Q2-1: Calculate the Gibb's free energy change for the following reaction. Give the answer in kJ/mol electrons.
Reaction: $CH_3COO^- + 2O_2 \rightarrow 2HCO_3^- + H^+$

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: $[CH_3COO^-]$ = 5 mM, $[O_2]$ = 0.21 atm, pH = 7.5, $[HCO_3^-]$ =3 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: $2H_2 + O_2 \rightarrow 2H_2O$. What would the anode and cathode potentials be at 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 pH = 7 (otherwise standard conditions). $CH_3COO^- + 4H_2O \rightarrow 2HCO_3^- + H^+ + 4H_2$

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
H2O(l)	-237.178	Water	Rittmann, Appendix A
O2	0	Oxygen	Rittmann, Appendix A
H2O2(aq)	-134.03	Hydrogen peroxide	Oxtoby, Freeman, Block
NO3-	-111.34	Nitrate	Rittmann, Appendix A
NO2-	-37.2	Nitrite	Rittmann, Appendix A
NO(g)	86.55		Oxtoby, Freeman, Block
N2O (g)	104.18		Oxtoby, Freeman, Block
N2	0	Nitrogen gas	Oxtoby, Freeman, Block
NH4+	-79.37	Ammonium	Rittmann, Appendix A
N2H4(aq)	128.1		Oxtoby, Freeman, Block
NH3(aq)	-26.5		Oxtoby, Freeman, Block
Fe3O4	-1015.5		Oxtoby, Freeman, Block
Fe(OH)3(s)	-486.6		Oxtoby, Freeman, Block
Fe3+	-4.6	Ferric iron	Rittmann, Appendix A
Fe2+	-78.87	Ferrrous iron	Rittmann, Appendix A
Fe(s)	0	Iron	Oxtoby, Freeman, Block
Mn2+	-228.1		Oxtoby, Freeman, Block
MnO4-	-447.2		Oxtoby, Freeman, Block
MnO2(s)	-465.17		Oxtoby, Freeman, Block
SO4 2-	-744.63	Sulfate	Rittmann, Appendix A
H2S(aq)	-27.87	Hydrogen sulfide	Rittmann, Appendix A
HS-	12.05	Bisulfide	Rittmann, Appendix A
CO2(aq)	-386.02		Rittmann, Appendix A
HCO3-	-586.85	Bicarbonate	Rittmann, Appendix A
CH4(aq)	-34.74	Methane	Rittmann, Appendix A
CH3COO-	-369.41	Acetate	Rittmann, Appendix A
HCOO-	-351.04	Formate	Rittmann, Appendix A
C2H5COO-	-361.08	Propionate	Rittmann, Appendix A
C4H7O2-	-352.63	Butyrate	Rittmann, Appendix A
C2H5OH	-181.75	Ethanol	Rittmann, Appendix A
C6H12O6	-917.22	Glucose	Rittmann, Appendix A
C4H2O4 2-	-604.21	Fumarate	Rittmann, Appendix A
C4H4O4 2-	-690.23	Succinate	Rittmann, Appendix A
CH3COCOO-	-474.63	Pyruvate	Rittmann, Appendix A
Cl-(aq)	-131.23	Chloride	Oxtoby, Freeman, Block
Cl2(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.