1.

Nernst equation : $E_{ion}\,(mV) = \frac{61.54}{z} \log \frac{[ion]_o}{[ion]_i}$ ← ionic eq. pot.

$E_{Cl^-} = \frac{61.54}{(-1)} \log \frac{150}{13} = -65.36\text{ mV}$

$E_{Ca^{2+}} = \frac{61.54}{2} \log \frac{2}{0.0002} = 123.08\text{ mV}$

2. $I_{ion} = g_{ion}(V_m - E_{ion})$ $V_m \approx -65.2\text{ mV}$

$E_{Cl^-} = -65.36\text{ mV}$

Case 1: Impermeable to Cl^-

- $g_{Cl} = 0$, $I_{Cl} = 0$
- No net movement of Cl^-

Case 2: Cl^- channels open @ membrane resting potential

- $V_m - E_{Cl^-} = (-65.2 - (-65.36)) = 0.16\text{ mV}$
- $g_{Cl^-} > 0$, $I_{Cl^-} > 0$
- Cl^- efflux (electric < diffusion movement)
- But $V_m - E_{Cl^-}$ is neglegible (≈ 0) so no net movement

∴ Since there is basically no net movement of Cl^-, the simplification is justifiable. The flow and dynamics are not significant.

3. $V_m = 61.54 \log \frac{P_{K^+}[K^+]_o + P_{Na^+}[Na^+]_o + P_{Cl^-}[Cl^-]_i}{P_{K^+}[K^+]_i + P_{Na^+}[Na^+]_i + P_{Cl^-}[Cl^-]_o} = 61.54 \log \frac{40(5) + 1(150) + P_{Cl^-}(13)}{40(100) + 1(15) + P_{Cl^-}(150)}$

$= 61.54 \log \frac{350 + 13P_{Cl^-}}{4015 + 150P_{Cl^-}} = 61.54 \log \left[\frac{13\cancel{(26.92 + P_{Cl^-})}}{150\cancel{(26.77 + P_{Cl^-})}}\right]$

Not including chloride ions for resting membrane potential (V_m) is justified because the ionic equilibrium potential for Cl^- (E_{Cl^-}) is very close to V_m ($\sim -65\text{ mV}$). Therefore, if the cell were to become permeable to Cl^- then it will have little affect on V_m (doesn't drive the potential of the cell to be more + or −).

Also, when looking at the above simplification, the permeability of Cl^- does not matter because the numerator and denominator "approx" cancel out, simplifying to $61.54 \log\left(\frac{13}{150}\right) \approx -65.36\text{ mV}$. The factor with P_{Cl^-} in the numerator and denominator is almost the same so it doesn't really affect the potential.

4. Without ATP, the sodium/potassium pump cannot function, as it requires ATP to actively transport sodium and potassium ions against their concentration gradient (3 Na^+ out, 2 Na^+ in). This maintains the negative resting membrane potential in the cells. Without the pump maintaining a concentration gradient, the ions would continue to move until equilibrium is eventually met (no net change in movement), resulting in no action potentials or brain activity.

