2023

AP® Chemistry

Sample Student Responses and Scoring Commentary

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Free-Response Question 3

- ☑ **Scoring Guidelines**
- ☑ **Student Samples**
- ☑ **Scoring Commentary**

Question 3: Long Answer — 10 points

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

Accept one of the following:

- $CaCO_3(s) + 2\,H^+(aq) \rightarrow Ca^{2+}(aq) + CO_2(g) + H_2O(l)$
- $CaCO_3(s) + 2\,H_3O^+(aq) \rightarrow Ca^{2+}(aq) + CO_2(g) + 3\,H_2O(l)$

(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* $[HCl]$*. The student's data for trials 1 and 4 (likewise for 3 and 6) show that changing* $[HCl]$ *significantly alters the time of reaction.*
- *Disagree. The reaction appears to be first order, not zeroth order, with respect to* $[HCl]$*. Tripling* $[HCl]$ *results in a reaction time that is 1/3 of that when* $[HCl] = 1.00\ M$*, 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**

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

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

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

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**

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

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

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

$1.00 \text{ g } CaCO_3 \times \frac{1 \text{ mol } CaCO_3}{100.09 \text{ g } CaCO_3} \times \frac{1 \text{ mol}_{rxn}}{1 \text{ mol } CaCO_3} = 0.00999 \text{ mol}_{rxn}$

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

Total for part (g) **2 points**

Total for question 3 **10 points**

Question 3

Begin your response to **QUESTION 3** on this page.

3. Answer the following questions about an experiment in which $CaCO_3(s)$ is combined with $HCl(aq)$, represented by the following balanced equation.

$$CaCO_3(s) + 2\,HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

(a) Write the balanced net ionic equation for the reaction.

$CaCO_{3(s)} + 2H^+_{(aq)} \longrightarrow Ca^{2+}_{(aq)} + CO_{2(g)} + H_2O_{(l)}$

A student performs an investigation to study factors that affect the rate of the reaction. In each trial the student combines 50.0 mL of $HCl(aq)$ at 21.2° C with 1.00 g of $CaCO_3(s)$ and measures the time required for the reaction to go to completion. The data are given in the following table.

Trial	Concentration of $HCl(aq)$ (M)	Particle Size of $CaCO_3(s)$	Time of Reaction (s)
1	1.00	Fine powder	67
2	1.00	Small chunks	112
3	1.00	Large chunk	342
4	3.00	Fine powder	22
5	3.00	Small chunks	227
6	3.00	Large chunk	114

(b) The student correctly identifies that trial 5 is inconsistent with the other trials. Explain why the student's claim is correct using the data in the table. The student's claim is correct because the time of reaction for small chunks should be between that of fine powder and large chunks. In trial 2, the time was 112s for small chunks, in between the 67s for fine powder at the same [HCl] and 342s for large chunk at the same [HCl]. In trial 5, however, the reaction time was 227s, greater than both other trials with [HCl] = 3.0M, having times of 22s and 114s for fine powder and a large chunk, respectively, which goes against the trend.

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Question 3

Continue your response to **QUESTION 3** on this page.

(c) Based on the reaction conditions and the collisions that occur between particles, explain the reason for the difference in the reaction times for trial 2 and trial 3.

Although the [HCl] was the same for trials 2 and 3, the smaller particle size of trial 2's small chunks compared to trial 3's large chunk increases the surface area of the $CaCO_3$, thus increasing the number of $CaCO_3$ exposed to collisions with HCl particles and increasing the reaction rate for trial 2 as more effective collisions can occur at a time, decreasing the time for the reaction to go to completion in trial 2.

(d) The student claims that the reaction is zero order with respect to HCl(*aq*). Do you agree or disagree with the student's claim? Justify your answer using the student's data. I disagree. Comparing Trials 1 and 3 with Trials 4 and 6 shows that at three times the concentration of HCl, the reaction time went down by a factor of three. This relationship implies a first-order kinetics, as the concentration of HCl does affect the reaction rate by a factor equal to the change in [HCl], disproving a zero-order relationship which would show a rate unaffected by the concentration of HCl.

