2019

AP® CollegeBoard

AP® Chemistry

Sample Student Responses and Scoring Commentary

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AP® CHEMISTRY
2019 SCORING GUIDELINES

Question 4

A student is doing experiments with $CO_2(g)$. Originally, a sample of the gas is in a rigid container at 299 K and 0.70 atm. The student increases the temperature of the $CO_2(g)$ in the container to 425 K.

(a) Describe the effect of raising the temperature on the motion of the $CO_2(g)$ molecules.

The average speed of the molecules increases as temperature increases.	1 point is earned for the correct answer.

(b) Calculate the pressure of the $CO_2(g)$ in the container at 425 K.

Both the volume and the number of molecules are constant, therefore $\frac{P_1}{T_1} = \frac{P_2}{T_2} \Rightarrow \frac{0.70 \text{ atm}}{299 \text{ K}} = \frac{P_2}{425 \text{ K}} \Rightarrow P_2 = 0.99 \text{ atm}$	1 point is earned for the correct answer.

(c) In terms of kinetic molecular theory, briefly explain why the pressure of the $CO_2(g)$ in the container changes as it is heated to 425 K.

Faster-moving gas particles collide more frequently with the walls of the container, thus increasing the pressure. OR Faster-moving gas particles collide more forcefully with the walls of the container, thus increasing the pressure.	1 point is earned for a correct explanation.

(d) The student measures the actual pressure of the $CO_2(g)$ in the container at 425 K and observes that it is less than the pressure predicted by the ideal gas law. Explain this observation.

The attractive forces between CO_2 molecules result in a pressure that is lower than that predicted by the ideal gas law.	1 point is earned for a correct explanation.

4. A student is doing experiments with $CO_2(g)$. Originally, a sample of the gas is in a rigid container at 299 K and 0.70 atm. The student increases the temperature of the $CO_2(g)$ in the container to 425 K.

   (a) Describe the effect of raising the temperature on the motion of the $CO_2(g)$ molecules.

   (b) Calculate the pressure of the $CO_2(g)$ in the container at 425 K.

   (c) In terms of kinetic molecular theory, briefly explain why the pressure of the $CO_2(g)$ in the container changes as it is heated to 425 K.

   (d) The student measures the actual pressure of the $CO_2(g)$ in the container at 425 K and observes that it is less than the pressure predicted by the ideal gas law. Explain this observation.

a. Since temperature is directly proportional to kinetic energy, raising the temperature will increase the kinetic energy of the CO_2 molecules, and therefore their velocity since $K=\frac{1}{2}mv^2$ and m (mass) is unchanged.

b. $PV=nRT \rightarrow \frac{P}{T}=\frac{nR}{V}$ $\quad \frac{P_1}{T_1}=\frac{P_2}{T_2}$ when n and V are constant

$$\frac{P_1T_2}{T_1}=P_2 \rightarrow \frac{(.70\,atm)(425\,K)}{(299\,K)}=P_2$$

$$P_2=.99\,atm$$

c. Since raising the temperature increases the velocity of the gas molecules, the molecules experience more collisions with the walls of the container in the same amount of time, which increases pressure since pressure is a measurement of these collisions.

d. The ideal gas law does not account for the intermolecular forces of attraction between gas molecules. Since the molecules are attracted to one another, they will strike the walls less frequently than expected, meaning the actual pressure will be less than the calculated pressure.

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4. A student is doing experiments with $CO_2(g)$. Originally, a sample of the gas is in a rigid container at 299 K and 0.70 atm. The student increases the temperature of the $CO_2(g)$ in the container to 425 K.

   (a) Describe the effect of raising the temperature on the motion of the $CO_2(g)$ molecules.

   (b) Calculate the pressure of the $CO_2(g)$ in the container at 425 K.

   (c) In terms of kinetic molecular theory, briefly explain why the pressure of the $CO_2(g)$ in the container changes as it is heated to 425 K.

   (d) The student measures the actual pressure of the $CO_2(g)$ in the container at 425 K and observes that it is less than the pressure predicted by the ideal gas law. Explain this observation.

