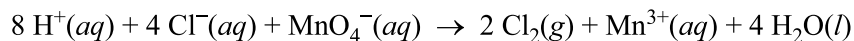


AP[®] CHEMISTRY
2010 SCORING GUIDELINES

Question 3
(9 points)



$\text{Cl}_2(\text{g})$ 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.

(a) A 25.00 mL sample of 0.250 M NaCl reacts completely with excess $\text{KMnO}_4(\text{aq})$. The $\text{Cl}_2(\text{g})$ produced is dried and stored in a sealed container. At 22°C the pressure of the $\text{Cl}_2(\text{g})$ in the container is 0.950 atm.

(i) Calculate the number of moles of $\text{Cl}^-(\text{aq})$ present before any reaction occurs.

$\text{mol Cl}^- = (0.02500 \text{ L})(0.250 \text{ M}) = 6.25 \times 10^{-3} \text{ mol}$	One point is earned for the correct numerical value.
--	--

(ii) Calculate the volume, in L, of the $\text{Cl}_2(\text{g})$ in the sealed container.

$\text{mol Cl}_2 = \frac{\text{mol Cl}^-}{2} = \frac{6.25 \times 10^{-3} \text{ mol}}{2} = 3.125 \times 10^{-3} \text{ mol Cl}_2$ $V = \frac{nRT}{P} = \frac{(3.125 \times 10^{-3} \text{ mol Cl}_2)(0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1})(295 \text{ K})}{0.950 \text{ atm}}$ $= 0.0797 \text{ L Cl}_2$	<p>One point is earned for the correct number of moles of Cl_2 based on stoichiometry.</p> <p>One point is earned for substitution into ideal gas law and correct numerical result.</p>
--	---

An initial-rate study was performed on the reaction system. Data for the experiment are given in the table below.

Trial	$[\text{Cl}^-]$	$[\text{MnO}_4^-]$	$[\text{H}^+]$	Rate of Disappearance of MnO_4^- in M s^{-1}
1	0.0104	0.00400	3.00	2.25×10^{-8}
2	0.0312	0.00400	3.00	2.03×10^{-7}
3	0.0312	0.00200	3.00	1.02×10^{-7}

AP[®] CHEMISTRY
2010 SCORING GUIDELINES

Question 3 (continued)

(b) Using the information in the table, determine the order of the reaction with respect to each of the following. Justify your answers.

(i) Cl^-

<p>The reaction is second order. Tripling $[\text{Cl}^-]$ between trials 1 and 2 with no change in $[\text{MnO}_4^-]$ results in a nine-fold increase in the rate:</p> $\left(\frac{0.0312\text{ M}}{0.0104\text{ M}}\right)^x = \frac{2.03 \times 10^{-7}}{2.25 \times 10^{-8}}$ $3^x = 9$ $x = 2$ <p>Thus the order of the reaction must be 2 with respect to Cl^-.</p>	<p>One point is earned for the correct order of reaction with justification.</p>
---	--

(ii) MnO_4^-

<p>The reaction is first order. Doubling $[\text{MnO}_4^-]$ between trials 3 and 2 with no change in $[\text{Cl}^-]$ results in a doubling of the rate:</p> $\left(\frac{0.00400\text{ M}}{0.00200\text{ M}}\right)^y = \frac{2.03 \times 10^{-7}}{1.02 \times 10^{-7}}$ $2^y = 2$ $y = 1$ <p>Thus the order of the reaction must be 1 with respect to MnO_4^-.</p>	<p>One point is earned for the correct order of reaction with justification.</p>
---	--

(c) The reaction is known to be third order with respect to H^+ . Using this information and your answers to part (b) above, complete both of the following:

(i) Write the rate law for the reaction.

$\text{rate} = k[\text{Cl}^-]^2[\text{MnO}_4^-][\text{H}^+]^3$	<p>One point is earned for the correct rate law.</p>
--	--

AP[®] CHEMISTRY
2010 SCORING GUIDELINES

Question 3 (continued)

(ii) Calculate the value of the rate constant, k , for the reaction, including appropriate units.

Using data from trial 1: $2.25 \times 10^{-8} M s^{-1} = k(0.0104 M)^2(0.00400 M)(3.00 M)^3$ $k = 1.93 \times 10^{-3} M^{-5} s^{-1}$	One point is earned for the correct numerical result. One point is earned for the correct units.
---	---

(d) Is it likely that the reaction occurs in a single elementary step? Justify your answer.

It is not likely that the reaction occurs in a single step because the orders of the reaction with respect to the reactants do not correspond to the coefficients in the balanced equation <p style="text-align: center;">OR</p> It is not likely that the reaction occurs in a single step because the reaction requires the collision of many (13) reactant particles and the frequency of a 13-particle collision is negligible.	One point is earned for the correct answer with justification.
---	--