2017

AP CollegeBoard

AP Chemistry

Sample Student Responses and Scoring Commentary

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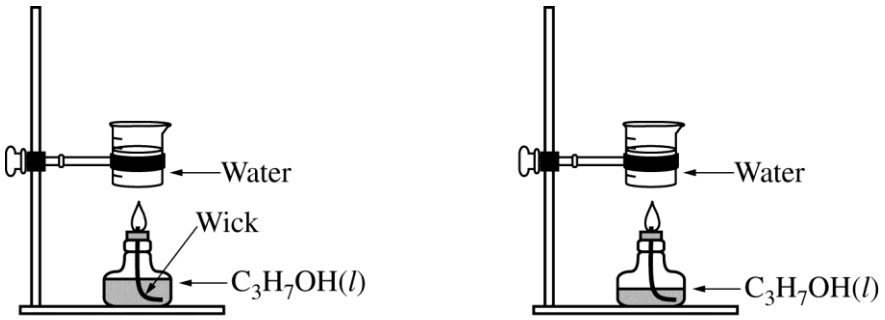
AP® CHEMISTRY
2017 SCORING GUIDELINES

Question 5

$$2\ C_3H_7OH(l) + 9\ O_2(g) \rightarrow 6\ CO_2(g) + 8\ H_2O(g)$$

A student performs an experiment to determine the enthalpy of combustion of 2-propanol, $C_3H_7OH(l)$, which combusts in oxygen according to the equation above. The student heats a sample of water by burning some of the $C_3H_7OH(l)$ that is in an alcohol burner, as represented below. The alcohol burner uses a wick to draw liquid up into the flame. The mass of $C_3H_7OH(l)$ combusted is determined by weighing the alcohol burner before and after combustion.



Initial Final

Data from the experiment are given in the table below.

Mass of $C_3H_7OH(l)$ combusted	0.55 g
Mass of water heated	125.00 g
Initial temperature of water	22.0°C
Final temperature of water	51.1°C
Specific heat of water	4.18 J/(g·°C)

(a) Calculate the magnitude of the heat energy, in kJ, absorbed by the water. (Assume that the energy released from the combustion is completely transferred to the water.)

$q = mc\Delta T$ $= (125.00\ g)(4.18\ J/(g\cdot°C))(51.1°C - 22.0°C)$ $= 15{,}200\ J = 15.2\ kJ$	1 point is earned for the correct calculation.

Question 5 (continued)

(b) Based on the experimental data, if one mole of $C_3H_7OH(l)$ is combusted, how much heat, in kJ, is released? Report your answer with the correct number of significant figures.

$1\ \text{mol}\ C_3H_7OH \times \frac{60.09\ \text{g}\ C_3H_7OH}{1\ \text{mol}\ C_3H_7OH} \times \frac{15.2\ \text{kJ}}{0.55\ \text{g}\ C_3H_7OH} = 1661\ \text{kJ}$ $= 1.7 \times 10^3\ \text{kJ}$	1 point is earned for the correct amount of heat released. 1 point is earned for reporting the answer to the appropriate number of significant figures based on the experimental data.

(c) A second student performs the experiment using the same mass of water at the same initial temperature. However, the student uses an alcohol burner containing $C_3H_7OH(l)$ that is contaminated with water, which is miscible with $C_3H_7OH(l)$. The difference in mass of the alcohol burner before and after the combustion in this experiment is also 0.55 g. Would the final temperature of the water in the beaker heated by the alcohol burner in this experiment be greater than, less than, or equal to the final temperature of the water in the beaker in the first student's experiment? Justify your answer.

The final temperature measured by the second student would be less than that measured by the first student because: the actual mass of $C_3H_7OH(l)$ combusted will be less than 0.55 g OR combustion of the contaminated sample will also require vaporization of the water in the sample.	1 point is earned for the correct choice **with** a valid explanation.

ADDITIONAL PAGE FOR ANSWERING QUESTION 5

$\Delta T = 51.7°C - 22.0°C$

a) $q = C \cdot m \cdot \Delta T$ $\Delta T = 29.1°C$

$m = 125.00\ g$

$q = 4.18 \frac{J}{g \cdot C°}\ 125.00\ g\ 29.1°C = 4.18\ J/g \cdot C°$

$q = 15{,}200\ J \Rightarrow$ approximately 15.2 kJ of energy was absorbed by the water

(b) $.55\ g\ C_2H_7OH \cdot \frac{mol\ C_2H_7OH}{60.094\ g}$

$.0092$ mol reacted

$\Delta H = \frac{15.2\ kJ}{.0092} \approx$ 1,700 kJ of energy is released

(C) The final temperature of the water would be less than that of the first student's beaker. This is because .55 g of water contaminated 2-propanol contains less moles of 2-propanol which would mean that less energy is produced in the reaction.

