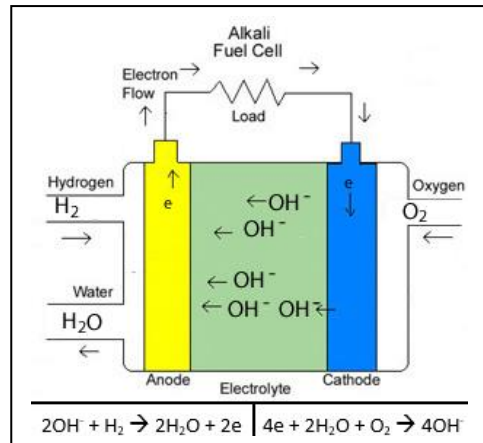
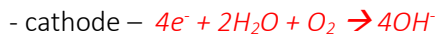
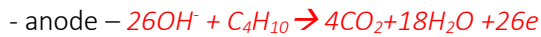


Alkaline fuel cells operate on compressed hydrogen and oxygen gases. The most common electrolyte is a solution of KOH. Efficiency is about 70 percent, and operating temperatures are about 150 to 200 °C For each fuel cell below write the half reactions occurring at the anode and cathode when the fuel used is:

- CH₄

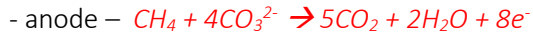


- C₄H₁₀

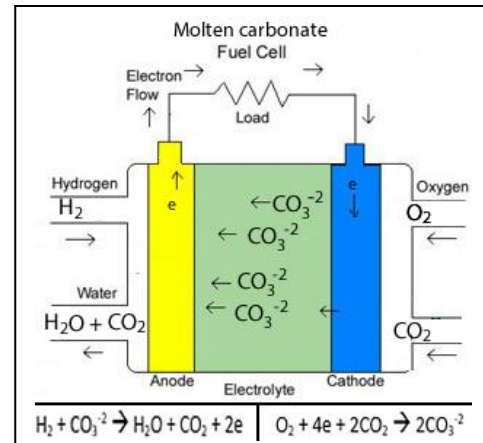
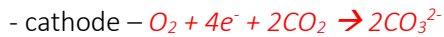
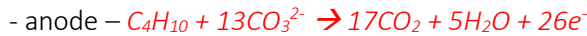


Molten Carbonate fuel cells (MCFC) use high-temperature compounds of salt (like sodium or magnesium) carbonates as the electrolyte. Efficiency ranges from 60 to 80 percent, and operating temperature is about 650 degrees °C

- CH₄

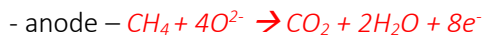


- C₄H₁₀

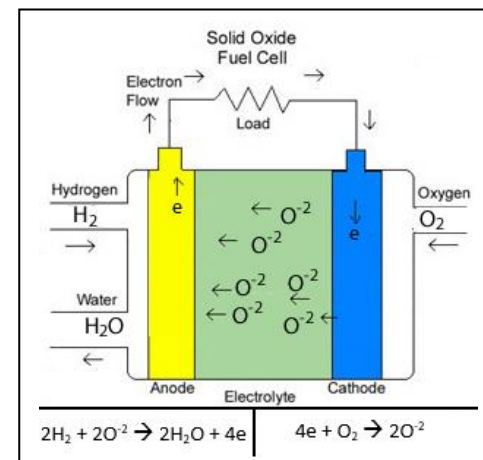
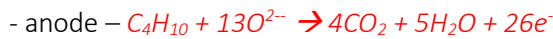


Solid Oxide fuel cells (SOFC) use a hard, ceramic compound of metal (like calcium or zirconium) oxides as an electrolyte. Efficiency is about 60 percent, and operating temperatures are about 1,000 °C

- CH₄



- C₄H₁₀

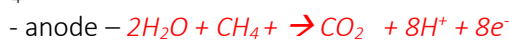


Phosphoric Acid fuel cells (PAFC) use phosphoric acid as the electrolyte. Efficiency ranges from 40 to 80% , and operating temperature is between 150 to 200 °C.

Proton Exchange Membrane (PEM) fuel cells work similar to the a PAFC but with a polymer electrolyte in the form of a thin, permeable sheet. This permeable membrane allows for H⁺ ions only to move from the anode to the cathode.

Efficiency is about 40 to 50%, and operating temperature is about 80 °C .

- CH₄



- C₄H₁₀

