

Solutions

Original marking guidance: M1 method, A1 accuracy, B1 explanation.

2.1 $2\text{H}_2 \rightarrow 4\text{H}^+ + 4\text{e}^-$. Atoms and charge/electrons.

2.2 $\text{O}_2 + 4\text{H}^+ + 4\text{e}^- \rightarrow 2\text{H}_2\text{O}$. Atoms and charge/electrons.

2.3 Fuel and oxidant continue to enter from outside while the cell operates.

3.1 $\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \rightarrow 4\text{OH}^-$. Cancel 4e^- and 4OH^- and two waters; overall $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$.

3.2 $2\text{CH}_3\text{OH} + 3\text{O}_2 \rightarrow 2\text{CO}_2 + 4\text{H}_2\text{O}$. Liquid methanol is easier to store/transport; operation emits CO_2 .

3.3 The cell itself produces water, but making hydrogen consumes energy with possible upstream CO_2 emissions. Storage/transport also require energy, so compare complete production pathways.