(e) The HCl(*aq*) was present in excess in all trials of the experiment. Determine the molarity of the HCl(*aq*) in the beaker after the reaction is complete in trial 2. Assume that the volume of the mixture remains constant at 50.0 mL throughout the trial. (The molar mass of $CaCO_3$ is 100.09 g/mol.)

$$1.009\ g\ CaCO_3 \cdot \frac{1\ mol\ CaCO_3}{100.09\ g/mol} \cdot \frac{2\ HCl_{(aq)}}{1\ CaCO_3} = 0.0200\ mol\ HCl\ reacted$$

Initial moles HCl: $50.0\ mL \cdot \frac{1.0\ moles\ HCl}{1000\ mL} = 0.0500\ moles\ HCl_{initial} - 0.0200\ mol\ HCl_{reacted}$

$$= \frac{0.0300\ moles\ HCl}{50.0\ mL} \cdot \frac{1000\ mL}{1\ L} = \boxed{0.600\ M\ HCl}$$

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Question 3

Continue your response to **QUESTION 3** on this page.

$$CaCO_3(s) + 2\,HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

In order to measure the enthalpy of the reaction shown, the student repeats trial 1 by mixing 50.0 mL of $HCl(aq)$ with 1.00 g of $CaCO_3(s)$ using a coffee cup calorimeter. The student records the temperature of the system every 20 seconds. The data are given in the following table.

Time (s)	Measured Temperature of Solution (° C)
0	21.20
20	21.51
40	21.70
60	21.85
80	21.90
100	21.90

(f) Is the reaction endothermic or exothermic? Justify your answer using the information in the table.

The reaction is exothermic. At time = 0 s, the solution temperature was 21.20°C, while at time = 100 s, the temperature was 21.90°C. Because the temperature increased (and since the solution is the surroundings), the reaction must be exothermic as the increase in temperature shows that energy was released from the reaction and absorbed by the surroundings.

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Question 3

Continue your response to **QUESTION 3** on this page.

(g) Based on the experimental data, the mass of the system is 51.0 g, and the specific heat of the reaction mixture is 4.0 J/(g · °C).

(i) Calculate the magnitude of heat transfer, q, in joules.

$q = mC\Delta T = (51.0\,g)\left(4.0\frac{J}{g°C}\right)(21.90°C - 21.20°C) = 140\,J$ transferred

(ii) Calculate the enthalpy of reaction in units of kJ/mol_{rxn}. Include the algebraic sign on your answer.

Reaction is exothermic, so energy was lost in reaction and gained by surroundings, ∴ q is negative.

$q_{rxn} = -q_{solution} = -(140\,J) = -140\,J$

$$\Delta H_{rxn} = \frac{q_{rxn}}{mol_{rxn}} = \frac{(-140\,J)}{\left(1.00\,g\,CaCO_3 \cdot \frac{1\,mol\,CaCO_3}{100.09\,g\,CaCO_3} \cdot \frac{1\,mol\,rxn}{1\,mol\,CaCO_3}\right)} \cdot \frac{1\,kJ}{1000\,J}$$

$\Delta H_{rxn} = -14\,kJ/mol\,rxn$

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Question 3

Begin your response to **QUESTION 3** on this page.

3. Answer the following questions about an experiment in which $CaCO_3(s)$ is combined with $HCl(aq)$, represented by the following balanced equation.

$$CaCO_3(s) + 2\,HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

(a) Write the balanced net ionic equation for the reaction.

$CaCO_3(s) + 2H^+(aq) + 2Cl^-(aq) \rightarrow Ca^{2+}(aq) + Cl_2^{-1}(aq) + CO_2(g) + H_2O(l)$

$CaCO_3(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + CO_2(g) + H_2O(l)$

A student performs an investigation to study factors that affect the rate of the reaction. In each trial the student combines 50.0 mL of $HCl(aq)$ at 21.2° C with 1.00 g of $CaCO_3(s)$ and measures the time required for the reaction to go to completion. The data are given in the following table.

Trial	Concentration of $HCl(aq)$ (M)	Particle Size of $CaCO_3(s)$	Time of Reaction (s)
1	1.00	Fine powder	67
2	1.00	Small chunks	112
3	1.00	Large chunk	342
4	3.00	Fine powder	22
5	3.00	Small chunks	227
6	3.00	Large chunk	114

(b) The student correctly identifies that trial 5 is inconsistent with the other trials. Explain why the student's claim is correct using the data in the table.

The student is correct because ~~the~~ data in trials 1-3 show that as the particle size of $CaCO_3(s)$ get larger the time of the rxn increases. In trial 5 the data shows that the reaction with small chunks takes more time than with large chunks which wouldn't be accurate.

