

Question 6: Short Answer 4 points

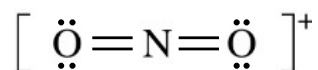
(a) For a correct explanation: 1 point

The plot of $\frac{1}{[\text{NO}_2]}$ versus time is the most linear, indicating that the reaction is second order with respect to NO_2 .

(b) For the correct calculated value: 1 point

$$6.52 \times 10^{-7} \text{ M/s} \times \frac{1 \text{ mol O}_2}{2 \text{ mol NO}_2} = 3.26 \times 10^{-7} \text{ M/s}$$

(c) (i) For the correct Lewis diagram: 1 point



(ii) For the correct answer and a valid justification, consistent with part (c)(i): 1 point

Accept one of the following:

- Agree. The angle of NO_2^+ is different from the angle in NO_2 because there would no longer be a nonbonding electron on the central atom in NO_2 , and the O atoms would spread farther apart, forming a linear structure with a 180° bond angle.
- Agree. The hybridization of N in NO_2 is sp^2 , which would result in a bond angle of approximately 120° . The hybridization of N in NO_2^+ is sp , which would result in a bond angle of 180° .

Total for part (c) 2 points

Total for question 6 4 points

Question 3: Long Answer

10 points

(a) For the correct balanced equation (state symbols not required): 1 point

Accept one of the following:

- $\text{CaCO}_3(s) + 2\text{H}^+(aq) \rightarrow \text{Ca}^{2+}(aq) + \text{CO}_2(g) + \text{H}_2\text{O}(l)$
- $\text{CaCO}_3(s) + 2\text{H}_3\text{O}^+(aq) \rightarrow \text{Ca}^{2+}(aq) + \text{CO}_2(g) + 3\text{H}_2\text{O}(l)$

(b) For a correct explanation: 1 point

Accept one of the following:

- Even though the concentration of HCl is greater in trial 5 than in trial 2, the reaction time is significantly longer. Both trial 2 and 5 occur under otherwise identical conditions. The trend for trial 1 and 4 indicates that the higher concentration of HCl results in a shorter time of reaction.
- The time of reaction in trial 5, with small chunks of calcium carbonate, is longer than trial 6 with large chunks. Both trial 5 and 6 occur under otherwise identical conditions. The trend for trials 1, 2, and 3 shows that larger chunks of the solid result in longer time of reaction.

(c) For a correct explanation of the effect of surface area on reaction time: 1 point

The time of reaction in trial 2 is shorter than that in trial 3 because the calcium carbonate in trial 2 has a larger surface area (meaning that more particles of calcium carbonate are exposed to the H^+ particles in the solution).

For a correct explanation of the effect of particle collisions on reaction rate: 1 point

The larger interface between the two reacting substances means there will be more collisions between the particles in a given amount of time, and thus, a higher frequency of successful collisions in which the particles react to form the products.

Total for part (c) 2 points

(d) For the correct answer and a valid justification: 1 point

Accept one of the following:

- Disagree. If the reaction was zeroth order with respect to HCl , then changing the concentration of HCl would not affect the rate of reaction, and the time of reaction would be the same for trials in which the only difference was $[\text{HCl}]$. The student's data for trials 1 and 4 (likewise for 3 and 6) show that changing $[\text{HCl}]$ significantly alters the time of reaction.
- Disagree. The reaction appears to be first order, not zeroth order, with respect to $[\text{HCl}]$. Tripling $[\text{HCl}]$ results in a reaction time that is $1/3$ of that when $[\text{HCl}] = 1.00 \text{ M}$, which means the reaction rate has also tripled, indicating a first-order process.

(e) For the correct calculated moles of HCl reacted (may be implicit): **1 point**

$$1.00 \text{ g CaCO}_3 \times \frac{1 \text{ mol}}{100.09 \text{ g}} = 0.00999 \text{ mol CaCO}_3$$

$$0.00999 \text{ mol CaCO}_3 \times \frac{2 \text{ mol HCl}}{1 \text{ mol CaCO}_3} = 0.0200 \text{ mol HCl reacted}$$

For the correct calculated [HCl] remaining, consistent with the number of moles reacted: **1 point**

$$0.0500 \text{ L} \times \frac{1.00 \text{ mol HCl}}{1 \text{ L}} = 0.0500 \text{ mol HCl initially present}$$

$$0.0500 \text{ mol} - 0.0200 \text{ mol} = 0.0300 \text{ mol remaining}$$

$$\frac{0.0300 \text{ mol}}{0.0500 \text{ L}} = 0.600 \text{ M HCl remaining}$$

Total for part (e) 2 points

(f) For the correct answer and a valid justification: **1 point**

Exothermic. The solution temperature increases as the reaction proceeds.

(g) (i) For the correct calculated value (sign not required): **1 point**

$$q_{\text{surr}} = mc\Delta T = (51.0 \text{ g})(4.0 \frac{\text{J}}{\text{g}\cdot^\circ\text{C}})(21.90^\circ\text{C} - 21.20^\circ\text{C}) = 140 \text{ J}$$

(ii) For the correct calculated value, consistent with (g)(i), and the correct sign, consistent with (f): **1 point**

$$q_{\text{sys}} = -q_{\text{surr}} = -140 \text{ J} = -0.14 \text{ kJ}$$

$$1.00 \text{ g CaCO}_3 \times \frac{1 \text{ mol CaCO}_3}{100.09 \text{ g CaCO}_3} \times \frac{1 \text{ mol}_{\text{rxn}}}{1 \text{ mol CaCO}_3} = 0.00999 \text{ mol}_{\text{rxn}}$$

$$\Delta H_{\text{rxn}}^\circ = \frac{-0.14 \text{ kJ}}{0.00999 \text{ mol}_{\text{rxn}}} = -14 \text{ kJ/mol}_{\text{rxn}}$$

Total for part (g) 2 points

Total for question 3 10 points