Chapter 3

Question 3.7

The glycerol molecule ($C_3H_8O_3$) is not electrically charged (see Figure D in Box 2.1). From Equation 3.3 it follows that the membrane permeability to glycerol can then be calculated by dividing the measured value of the glycerol flux (0.02 mmol m^{-2} s^{-1}) by the concentration difference of glycerol across the membrane (10 mmol L^{-1} – 0 mmol L^{-1} = 10 mmol L^{-1}) which yields a value of **2×10^{-6} m s^{-1}** for membrane permeability to glycerol (0.02 mmol m^{-2} s^{-1}/ 10 mmol L^{-1} = 0.002 (mmol/mmol) × (m^{-2} L) s^{-1} = 0.002 × 1 × (m^{-2} × 10^{-3} m^3) s^{-1} = 2 × 10^{-6} m s^{-1}). **Since the glycerol molecule is not electrically charged, its rate of entry across the membrane does not depend on the electrical potential difference across the membrane.**

Question 3.9

The equilibrium potential for Na$^+$ is calculated using Equation 3.6:

$$V^{ion}_{right-left} = 2.3 \frac{RT}{zF} \, log \frac{[ion_{left}]}{[ion_{right}]} \qquad \text{Equation 3.6}$$

where R is the gas constant (8.31 J mol^{-1} K^{-1}), T is the absolute temperature (273 + 7 K = 280 K), z is the charge carried by the Na$^+$ ion (+1), F is the Faraday number representing the number of electrical charges carried by one mol of monovalent ions (96,485 C mol^{-1}), [ion$_{left}$] is the concentration of Na$^+$ on the left side of the barrier (100 mmol L^{-1}) and [ion$_{right}$] is the concentration of Na$^+$ on the right side of the barrier (50 mmol L^{-1}). Substituting the various parameters in Equation 3.6, it follows that:

$V^{Na}_{right-left}$ = 2.3 × 8.31 J mol^{-1} K^{-1} × 280 K /96,485 C mol^{-1} × log (100 mmol L^{-1}/50 mmol L^{-1})

= 0.0555 J C^{-1} × log 2
= 0.0167 J C^{-1}
= **16.7 mV** because 1 J C^{-1} = 1 V as explained in Box 3.1. This means that the sodium ion will be at equilibrium between the two compartments separated by the barrier, when the electrical potential on the right side of the barrier is 16.7 mV more positive than the electrical potential on the left side of the barrier.

Note that the equilibrium potential of an ion (sodium ion in this case) does not change when the concentration of the respective ion changes by the same factor on both sides of the barrier, because the equilibrium potential of an ion depends on the logarithm of the ratio between the concentrations of the respective ion on the two sides of the barrier. **Therefore, doubling the Na$^+$ concentration on both sides of the barrier (200 mmol L^{-1} from 100 mmol L^{-1} on the left and 100 mmol L^{-1} from 50 mmol L^{-1} on the right side of the barrier) does not change the value of the log [Na$^+$$_{left}$] /[Na$^+$$_{right}$] which remains log 2 = 0.301.**

Question 3.10

The Goldman-Hodgkin-Katz equation (Equation 3.9) is reproduced below:

$$V_{right-left}^{GHK} = 2.3\ \frac{RT}{F}\ \log\ \frac{P_K[K^+{}_{left}] + P_{Na}[Na^+{}_{left}] + P_{Cl}[Cl^-{}_{right}]}{P_K[K^+{}_{right}] + P_{Na}[Na^+{}_{right}] + P_{Cl}[Cl^-{}_{left}]} \qquad \text{Equation 3.9}$$

The term 2.3 *RT/F* for 17°C (T = 273 + 17 = 290 K) amounts to 57.4 mV:

2.3 × 8.31 J mol^{-1} K^{-1} × 290 K/96,485 C mol^{-1}
= 0.0574 J C^{-1}
= 0.0574 V
= 57.4 mV since 1 J C^{-1} = 1 V as explained in Box 3.1.

Using the values for Na$^+$ and Cl$^-$ permeabilities relative to K$^+$ permeability and the ion concentrations in the text of Question 3.10, the numerator of the log fraction becomes:
P_K × 10 mmol L^{-1} + P_{Na} × 100 mmol L^{-1} + P_{Cl} × 110 mmol L^{-1}
= P_K × 10 mmol L^{-1} + 0.01 P_K × 100 mmol L^{-1} + 0.01 P_K × 110 mmol L^{-1}
= 12.1 P_K mmol L^{-1}.

Similarly, for the conditions indicated in the text of Question 3.10, the denominator of the log fraction becomes:
P_K × 100 mmol L^{-1} + 0.01 P_K × 10 mmol L^{-1} + 0.01 P_K × 110 mmol L^{-1}
= 101.2 P_K mmol L^{-1}.

Therefore, the value of log term in Equation 3.9 is: log (12.1 P_K mmol L^{-1}/101.2 P_K mmol L^{-1}) = log 0.1196 = -0.922.

Consequently, $V_{right-left}^{GHK} = 57.4$ mV × $(-0.922) =$ **-52.95 mV**