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Question 3

Continue your response to QUESTION 3 on this page.

(c) Based on the reaction conditions and the collisions that occur between particles, explain the reason for the difference in the reaction times for trial 2 and trial 3.

The larger the particle size the less surface area of the molecule is exposed to the reactant, HCl, so the reaction time for large chunks of $CaCO_3$ is greater than small chunks because HCl is able to react with ~~less~~ only the surface area of $CaCO_3$ taking longer to expose more of the $CaCO_3$ to HCl.

(d) The student claims that the reaction is zero order with respect to HCl(*aq*). Do you agree or disagree with the student's claim? Justify your answer using the student's data.

I disagree with the student because by changing the concentration of a reactant, HCl, the time it takes to complete the reaction also changes, this can be seen in the different times of reactions in trials 1 and 4 where the concentration is changed while keeping particle size of $CaCO_3$ the same.

(e) The HCl(*aq*) was present in excess in all trials of the experiment. Determine the molarity of the HCl(*aq*) in the beaker after the reaction is complete in trial 2. Assume that the volume of the mixture remains constant at 50.0 mL throughout the trial. (The molar mass of $CaCO_3$ is 100.09 g/mol.)

$1.00 = \frac{n}{0.05L}$ $n = 0.05 \text{ mol HCl}$

$1.00 \text{ g } CaCO_3 \times \frac{1 \text{ mol}}{100.09 \text{ g}} = 0.00999 \text{ mol } CaCO_3 \times \frac{2 \text{ mol HCl}}{1 \text{ mol } CaCO_3}$

$= \frac{0.0200 \text{ mol HCl}}{0.05L} = 0.4 \text{ M HCl}$

Question 3

Continue your response to **QUESTION 3** on this page.

$$CaCO_3(s) + 2\,HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

In order to measure the enthalpy of the reaction shown, the student repeats trial 1 by mixing 50.0 mL of $HCl(aq)$ with 1.00 g of $CaCO_3(s)$ using a coffee cup calorimeter. The student records the temperature of the system every 20 seconds. The data are given in the following table.

Time (s)	Measured Temperature of Solution (° C)
0	21.20
20	21.51
40	21.70
60	21.85
80	21.90
100	21.90

(f) Is the reaction endothermic or exothermic? Justify your answer using the information in the table.

The reaction is exothermic, according to the table as the reaction proceeds the temperature of the solution increases indicating that heat is being produced/released making the rxn exothermic.

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Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 3

Continue your response to **QUESTION 3** on this page.

(g) Based on the experimental data, the mass of the system is 51.0 g, and the specific heat of the reaction mixture is 4.0 J/(g · °C).

(i) Calculate the magnitude of heat transfer, q, in joules.

$q = mc\Delta T$

$= 51.0g(4.0J/g\cdot°C)(21.90 - 21.20°C)$

$= 142.8J$

(ii) Calculate the enthalpy of reaction in units of kJ/mol_{rxn}. Include the algebraic sign on your answer.

~~$\Delta H = -142.8$~~

$142.8J \times \frac{1kJ}{1000J} = 0.1428kJ$

$\Delta H = -0.1428kJ$

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Question 3

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3. Answer the following questions about an experiment in which $CaCO_3(s)$ is combined with $HCl(aq)$, represented by the following balanced equation.

$$CaCO_3(s) + 2\,HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

(a) Write the balanced net ionic equation for the reaction.

$CO_{3(s)} + 2H^{+} \longrightarrow CO_{2(g)} + H_2O_{(l)}$

A student performs an investigation to study factors that affect the rate of the reaction. In each trial the student combines 50.0 mL of $HCl(aq)$ at 21.2° C with 1.00 g of $CaCO_3(s)$ and measures the time required for the reaction to go to completion. The data are given in the following table.

Trial	Concentration of $HCl(aq)$ (M)	Particle Size of $CaCO_3(s)$	Time of Reaction (s)
1	1.00	Fine powder	67
2	1.00	Small chunks	112
3	1.00	Large chunk	342
4	3.00	Fine powder	22
5	3.00	Small chunks	227
6	3.00	Large chunk	114

(b) The student correctly identifies that trial 5 is inconsistent with the other trials. Explain why the student's claim is correct using the data in the table.

greater time of reaction

The student's claim is correct because with the other trials, the 1.00M of a certain particle size was [redacted] than the 3.00M of the same particle size. However, the "small chunks" variation was inconsistent because the 3.00M trial yielded a greater time of reaction than the 1.00 "small chunks" trial.

