Unit 5: AP Quiz Free Response Practice [2010 #3, 8 points, modified]

$$8\,H^+(aq) + 4\,Cl^-(aq) + MnO_4^-(aq) \rightarrow 2\,Cl_2(g) + Mn^{3+}(aq) + 4\,H_2O(l)$$

1. $Cl_2(g)$ can be generated in the laboratory by reacting potassium permanganate with an acidified solution of sodium chloride. The net ionic equation for the reaction is given above. An initial rate study was performed on the reaction system. Data for the experiment are given in the table below.

Trial	$[Cl^-]$	$[MnO_4^-]$	$[H^+]$	Rate of Disappearance of MnO_4^- in $M\,s^{-1}$
1	×3 0.0104	0.00400	3.00	×9 2.25×10^{-8}
2	0.0312	0.00400 ×2	3.00	2.03×10^{-7} no change!
3	0.0312	0.00200	3.00	2.03×10^{-7}

a. Using the information in the table, determine the order of the reaction with respect to each of the following. Be sure to justify your answers.

i. Cl^- [1 point] trials 1+2: $3 \times [Cl^-]$, $[MnO_4^-]$ and $[H^+]$ constant, 9 x rate

⇒ rxn is 2nd order w/ respect to Cl^-.

ii. MnO_4^- [1 point] trials 3+2: $2 \times [MnO_4^-]$, $[Cl^-]$ and $[H^+]$ constant,

no change in rate ⇒ rxn is 0th order w/ respect to MnO_4^-.

b. What other experiments would need to be run in order to determine the reaction order with respect to H^+? [1 point]

You would need to run one more trial while holding $[Cl^-]$ and $[MnO_4^-]$ constant but changing $[H^+]$, then measure the effect on the rxn rate.

c. After further experimentation, the reaction is determined to be second order with respect to H^+. Using this information and your answers to part (a) above, complete the following:

i. Write the rate law for the reaction. [1 point]

→ $rate = k[Cl^-]^2[MnO_4^-]^0[H^+]^2$

OR

→ $rate = k[Cl^-]^2[H^+]^2$

($k[Cl^-]^2[H^+]^2$ no credit, must have "rate = ")

ii. Calculate the value of the rate constant, *k*, for the reaction, including appropriate units. [2 points]

$rate = k[Cl^-]^2[H^+]^2$

$$\Rightarrow k = \frac{rate}{[Cl^-]^2[H^+]^2} = \underbrace{\frac{2.25E{-}8\ M/s}{(0.0104\ M)^2(3.00\ M)^2}}_{\text{you can use data from any trial}} = \overbrace{2.31 \times 10^{-5}}^{1\ pt}\ \overbrace{M^{-3}s^{-1}}^{1\ pt}$$

or $\frac{1}{M^3 s}$

d. Three graphs are constructed: $[H^+]$ vs time, $\ln[H^+]$ vs time, and $1/[H^+]$ vs time.

i. Which graph would have the most linear slope and why? [1 point]

The graph of $\frac{1}{[H^+]}$ vs. time would have the most linear slope, b/c the rxn is 2^{nd} order w/ respect to H^+.

ii. How could you use these graphs to determine the rate constant, *k*, for the reaction? [1 point]

Find the absolute value of the slope from the $\frac{1}{[H^+]}$ vs. time graph

$k = |\text{slope}|$