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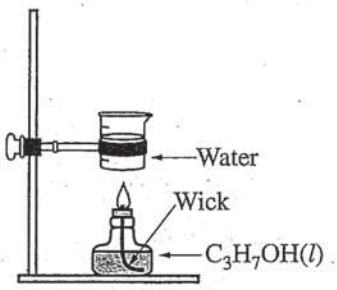
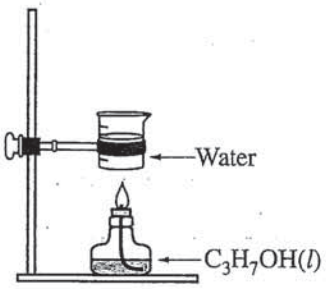
$$2\ C_3H_7OH(l) + 9\ O_2(g) \rightarrow 6\ CO_2(g) + 8\ H_2O(g)$$

5. A student performs an experiment to determine the enthalpy of combustion of 2-propanol, $C_3H_7OH(l)$, which combusts in oxygen according to the equation above. The student heats a sample of water by burning some of the $C_3H_7OH(l)$ that is in an alcohol burner, as represented below. The alcohol burner uses a wick to draw liquid up into the flame. The mass of $C_3H_7OH(l)$ combusted is determined by weighing the alcohol burner before and after combustion.



Initial



Final

Data from the experiment are given in the table below.

Mass of $C_3H_7OH(l)$ combusted	0.55 g
Mass of water heated	125.00 g
Initial temperature of water	22.0°C
Final temperature of water	51.1°C
Specific heat of water	4.18 J/(g·°C)

(a) Calculate the magnitude of the heat energy, in kJ, absorbed by the water. (Assume that the energy released from the combustion is completely transferred to the water.)

(b) Based on the experimental data, if one mole of $C_3H_7OH(l)$ is combusted, how much heat, in kJ, is released? Report your answer with the correct number of significant figures.

(c) A second student performs the experiment using the same mass of water at the same initial temperature. However, the student uses an alcohol burner containing $C_3H_7OH(l)$ that is contaminated with water, which is miscible with $C_3H_7OH(l)$. The difference in mass of the alcohol burner before and after the combustion in this experiment is also 0.55 g. Would the final temperature of the water in the beaker heated by the alcohol burner in this experiment be greater than, less than, or equal to the final temperature of the water in the beaker in the first student's experiment? Justify your answer.

a) $q = mc\Delta t$

$(125g)(4.18J/g°C)(29.1°C) = 15200J = \boxed{15.2\ kJ}$

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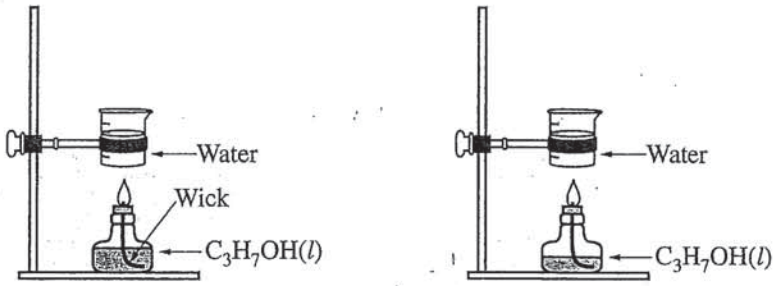
ADDITIONAL PAGE FOR ANSWERING QUESTION 5

b. $\frac{15.2\ \text{kJ}}{.55\text{g}\ C_3H_7OH} \cdot \frac{60.094\text{g}}{1\ \text{mol}} = \boxed{1700\ \text{kJ/mol}}$

c. The final temperature would be less that the final temperature of the water in the first student's beaker because the vaporization of water does not evolve nearly as much heat as the combustion of 2-propanol does.

$$2\ C_3H_7OH(l) + 9\ O_2(g) \rightarrow 6\ CO_2(g) + 8\ H_2O(g)$$ 5C 1 of 2

5. A student performs an experiment to determine the enthalpy of combustion of 2-propanol, $C_3H_7OH(l)$, which combusts in oxygen according to the equation above. The student heats a sample of water by burning some of the $C_3H_7OH(l)$ that is in an alcohol burner, as represented below. The alcohol burner uses a wick to draw liquid up into the flame. The mass of $C_3H_7OH(l)$ combusted is determined by weighing the alcohol burner before and after combustion.



