2023

AP® Chemistry

Sample Student Responses and Scoring Commentary

Inside:

Free-Response Question 4

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

Question 4: Short Answer — 4 points

(a) For the correct calculated value: **1 point**

$$0.00250 \text{ mol } CH_3NH_3Cl \times \frac{67.52 \text{ g}}{1 \text{ mol}} = 0.169 \text{ g}$$

(b) For a correct description of step 1: **1 point**

Accept one of the following:

- *Use the spatula, balance, and weighing paper to measure out exactly* 0.169 g *of* $CH_3NH_3Cl(s)$.
- *Use the balance to weigh out the mass of solid in part (a).*

For a correct description of step 4: **1 point**

Rinse the buret with a small amount of $0.100\ M\ CH_3NH_2(aq)$*, drain, and refill with* $0.100\ M\ CH_3NH_2(aq)$.

Total for part (b) 2 points

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

Equal to. The ratio of weak acid to conjugate base is still 1:1.

Total for question 4 4 points

Question 4

Begin your response to QUESTION 4 on this page.

4. A student is asked to prepare a buffer solution made with equimolar amounts of $CH_3NH_2(aq)$ and $CH_3NH_3Cl(s)$. The student uses 25.00 mL of 0.100 *M* $CH_3NH_2(aq)$, which contains 0.00250 mol of CH_3NH_2, to make the buffer.

(a) Calculate the mass of $CH_3NH_3Cl(s)$ that contains 0.00250 mol of CH_3NH_3Cl.

$$0.00250 \text{ mol } CH_3NH_3Cl \cdot \frac{67.518 \text{ g } CH_3NH_3Cl}{1 \text{ mol } CH_3NH_3Cl} = 0.169 \text{ g } CH_3NH_3Cl$$

The student has the following materials and equipment available.

• Distilled water	• Electronic balance	• 50 mL beaker	• Pipets
• 0.100 *M* $CH_3NH_2(aq)$	• Weighing paper	• 10.0 mL graduated cylinder	• pH meter
• Solid CH_3NH_3Cl	• 50.00 mL buret	• Small spatula	

(b) The following table contains a partial procedure for making the buffer solution. Fill in steps 1 and 4 to complete the procedure using only materials and equipment selected from the choices given. (Not all materials listed will be used. Assume that all appropriate safety measures are already in place.)

Step	Procedure
1	Record the mass of the weighing paper on the electronic balance, then add $CH_3NH_3Cl(s)$ until the balance reads (0.169 g + [mass of weighing paper]). (The small spatula can be used to scoop the solid onto the weighing paper.)
2	Place the solid in the 50 mL beaker.
3	Clean the buret and rinse with distilled water.
4	Rinse buret with 0.100 M CH_3NH_2. Add 0.100 M CH_3NH_2 into the buret (more than 25.00 mL of it). (50.00 mL)
5	Use the buret to add 25.00 mL of 0.100 *M* $CH_3NH_2(aq)$ to the beaker.
6	Mix well.
7	Check the pH with the pH meter.

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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.

0138555

Q5185/12

Question 4

Continue your response to **QUESTION 4** on this page.

The value of K_b for $CH_3NH_2(aq)$ is 4.4×10^{-4}, and the pH of the buffer the student prepared is 10.64.

(c) The student prepares a second buffer solution. The student uses 25.00 mL of 0.050 *M* $CH_3NH_2(aq)$ instead of 25.00 mL of 0.100 *M* $CH_3NH_2(aq)$, and half the mass of $CH_3NH_3Cl(s)$ that was used in the first buffer. Is the pH of the second buffer greater than, less than, or equal to the pH of the first buffer? Justify your answer.

$0.02500\ L \cdot 0.050\ M = 0.00125\ mol\ CH_3NH_2$

$\frac{0.169\ g}{2} \cdot \frac{1\ mol}{67.518\ g} = 0.00125\ mol\ CH_3NH_3Cl$

Since CH_3NH_2 and CH_3NH_3Cl are still present in equimolar amounts in the second buffer, ~~[illegible]~~ the two buffers have equal pH.

