Innovation

Reversible Solid Oxide Fuel Cells (RSOCs):

RSOCs can operate both as fuel cells, generating electricity from fuels like hyd1ogen and as electrolysis cells, producing hydrogen from electricity or syngas from CO_2 and H_2O. This dual functionality offers a versatile solution for energy storage and conversion. Here are a few points of why RSOC are important:

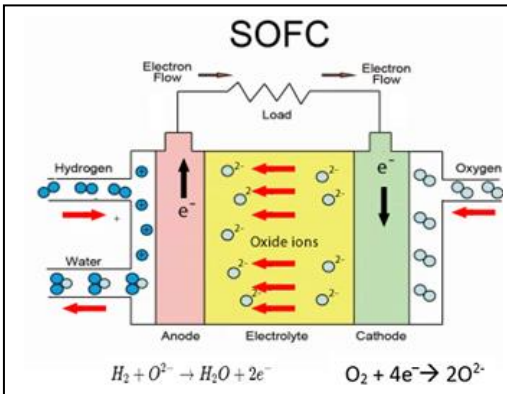

Diagram 1

- Efficient Energy Storage - They can store excess renewable energy by producing hydrogen when electricity demand is low.
- Dual Functionality - A single system can generate electricity from fuels or create fuels from electricity.
- High Efficiency - RSOCs operate at 600–900°C, leading to better efficiency compared to low-temperature electrolysis.
- Carbon Capture Potential: Can convert CO_2 and H_2O into syngas ($CO_2 + H_2O \rightarrow H_2 + CO + O_2$), enabling synthetic fuel production.

RSOCs work by operating in two modes:

1. Fuel Cell Mode (SOFC - Solid Oxide Fuel Cell):
    - Converts chemical energy in the form of hydrogen, syngas, or other fuels, into electricity.
    - Oxygen from the air is reduced at the cathode, forming oxide ions. According to the reduction half equation $O_2 + 4e \rightarrow 2O^{2-}$
    - These oxide ions migrate through the solid oxide electrolyte to the anode, where they react with hydrogen or another fuel, releasing electrons and producing water, carbon dioxide, if using hydrocarbons and heat.
    - Electrons flow through an external circuit, generating electric power.
2. Electrolysis Mode (SOEC - Solid Oxide Electrolysis Cell):
    - Uses electricity, from renewable sources like wind or solar, to split water or CO_2 into hydrogen and oxygen
    - Oxygen ions migrate to the anode, through the electrolyte, in reverse direction when compared to the fuel cell mode.
    - At the cathode, water is reduced to form hydrogen and oxide ions. Whilst oxide ions are oxidised to oxygen gas at the anode.

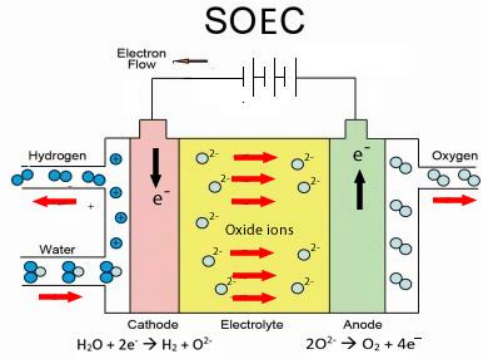

Diagram 2

1. The use of RSOCs align well with a number of United Nations Sustainable Development Goals. Identify three and justify each of your selections.

i. _____

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ii. _____

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iii. _____

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2. A RSOC is operated as an **<u>electrolytic cell</u>**, using an external, renewable power source. Carbon dioxide and water are feedstocks to the formation of syngas (CO and H_2).

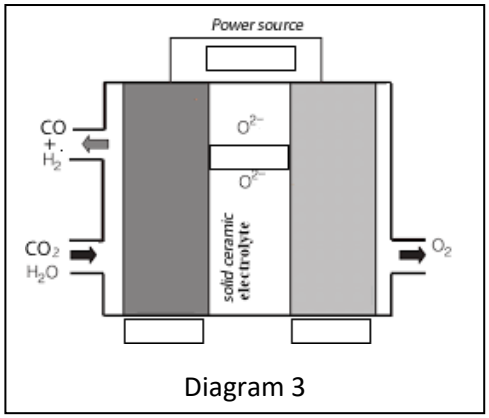

Diagram 3

a. Consider diagram 3. Label the:
   i. Anode and cathode
   ii. Give the polarity of each electrode.
   Anode _____
   Cathode _____
   iii. Direction of electron flow
   iv. Direction of ion flow.

b. Complete the following half equation taking place at one of the electrodes.

_____+ CO_2 + H_2O → H_2 + CO + ____

c. Is the reaction given by the half equation in question b. above taking place at the anode or the cathode? Circle the correct response and justify your answer.

Anode Cathode

_____

_____

_____

d. Give the balanced half equation taking place at the other electrode.

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e. The external power source delivers a current of 13.0 amps for 13.00 hours as the sun is shining. This energy is surplus to requirements. It is decided that syngas will be formed from the energy source and stored for later use.
Given that the cell is 70.0% efficient, calculate the mass, in kg, of hydrogen gas that is formed. Give your answer to the right number of significant figures.

f. RSOC cells provide an innovative solution to the mitigation of climate change. When operating as a SOFC the cell burns all forms of fuel including fossil fuels thus contributing to the net increase of atmospheric carbon dioxide.

i. Give the overall equation for the combustion of ethane in an RSOC acting as a fuel cell, states not included.

_____

ii. RSOC cells, when operating as electrolytic cells, are said to help reduce the human impact on climate change.
Explain how RSOCs achieve this. In your answer, describe what happens to ethane (C_2H_6) when the RSOC is operating as a fuel cell and suggest what could be done with any byproducts to make the system more sustainable.

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3. Consider diagrams 1 and 2.

    a. How does the polarity of each electrode change as the RSOC changes modes from fuel cell to electrolytic cell?

    _____

    _____

    b. Consider an RSOC burning butane to generate electrical energy.

        i. Give the anode half equation, states not required, of an RSOC burning liquid butane whilst in fuel cell mode.

        _____

        ii. Give the anode half equation for the same cell in electrolytic mode.

        _____

4. RSOC operate at high temperatures and unlike other fuel cells can undergo steam reformation inside the cell rather than in a separate steam reformer as do other cells such as PEMFC which can not directly burn hydrocarbons.