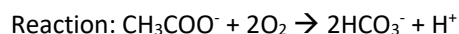


Q2-1: Calculate the Gibb's free energy change for the following reaction. Give the answer in kJ/mol electrons.



Q2-2: Assume the reaction in Q2-1 could take place in a fuel cell. Write out the anode and cathode half-reactions.

Q2-3: Consider the fuel cell described in Q2-2. What would the emf in the system be under the following conditions: $[\text{CH}_3\text{COO}^-] = 5 \text{ mM}$, $[\text{O}_2] = 0.21 \text{ atm}$, $\text{pH} = 7.5$, $[\text{HCO}_3^-] = 3 \text{ mM}$, temperature = 10°C ?

Q2-4: Consider the fuel cell described in Q2-2. What would the emf be if the anode pH was 7.5 and the cathode pH was 11.5? Otherwise the conditions are the same as in Q2-3.

Q2-5: Consider a hydrogen fuel cell with the overall reaction: $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$. What would the anode and cathode potentials be at $\text{pH} = 7$ (otherwise standard conditions)?

Q2-6: Consider the hydrogen fuel cell in Q2-5. What would the anode and cathode potentials be, if measured against a Ag/AgCl reference electrode (the reference electrode has a 2M KCl electrolyte)?

Q2-7: Consider the hydrogen fuel cell in Q2-5. If the current is 10 mA and the internal resistance 25 Ω , what is the output voltage?

Q2-8: Calculate the emf if the following reaction took place in an electrochemical reactor. Assume $\text{pH} = 7$ (otherwise standard conditions). $\text{CH}_3\text{COO}^- + 4\text{H}_2\text{O} \rightarrow 2\text{HCO}_3^- + \text{H}^+ + 4\text{H}_2$

Q2-9: Consider the electrochemical reactor in Q2-8. What would the anode and cathode potentials be, if measured against a Ag/AgCl reference electrode (the reference electrode has a 3M NaCl electrolyte)?

Q2-10: Consider the electrochemical reactor in Q2-8. What type of electrochemical system is this (galvanic or electrolytic)? Why?

Gibb's free energy of formation (standard conditions, T=25°C)

	(kJ/mol)		Reference
H+	0	Hydrogen ion	Rittmann, Appendix A
H ₂ O(l)	-237.178	Water	Rittmann, Appendix A
O ₂	0	Oxygen	Rittmann, Appendix A
H ₂ O ₂ (aq)	-134.03	Hydrogen peroxide	Oxtoby, Freeman, Block
NO ₃ ⁻	-111.34	Nitrate	Rittmann, Appendix A
NO ₂ ⁻	-37.2	Nitrite	Rittmann, Appendix A
NO(g)	86.55		Oxtoby, Freeman, Block
N ₂ O (g)	104.18		Oxtoby, Freeman, Block
N ₂	0	Nitrogen gas	Oxtoby, Freeman, Block
NH ₄ ⁺	-79.37	Ammonium	Rittmann, Appendix A
N ₂ H ₄ (aq)	128.1		Oxtoby, Freeman, Block
NH ₃ (aq)	-26.5		Oxtoby, Freeman, Block
Fe ₃ O ₄	-1015.5		Oxtoby, Freeman, Block
Fe(OH) ₃ (s)	-486.6		Oxtoby, Freeman, Block
Fe ³⁺	-4.6	Ferric iron	Rittmann, Appendix A
Fe ²⁺	-78.87	Ferrous iron	Rittmann, Appendix A
Fe(s)	0	Iron	Oxtoby, Freeman, Block
Mn ²⁺	-228.1		Oxtoby, Freeman, Block
MnO ₄ ⁻	-447.2		Oxtoby, Freeman, Block
MnO ₂ (s)	-465.17		Oxtoby, Freeman, Block
SO ₄ ²⁻	-744.63	Sulfate	Rittmann, Appendix A
H ₂ S(aq)	-27.87	Hydrogen sulfide	Rittmann, Appendix A
HS ⁻	12.05	Bisulfide	Rittmann, Appendix A
CO ₂ (aq)	-386.02		Rittmann, Appendix A
HCO ₃ ⁻	-586.85	Bicarbonate	Rittmann, Appendix A
CH ₄ (aq)	-34.74	Methane	Rittmann, Appendix A
CH ₃ COO ⁻	-369.41	Acetate	Rittmann, Appendix A
HCOO ⁻	-351.04	Formate	Rittmann, Appendix A
C ₂ H ₅ COO ⁻	-361.08	Propionate	Rittmann, Appendix A
C ₄ H ₇ O ₂ ⁻	-352.63	Butyrate	Rittmann, Appendix A
C ₂ H ₅ OH	-181.75	Ethanol	Rittmann, Appendix A
C ₆ H ₁₂ O ₆	-917.22	Glucose	Rittmann, Appendix A
C ₄ H ₂ O ₄ ²⁻	-604.21	Fumarate	Rittmann, Appendix A
C ₄ H ₄ O ₄ ²⁻	-690.23	Succinate	Rittmann, Appendix A
CH ₃ COCOO ⁻	-474.63	Pyruvate	Rittmann, Appendix A
Cl ⁻ (aq)	-131.23	Chloride	Oxtoby, Freeman, Block
Cl ₂ (g)	0	Chlorine gas	Oxtoby, Freeman, Block
Cl(g)	105.71		Oxtoby, Freeman, Block
OCl ⁻ (aq)	-36.8	Hypochlorite	Oxtoby, Freeman, Block
Ag(s)	0	Silver	Oxtoby, Freeman, Block
AgCl(s)	-109.81		Oxtoby, Freeman, Block
Ag ⁺	77.1		Oxtoby, Freeman, Block
Cu(s)	0.00	Copper	Oxtoby, Freeman, Block
Cu ²⁺	65.49		Oxtoby, Freeman, Block
Cu ⁺	49.98		Oxtoby, Freeman, Block

References: Rittman & McCarty, Environmental Biotechnology: Principles and applications, McGraw-Hill, 2001. Oxtoby, Freeman & Block, Chemistry -Science of Change 3rd Ed. Saunders College Publishing, 1998.