Question 4

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4. A student is asked to prepare a buffer solution made with equimolar amounts of $CH_3NH_2(aq)$ and $CH_3NH_3Cl(s)$. The student uses 25.00 mL of 0.100 *M* $CH_3NH_2(aq)$, which contains 0.00250 mol of CH_3NH_2, to make the buffer.

(a) Calculate the mass of $CH_3NH_3Cl(s)$ that contains 0.00250 mol of CH_3NH_3Cl.

molar mass = 67.518 g/mol

$0.00250 \text{ mol} \cdot \frac{67.518 \text{ g}}{1 \text{ mol}} = 0.169 \text{ g } CH_3NH_3Cl$

The student has the following materials and equipment available.

- Distilled water ✓
- Electronic balance ✓
- 50 mL beaker ✓
- Pipets
- 0.100 *M* $CH_3NH_2(aq)$
- Weighing paper ✓
- 10.0 mL graduated cylinder
- pH meter
- Solid CH_3NH_3Cl ✓
- 50.00 mL buret ✓
- Small spatula ✓

(b) The following table contains a partial procedure for making the buffer solution. Fill in steps 1 and 4 to complete the procedure using only materials and equipment selected from the choices given. (Not all materials listed will be used. Assume that all appropriate safety measures are already in place.)

Step	Procedure
1	measure 0.169 g CH_3NH_3Cl (s) using a small spatula and weighing paper on an electronic balance (make sure to zero scale after putting paper on).
2	Place the solid in the 50 mL beaker.
3	Clean the buret and rinse with distilled water.
4	rinse the buret with a small amount of the CH_3NH_2 solution and then fill buret w/ solution. mark the initial volume of buret.
5	Use the buret to add 25.00 mL of 0.100 *M* $CH_3NH_2(aq)$ to the beaker.
6	Mix well.
7	Check the pH with the pH meter.

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0135227

Q5185/12

Question 4

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The value of K_b for $CH_3NH_2(aq)$ is 4.4×10^{-4}, and the pH of the buffer the student prepared is 10.64.

(c) The student prepares a second buffer solution. The student uses 25.00 mL of 0.050 *M* $CH_3NH_2(aq)$ instead of 25.00 mL of 0.100 *M* $CH_3NH_2(aq)$, and half the mass of $CH_3NH_3Cl(s)$ that was used in the first buffer. Is the pH of the second buffer greater than, less than, or equal to the pH of the first buffer? Justify your answer.

moles of CH_3NH_2 = 1/2

1/2 mass = 1/2 moles of CH_3NH_3Cl (0.00125)

$CH_3NH_2 + H_2O \rightarrow CH_3NH_3^+ + OH^-$

2nd →

	0.05	0	0
	−x	+x	+x
	0.05−x	x	x

2nd $4.4 \cdot 10^{-4} = \frac{x^2}{0.05 - x}$ $x = 0.00448\ M$

$[OH^-] = 0.00448\ M$

1st $4.4 \cdot 10^{-4} = \frac{x^2}{0.1 - x}$ $x = 0.00642\ M$

$[OH^-] = 0.00642\ M$

since 0.00448 M < 0.00642 M, $[OH^-]$ in the 2nd is less than $[OH^-]$ in the 1st. The ↑ the concentration of OH^-, the ↑ the pH is (closer to 14 / more basic). Since $[OH^-]$ is lower in the 2nd one, it will have a pH that is lower, than the 1st buffer. (less basic)

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Question 4

Begin your response to **QUESTION 4** on this page.

4. A student is asked to prepare a buffer solution made with equimolar amounts of $CH_3NH_2(aq)$ and $CH_3NH_3Cl(s)$. The student uses 25.00 mL of 0.100 *M* $CH_3NH_2(aq)$, which contains 0.00250 mol of CH_3NH_2, to make the buffer.

(a) Calculate the mass of $CH_3NH_3Cl(s)$ that contains 0.00250 mol of CH_3NH_3Cl.

12 14 35.45
67.47

.169 g CH_3NH_3Cl

~~C 110 5 CH 3 NH 3 Cl~~

The student has the following materials and equipment available.