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(a) Calculate the magnitude of the heat energy, in kJ, absorbed by the water. (Assume that the energy released from the combustion is completely transferred to the water.)

(b) Based on the experimental data, if one mole of $C_3H_7OH(l)$ is combusted, how much heat, in kJ, is released? Report your answer with the correct number of significant figures.

(c) A second student performs the experiment using the same mass of water at the same initial temperature. However, the student uses an alcohol burner containing $C_3H_7OH(l)$ that is contaminated with water, which is miscible with $C_3H_7OH(l)$. The difference in mass of the alcohol burner before and after the combustion in this experiment is also 0.55 g. Would the final temperature of the water in the beaker heated by the alcohol burner in this experiment be greater than, less than, or equal to the final temperature of the water in the beaker in the first student's experiment? Justify your answer.

5. a) $\Delta Q = (125\ g\ H_2O)\left(4.18\ \frac{J}{g°C}\ H_2O\right)(29.1°C) = 15204.75\ J\left(\frac{0.001\ KJ}{1\ J}\right)$

$\Delta Q = 15.2\ KJ$

b) $1\ mol\ C_3H_7OH \left| \frac{60.11\ g\ C_3H_7OH}{1\ mol\ C_3H_7OH} \right| \frac{15.2\ KJ}{0.55\ g\ C_3H_7OH} \Big| = 1.66 \times 10^3\ KJ$

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ADDITIONAL PAGE FOR ANSWERING QUESTION 5

c) The water in the beaker heated by the alcohol burner would be less than the final temperature of the first experiment. Since water has a high specific heat, it does not realease as much heat from the burner.

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Question 5

Overview

This question required students to analyze the results of a heat transfer experiment in which a sample of water was heated by the combustion of 2-propanol.

In this question the Learning Objective (LO) assessed was 5.7. The Science Practices (SP) assessed were 4.2, 5.1, and 6.4.

Part (a) required students to use the appropriate experimental data to calculate the amount of energy transferred when a sample of water was heated by the combustion of 2-propanol. Part (b) required students to relate the amount of heat energy transferred from the combustion of 0.55 g of propanol to the amount of heat energy expected from the combustion of one mole of 2-propanol. Part (c) required students to make a choice and justify that choice. Justification problems are inherently difficult as they require students to express their ideas in clear statements. When the scientific language is not yet fully developed within the student, expressing justification regarding changes in an experiment makes this a difficult question.

Sample: 5A
Score: 4

This response earned 4 out of 4 possible points. The student earned 1 point in part (a) for calculating the heat energy, in kJ, using the appropriate data and the equation $q = mc\Delta T$. The student earned 1 point in part (b) for calculating the heat energy, in kJ, per mole of C_3H_7OH. The response earned an additional 1 point in part (b) because the answer was reported with the appropriate number of significant figures (two significant figures) based on the use of the appropriate data (0.55 g). The student earned 1 point in part (c) for stating that the final temperature in the second experiment was less than the final temperature in the first experiment and for justifying this by stating that there was less C_3H_7OH actually used in the second experiment.

Sample: 5B
Score: 3

This response earned 3 out of 4 possible points. The student earned 1 point in part (a) for calculating the heat energy, in kJ, using the appropriate data and the equation $q = mc\Delta T$. The student earned 1 point in part (b) for calculating the heat energy, in kJ, per mole of C_3H_7OH. The response earned an additional 1 point in part (b) because the answer was reported with the appropriate number of significant figures. In part (c) the point was not earned because, although it is true that water will be vaporized from the contaminated 0.55 g sample, the student also indicates that the vaporization of water will evolve heat, which is not correct.

Sample: 5C
Score: 2

This response earned 2 out of 4 possible points. The student earned 1 point in part (a) for calculating the heat energy, in kJ, using the appropriate data and the equation $q = mc\Delta T$. The student earned 1 point in part (b) for calculating the heat energy, in kJ, per mole of C_3H_7OH. An additional point was not earned in part (b) because the answer was not reported with the appropriate number of significant figures. In part (c) the student indicates that the final temperature in the second experiment is less than the final temperature in the first experiment, but the justification does not explain the reason for the lower final temperature and no point was earned.