(a) Raising the temperature would increase the speed of the CO_2 molecules as they move faster at higher temperatures

(b) $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

$\frac{0.70\ atm}{299\ K} = \frac{X}{425\ K}$

$297.5 = 299\ K\ (X)$

$X = 0.99\ atm$

(c) Since the particles are moving faster at the higher temperature, this causes more collisions on the rigid container. The increase in harder and more frequent collisions increases the pressure as more force is being exerted on the container walls.

(d) The ideal gas law does not account for very high temperatures and this causes the discrepency.

4. A student is doing experiments with $CO_2(g)$. Originally, a sample of the gas is in a rigid container at 299 K and 0.70 atm. The student increases the temperature of the $CO_2(g)$ in the container to 425 K.

   (a) Describe the effect of raising the temperature on the motion of the $CO_2(g)$ molecules.

   (b) Calculate the pressure of the $CO_2(g)$ in the container at 425 K.

   (c) In terms of kinetic molecular theory, briefly explain why the pressure of the $CO_2(g)$ in the container changes as it is heated to 425 K.

   (d) The student measures the actual pressure of the $CO_2(g)$ in the container at 425 K and observes that it is less than the pressure predicted by the ideal gas law. Explain this observation.

a) Increasing the temperature, increases how fast the $CO_{2(g)}$ molecules move. There is more motion and more collisions.

b) $\frac{P_1}{T_1} = \frac{P_2}{T_2}$ $\quad \frac{0.70\ atm}{299\ K} = \frac{P_2}{425\ K}$

$0.99\ atm = P_2$

c) The pressure increases when temperature is raised because gas molecules move faster and collide with each other more when temperature is raised.

d) The conditions of the CO_2 gas at 425 K are not ideal conditions.

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AP® CHEMISTRY
2019 SCORING COMMENTARY

Question 4

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

Overview

This question assesses students' mathematical and conceptual understanding of the behavior of gaseous CO_2 at both the particle and macroscopic levels. In part (a) students need to associate an increase in temperature with an increase in the average kinetic energy (average velocity) of the gas particles (LO 2.4; SP 1.4, 6.4). Part (b) asks students to calculate the pressure of $CO_2(g)$ at a new elevated temperature. The most straightforward solution uses Gay-Lussac's law, since the volume of the container and the number of moles of gas particles remain constant, but another valid method uses the ideal gas equation (LO 2.6; SP 2.2). In part (c) students must explain, using principles of kinetic molecular theory, why the pressure of the gas changes as it is heated (LO 2.4; SP 1.4, 6.4). They must recognize that pressure is caused by molecules of gas colliding with the walls of the container and that at higher temperatures those collisions are more frequent and more forceful. Part (d) presents students with a scenario in which the actual pressure of CO_2 at elevated temperature is less than that predicted by the ideal gas law (LO 2.12; SP 5.1, 6.5). Although gases may deviate from ideal behavior for a few different reasons, the presence of an attractive force between gas particles is most consistent with this experimental observation.

Sample: 4A
Score: 4

The response earned 4 out of 4 possible points. In part (a) the student correctly describes that the velocity of molecules increases and earned 1 point. In part (b) the student correctly calculates the pressure and earned 1 point. In part (c) the student correctly explains that molecules experience more collisions with the walls of the container in the same amount of time and earned 1 point. In part (d) the student correctly explains that intermolecular forces of attraction between gas molecules cause the deviation and earned 1 point.

Sample: 4B
Score: 3

The response earned 3 out of 4 possible points. In part (a) the student correctly describes an increase in speed of the molecules and earned 1 point. In part (b) the student correctly calculates the pressure and earned 1 point. In part (c) the student correctly explains that harder and more frequent collisions exert more force on the container walls and earned 1 point. In part (d) the student incorrectly states that the ideal gas law does not account for high temperatures and did not earn the point.

Sample: 4C
Score: 2

The response earned 2 out of 4 possible points. In part (a) the student correctly describes an increase in how fast the molecules move and earned 1 point. In part (b) the student correctly calculates the pressure and earned 1 point. In part (c) the student states that particles collide more with each other but does not further explain that particles collide more with the walls of the container and did not earn the point. In part (d) the student incorrectly identifies nonideal conditions as the explanation and did not earn the point.