Q1

$$\frac{1}{28}HCO_3{}^-(aq) + \frac{3}{14}CO_2(g) + \frac{1}{28}Cl^-(aq) + \frac{29}{28}H^+(aq) + e^- \rightarrow \frac{1}{28}C_6H_4ClCOO^-(aq) + \frac{13}{28}H_2O(l)$$

$$\Delta G_r{}^{0\prime} = -\left\{\frac{1}{28}\times(-586.85) + \frac{3}{14}\times(-394.36) + \frac{1}{28}\times(-31.35) + \frac{29}{28}\times(-39.87)\right\} + \left\{\frac{1}{28}\times(-237.9) + \frac{13}{28}\times(-237.18)\right\}$$

$$= \mathbf{29.26\ kJ/e^-\ eq}$$

Q2

R_d: O-5; $\Delta G_r^{0'} = 31.18\ kJ/e^-\ eq$

R_a: I-14; $\Delta G_r^{0'} = -78.72\ kJ/e^-\ eq$

$R_e = R_a - R_d$

$$\Delta G_r^{0'}(R_e) = \Delta G_r^{0'}(R_a) - \Delta G_r^{0'}(R_d)$$

$$= -78.72 - 31.18$$

$$= \mathbf{-109.90\ kJ/e^-\ eq}$$

R_a: $\frac{1}{4}O_2 + H^+ + e^- = \frac{1}{2}H_2O$

$-R_d$: $\frac{1}{12}C_2H_5OH + \frac{1}{4}H_2O = \frac{1}{6}CO_2 + H^+ + e^-$

R_e: $\frac{1}{12}C_2H_5OH + \frac{1}{4}O_2 = \frac{1}{6}CO_2 + \frac{1}{4}H_2O$

Q3

$$\Delta G_r{}^{0'} = -109.90\ kJ/e^-\ eq$$

R_e: $\frac{1}{12}C_2H_5OH + \frac{1}{4}O_2 = \frac{1}{6}CO_2 + \frac{1}{4}H_2O$ (Q2)

$$\Delta G_r{}^{0} = \Delta G_r{}^{0'} - \mathrm{RT}v_{H^+}ln[10^{-7}] = G_r{}^{0'} - 0 = G_r{}^{0'}$$

$$\Delta G_r = \Delta G_r{}^{0} + RT\sum_{i=1}^{n} v_{ir}lna_i$$

$$= -109.90\ kJ/e^-\ eq + (8.314 \times 10^{-3}\ kJ/mole - K) \times (293\ K)$$

$$\times \left\{-\frac{1}{12}ln(2 \times 10^{-3}) - \frac{1}{4}ln(0.21) + \frac{1}{6}ln(3 \times 10^{-4}) + \frac{1}{4}ln(1)\right\}$$

$$= \boldsymbol{-110.98\ kJ/e^-\ eq}$$

$a_{H_2O} = 1$ for aqueous solutions; you may omit the water term

Q4

From O-1, $\Delta {G_c}^{0'} = 27.40\ kJ/e^-\ eq$

$\Delta G_p = 35.09 - 27.40 = 7.69\ kJ/e^-\ eq$

$\Delta G_r = \Delta G_a - \Delta G_d = -78.72 - 27.40 = -106.12\ kJ/e^-\ eq$

$\because \Delta G_d = 27.40\ kJ/e^-\ eq, \Delta G_a = -78.72\ kJ/e^-\ eq$ (from I-14)

$\Delta G_p > 0 \rightarrow n = +1$

$$A = -\frac{\frac{\Delta G_p}{\varepsilon^n} + \frac{\Delta G_{pc}}{\varepsilon}}{\varepsilon \Delta G_r} = -\frac{\frac{7.69}{\varepsilon^{+1}} + \frac{18.8}{\varepsilon}}{-106.12}$$

$\epsilon = 0.4 :\ A = 1.56$

$\epsilon = 0.6 :\ A = 0.69$

$$\xrightarrow{{f_s}^0 = \frac{1}{1+A}}$$

$\epsilon = 0.4 :\ {f_s}^0 = 0.39$

$\epsilon = 0.6 :\ {f_s}^0 = 0.59$