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Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 3

Continue your response to **QUESTION 3** on this page.

(c) Based on the reaction conditions and the collisions that occur between particles, explain the reason for the difference in the reaction times for trial 2 and trial 3.

Trial 3 had a greater reaction time because it was with the larger chunk, which would make the reaction time slower than that of a smaller chunk.

(d) The student claims that the reaction is zero order with respect to HCl(*aq*). Do you agree or disagree with the student's claim? Justify your answer using the student's data.

I agree with this claim because although the time of reactions are increasing, the concentration of HCl is staying the same.

(e) The HCl(*aq*) was present in excess in all trials of the experiment. Determine the molarity of the HCl(*aq*) in the beaker after the reaction is complete in trial 2. Assume that the volume of the mixture remains constant at 50.0 mL throughout the trial. (The molar mass of $CaCO_3$ is 100.09 g/mol.)

$1.00M = \frac{mol}{.05L}$ $\quad \frac{.05mol}{1} \times \frac{112s}{67s} = 0.084mol$

$M = \frac{.084mol}{.050L} = 1.68M \approx 1.7M$

Question 3

Continue your response to **QUESTION 3** on this page.

$$CaCO_3(s) + 2\,HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

In order to measure the enthalpy of the reaction shown, the student repeats trial 1 by mixing 50.0 mL of $HCl(aq)$ with 1.00 g of $CaCO_3(s)$ using a coffee cup calorimeter. The student records the temperature of the system every 20 seconds. The data are given in the following table.

Time (s)	Measured Temperature of Solution (° C)
0	21.20
20	21.51
40	21.70
60	21.85
80	21.90
100	21.90

(f) Is the reaction endothermic or exothermic? Justify your answer using the information in the table.

This reaction is exothermic, because as time progresses, the temperature continues to increase. For instance, at 0 seconds, the solution is at 21.20°C, but at 100 seconds, the solution is at 21.90°C.

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Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 3

Continue your response to **QUESTION 3** on this page.

(g) Based on the experimental data, the mass of the system is 51.0 g, and the specific heat of the reaction mixture is 4.0 J/(g · °C). $q = MC\Delta T$

(i) Calculate the magnitude of heat transfer, q, in joules.

$q = (51.0\,g)\left(\frac{4.0\,J}{g \cdot °C}\right)(0.70\,°C)$

$q = 142.8\,J \approx q = 140\,J$

(ii) Calculate the enthalpy of reaction in units of kJ/mol_{rxn}. Include the algebraic sign on your answer.

$\Delta H = -\frac{q}{\text{Mol LR}}$ $\Delta H = -\frac{140\,J}{0.00998\,mol}$

$\Delta H = -14141 \approx$

$\Delta H = -14100\ \frac{kJ}{mol_{rxn}}$

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Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 3

Note: Student samples are quoted verbatim and may contain spelling and grammatical errors.

Overview

Question 3 presented students with a series of questions concerning an experiment in which solid calcium carbonate is reacted with an excess of aqueous hydrochloric acid.

Part (a) of this question required students to write the net ionic equation for the reaction between aqueous hydrochloric acid and solid calcium carbonate (Learning Objective TRA-1.B, Skill 5.E from the *AP Chemistry Course and Exam Description*).

Part (b) presented students with a table that lists time-of-reaction data for multiple trials of the reaction between HCl and $CaCO_3$. Each trial either varies the HCl concentrations or the $CaCO_3$ particle size. The question asked students to explain the relationship between the rate of a chemical reaction and the experimental conditions (TRA-3.A, 2.E). The response was expected to confirm a claim, with an explanation using the experimental data, that one trial of a multitrial experiment is inconsistent with the other trials. The explanation can be based on the varying HCl concentrations or the $CaCO_3$ particle sizes.

Part (c) required students to make the connection between the number of particle collisions and the reaction times for two trials under different particle size reaction conditions. A student could earn up to 2 points in part (c). The first point was earned for correctly relating the particle size of a solid reactant to the surface area available for reaction (TRA-4.B, 6.F). The second point was earned for correctly relating the number of reactant particle collisions to the reaction times in the data table (TRA-4.B, 4.B).