Assignment 1 Q7

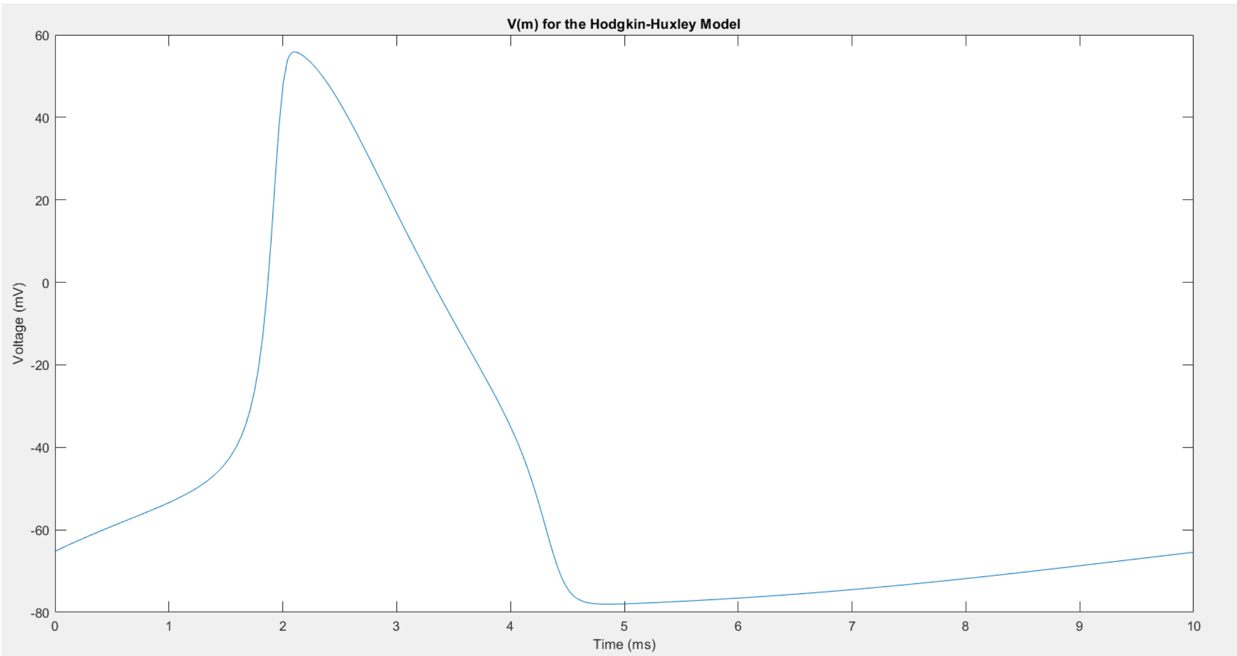

Figure 1. V(m) for the Hodgkin-Huxley Model

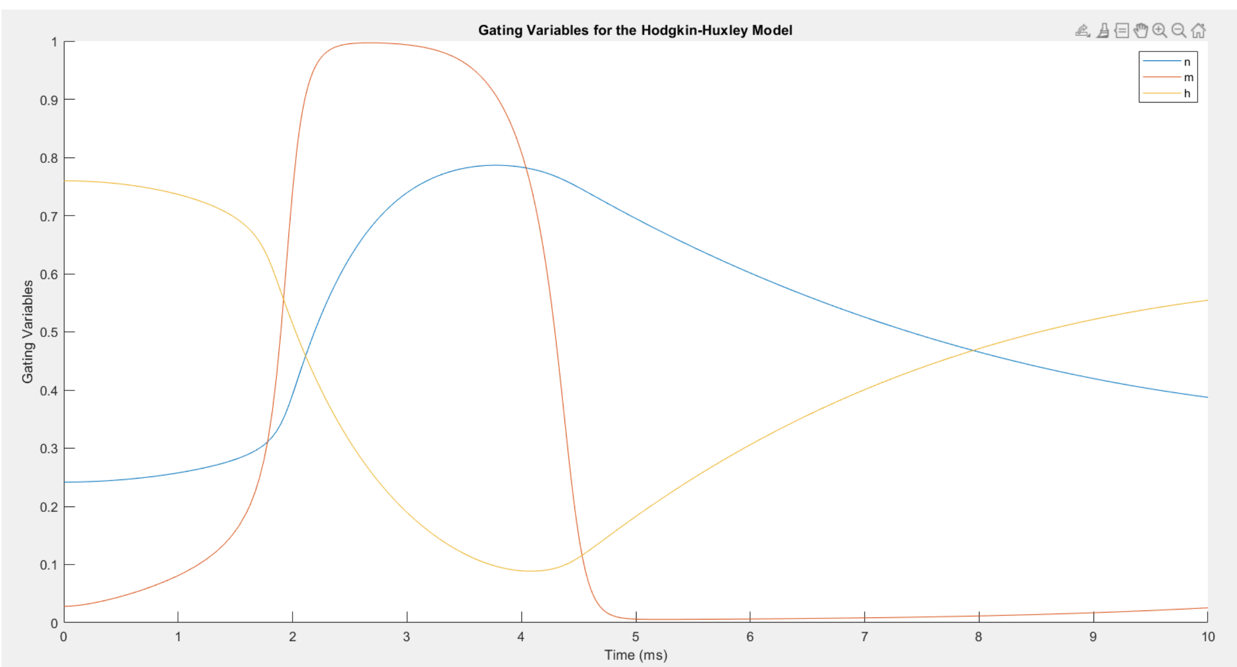

Figure 2. Gating Variables for the Hodgkin-Huxley Model

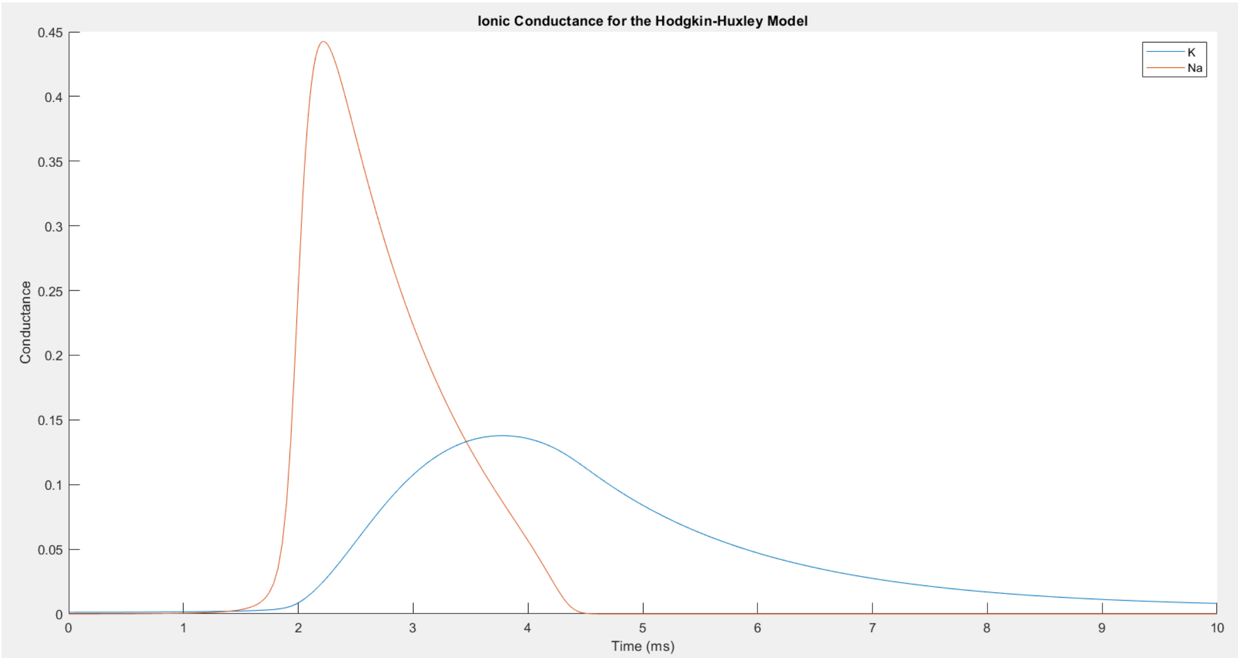

Figure 3. Sodium and Potassium Conductance for the Hodgkin-Huxley Model

The gating variables in general, are dimensionless probabilities between 0-1 and model the voltage dependent dynamics of the voltage-gated ion channels. The gating variables represent the probability of ion channels being open at a given moment in time. Gating variable h is associated with sodium ion channel inactivation, m is associated with sodium channel activation, n is associated with potassium ion channel activation.

Because ionic conductance is proportional to the number of open channels, we can see that the conductance of potassium is high (more open channels) when the probability of potassium channel activation is high (n gating variable). This leads to the conductance of potassium and gating variable n having a similar shape since they are directly proportional to one another. For potassium channels, the gating variable n also grows with respect to membrane voltage. For sodium, we can see that the conductance of sodium is decreased (less number of open channels) when the probability of channel inactivation is high (h gating variable) and the conductance of sodium is high (larger number of open channels) when the probability of channel activation is high (m gating variable). Gating variable m^3 and h are proportional to the conductance of sodium. When m rises, this has a large effect on the conductance of sodium, and the conductance of sodium decreases almost immediately when h is decreased. When m is very small or approaching 0, the conductance of sodium is also negligible.
The activation variable m also increases with membrane potential while the inactivation variable h decreases with it.

Over the course of the action potential, the varying changes in conductance represent the changing number of open gates which dictates membrane potential over this time period, as can be seen in Figure 1 and explained in detail above. If we examine the mechanics of the action potential in detail (as we did in lecture), we see the influx/efflux of sodium and potassium ions based the channels opening/closing, which is determined by the membrane potential surpassing the threshold voltage and further experiencing depolarization, repolarization and hyperpolarization. Moreover, comparing Figure 1 to Figure 3 shows that potassium is the more permeable and its concentration mostly dictates the membrane potential (the shape of Vm closely follows the shape of potassium conductance).