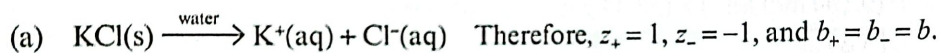
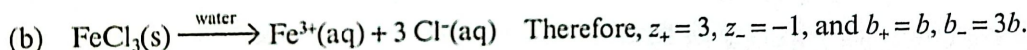


**Exc.1** For a solution that contains a single cation and anion:

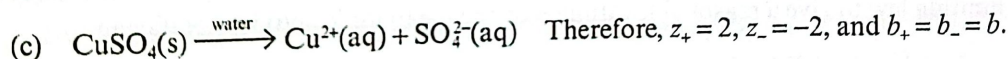
$$I = \frac{1}{2} \sum_i z_i^2 b_i / b^\circ \quad [5.5b] = \frac{1}{2} \{z_+^2 b_+ + z_-^2 b_-\} / b^\circ, \text{ where } b^\circ = 1 \text{ mol kg}^{-1}$$



$$I = \frac{1}{2} \{1^2 b + 1^2 b\} / b^\circ = \boxed{b/b^\circ}$$



$$I = \frac{1}{2} \{3^2 b + 1^2(3b)\} / b^\circ = \boxed{6b/b^\circ}$$

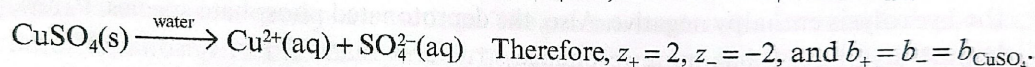
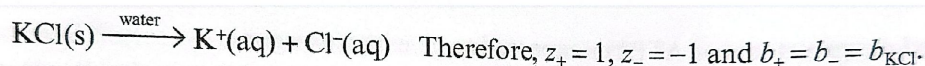


$$I = \frac{1}{2} \{2^2 b + 2^2 b\} / b^\circ = \boxed{4b/b^\circ}$$

**Exc.2**

$$I = I_{\text{KCl}} + I_{\text{CuSO}_4} = \frac{1}{2} (z_+^2 b_+ + z_-^2 b_-)_{\text{KCl}} + \frac{1}{2} (z_+^2 b_+ + z_-^2 b_-)_{\text{CuSO}_4} \quad [5.5b]$$

Let the preparation molalities, the formal concentrations, be  $b_{\text{KCl}}$  and  $b_{\text{CuSO}_4}$ . Determination of solution ionic strength requires the deduction of  $z_+^2$ ,  $b_+$ ,  $z_-^2$ , and  $b_-$  for each ionic compound. These values are substituted into the above equation.



$$\begin{aligned} I &= \frac{1}{2} \{1^2 b_{\text{KCl}} + 1^2 b_{\text{KCl}}\} / b^\circ + \frac{1}{2} \{2^2 b_{\text{CuSO}_4} + 2^2 b_{\text{CuSO}_4}\} / b^\circ = (b_{\text{KCl}} + 4b_{\text{CuSO}_4}) / b^\circ \\ &= 0.10 + 4 \times (0.20) \\ &= \boxed{0.90} \end{aligned}$$

**COMMENT:** Note that the ionic strength of a solution of more than one electrolyte may be calculated by summing the ionic strengths of each electrolyte considered as a separate solution, as in the solution to this exercise, or by summing the product  $\frac{1}{2} b_i z_i^2$  for each individual ion, as in the definition of  $I$  [5.5b].

**Exc.3**

The concentrations  $b_{\text{CaCl}_2}/b^\circ = 0.010$  and  $b_{\text{NaF}}/b^\circ = 0.030$  are sufficiently dilute for the Debye-Hückel limiting law to give a reasonable estimate of the mean ionic activity coefficients.

$$\begin{aligned} I &= \frac{1}{2} \sum_i z_i^2 b_i \quad [5.5b] = I_{\text{CaCl}_2} + I_{\text{NaF}} \\ &= \frac{1}{2} \{ (4 \times 0.010) + (1 \times 0.020) \} + \frac{1}{2} \{ (1 \times 0.030) + (1 \times 0.030) \} \\ &= \boxed{0.060} \end{aligned}$$

For  $\text{CaCl}_2(\text{aq})$ :

$$\log(\gamma_{\pm})_{\text{CaCl}_2} = -A |z_+ z_-| I^{1/2} \quad [5.4] = -0.509 \times |2 \times (-1)| \times (0.060)^{1/2} = -0.2494$$

$$(\gamma_{\pm})_{\text{CaCl}_2} = 10^{-0.2494} = \boxed{0.563}$$

$$a_{\text{Ca}^{2+}} = (\gamma_{\pm})_{\text{CaCl}_2} b_{\text{Ca}^{2+}} = (0.563) \times (0.010) = \boxed{0.0056}$$

$$a_{\text{Cl}^-} = (\gamma_{\pm})_{\text{CaCl}_2} b_{\text{Cl}^-} = (0.563) \times (0.020) = \boxed{0.011}$$

For  $\text{NaF}(\text{aq})$ :

$$\log(\gamma_{\pm})_{\text{NaF}} = -A |z_+ z_-| I^{1/2} \quad [5.4] = -0.509 \times |1 \times (-1)| \times (0.060)^{1/2} = -0.125$$

$$(\gamma_{\pm})_{\text{NaF}} = 10^{-0.125} = \boxed{0.750}$$

$$a_{\text{Na}^+} = (\gamma_{\pm})_{\text{NaF}} b_{\text{Na}^+} = (0.750) \times (0.030) = \boxed{0.0225}$$

$$a_{\text{F}^-} = (\gamma_{\pm})_{\text{NaF}} b_{\text{F}^-} = (0.750) \times (0.030) = \boxed{0.0225}$$

#### Exc. 4

$$E_{K^+}^{(in)} = 27mV \ln \frac{[K^+]_{out}}{[K^+]_{in}} \approx 27mV \ln \frac{20mM}{400mM} = -80mV$$

$$E_{Na^+}^{(in)} = 27mV \ln \frac{[Na^+]_{out}}{[Na^+]_{in}} \approx 27mV \ln \frac{440mM}{50mM} = +59mV$$

Example  $Cl^-$ :

$$E_{Cl^-}^{(in)} = \frac{27mV}{-1} \ln \frac{[Cl^-]_{out}}{[Cl^-]_{in}} \approx -27mV \ln \frac{450mM}{40mM} = -65mV$$

Example  $Ca^{2+}$ :

$$E_{Ca^{2+}}^{(in)} = \frac{27mV}{+2} \ln \frac{[Ca^{2+}]_{out}}{[Ca^{2+}]_{in}} \approx 13.5mV \ln \frac{2mM}{0.0002mM} = 124mV$$

#### Exc. 5

$$E_{rest} = 27mV \ln \frac{[K^+]_{out} + b[Na^+]_{out} + c[Cl^-]_{in}}{[K^+]_{in} + b[Na^+]_{in} + c[Cl^-]_{out}}$$

$$E_{rest} = 27mV \ln \frac{20 + 0.03 \cdot 440 + 0.1 \cdot 40}{400 + 0.03 \cdot 50 + 0.1 \cdot 450} = -67mV$$