The intent of part (d) was to analyze the data in the reaction timetable to determine the reaction order of the aqueous HCl reactant (TRA-3.B, 6.D). The student must determine that the claim of zero order is incorrect and cite data from the table as evidence.

Part (e) was a 2-point stoichiometry problem (SPQ-4.A, 5.F) involving the molarity of aqueous reactant remaining at the conclusion of a reaction (SPQ-3.A, 5.F). The first point was earned by correctly calculating the moles of HCl that will be consumed by the $CaCO_3$. The second point was earned by subtracting those moles from the initial moles of HCl, then dividing that by the total solution volume to determine the molarity of HCl remaining.

Part (f) provided temperature and time data for a calorimetry experiment using the $CaCO_3$ and HCl reaction. The student must state whether the reaction is exothermic or endothermic (ENE-2.A, 6.D), justifying their answer with information from the table.

Part (g) is a 2-point problem that asked the student to calculate the change in enthalpy of the reaction based on the experimental data presented in part (f) and other provided data. The first point was earned by successfully calculating the heat (q) absorbed by the solution (ENE-2.D, 5.F). The second point was earned by dividing q by the moles of $CaCO_3$ reacted and applying the algebraic sign that is consistent with the response in part (f) (ENE-2.F, 5.F).

Question 3 (continued)

Sample: 3A
Score: 10

This response earned 10 points. In part (a) the point was earned for a correct balanced net ionic equation. In part (b) the point was earned for a valid explanation that relates the particle size of $CaCO_3$ to reaction times in trials 1 through 3 and compares those results to trials 4 through 6. In part (c) the first point was earned for correctly relating $CaCO_3$ particle size to surface area. The second point was earned for a correct explanation relating increased surface area to increased chances of effective collisions. In part (d) the point was earned for disagreeing with the student's claim and explaining that when concentration triples, the new reaction time is one-third the original reaction time, making the reaction first order with respect to HCl. In part (e) the first point was earned for a correct calculation of the number of moles of HCl reacted. The second point was earned for the correct calculated [HCl] remaining, consistent with the number of moles reacted. In part (f) the point was earned for correctly classifying the reaction as exothermic based on the increase in temperature. In part (g)(i) the point was earned for the correct calculated value of q. In part (g)(ii) the point was earned for the correct calculated value of ΔH° with the correct sign, consistent with the response in part (f).

Sample: 3B
Score: 7

This response earned 7 points. In part (a) the point was earned for a correct balanced net ionic equation. In part (b) the point was earned for a valid explanation that cites the relationship between particle size and reaction time in trials 1, 2, and 3 as evidence that the small chunks in trial 5 should not have had a longer reaction time than the large chunk in trial 6. In part (c) the first point was earned for correctly relating $CaCO_3$ particle size to surface area. The second point was not earned because the response makes no reference to collisions between particles. In part (d) the point was earned for disagreeing with the student's claim and stating that the reaction cannot be zero-order with respect to HCl if a change in HCl concentration causes a change in reaction time. In part (e) the first point was earned for a correct calculation of the number of moles of HCl reacted. The second point was not earned because the response reports the concentration of the HCl consumed and not the concentration of the remaining HCl. In part (f) the point was earned for correctly classifying the reaction as exothermic based on the increase in temperature. In part (g)(i) the point was earned for the correct calculated value of q. In part (g)(ii) no point was earned because the response only shows the conversion of the value of q to kilojoules and not the calculation of ΔH°.

Sample: 3C
Score: 3

This response earned 3 points. In part (a) no point was earned because some of the reactants and products are incorrect. In part (b) the point was earned for a valid explanation stating that trial 5 was the only 3.00 M reaction with a greater reaction time than its 1.00 M counterpart with the same particle size. In part (c) the first point was not earned because the response makes no reference to surface area. The second point was not earned because the response makes no reference to increased collisions between particles in trial 2. In part (d) no point was earned because the response

Question 3 (continued)

agrees with the student's claim. In part (e) the first point was not earned because the response attempts to use a time ratio to convert from initial moles of HCl to moles of HCl reacted. The second point was not earned because the response gives the concentration of HCl consumed instead of the concentration of HCl remaining. In part (f) the point was earned for correctly classifying the reaction as exothermic based on the increase in temperature. In part (g)(i) the point was earned for the correct calculated value. In part (g)(ii) the point was not earned because the response contains an error in converting from J to kJ/mol_{rxn}.