• Distilled water	• Electronic balance	• 50 mL beaker	• Pipets
X • 0.100 *M* $CH_3NH_2(aq)$	• Weighing paper	• 10.0 mL graduated cylinder	• pH meter
• Solid CH_3NH_3Cl	• 50.00 mL buret	• Small spatula	

(b) The following table contains a partial procedure for making the buffer solution. Fill in steps 1 and 4 to complete the procedure using only materials and equipment selected from the choices given. (Not all materials listed will be used. Assume that all appropriate safety measures are already in place.)

Step	Procedure
1	Weigh .169 g CH_3NH_3Cl
2	Place the solid in the 50 mL beaker.
3	Clean the buret and rinse with distilled water.
4	place > 25.00 mL of .1 M $CH_3NH_{2(aq)}$ in buret
5	Use the buret to add 25.00 mL of 0.100 *M* $CH_3NH_2(aq)$ to the beaker.
6	Mix well.
7	Check the pH with the pH meter.

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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.

0106440

Q5185/12

Question 4

Continue your response to **QUESTION 4** on this page.

The value of K_b for $CH_3NH_2(aq)$ is 4.4×10^{-4}, and the pH of the buffer the student prepared is 10.64.

(c) The student prepares a second buffer solution. The student uses 25.00 mL of 0.050 *M* $CH_3NH_2(aq)$ instead of 25.00 mL of 0.100 *M* $CH_3NH_2(aq)$, and half the mass of $CH_3NH_3Cl(s)$ that was used in the first buffer. Is the pH of the second buffer greater than, less than, or equal to the pH of the first buffer? Justify your answer.

Equal to the pH of the first buffer

because the proportions of CH_3NH_2 to CH_3NH_3Cl are the same in both solutions

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Question 4

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

Overview

Question 4 presented students with an array of questions concerning the preparation and analysis of buffer solutions with equimolar amounts of the weak base, CH_3NH_2, and its conjugate acid, $CH_3NH_3^+$.

Part (a) required students to apply mathematical routines to determine the mass of $CH_3NH_3Cl(s)$ required to prepare the desired buffer (Learning Objective SPQ-1.A, Skill 5.F from the *AP Chemistry Course and Exam Description*). The student must use the periodic table to determine the molar mass of CH_3NH_3Cl to convert a given mole value to grams to earn the point.

Part (b) required students to identify appropriate experimental procedures required to accurately weigh a mass of solid (SPQ-1.A, 2.C) and prepare a buret to deliver a precise volume of solution (SPQ-3.A, 2.C). The students were presented with an incomplete procedure and tasked with filling in two missing procedural steps. The first point was earned for the correct selection of the electronic balance to measure the mass of $CH_3NH_3Cl(s)$ calculated in part (a) in Step 1 of the procedure. The second point was earned for rinsing the wet buret with the 0.100 *M* CH_3NH_2 solution prior to filling it with the 0.100 *M* CH_3NH_2, in order to prevent dilution of the solution in Step 4 of the procedure.

Part (c) required students to integrate mathematical and conceptual reasoning to predict the outcome of an experimental modification to the preparation of the buffer (SAP-10.C, 2.F). The procedure was modified by halving both the moles of CH_3NH_2 and the mass of CH_3NH_3Cl. The point was earned for a response that indicates the pH would remain the same, employing a mathematical and/or conceptual justification that the mole ratio of buffer components is the same as in the first buffer solution; therefore, the pH of the second solution is the same as the first solution.

Sample: 4A
Score: 4

This response earned 4 points. In part (a) the point was earned for correctly calculating the mass of CH_3NH_3Cl with supporting work. In part (b) the first point was earned for correctly indicating the need to measure the mass of CH_3NH_3Cl using the electronic balance. The second point was earned for first rinsing and then filling the buret with 0.100 *M* CH_3NH_2. In part (c) the point was earned for correctly claiming that the pH of the first buffer is equal to the pH of the second buffer with supporting justification using the consistent 1:1 molar ratios of conjugate acid to base.

Sample: 4B
Score: 3

This response earned 3 points. In part (a) the point was earned for correctly calculating the mass of CH_3NH_3Cl with supporting work. In part (b) the first point was earned for correctly indicating the need to measure the mass of CH_3NH_3Cl using the electronic balance. The second point was earned

Question 4 (continued)

for both rinsing and filling the buret with 0.100 *M* CH_3NH_2. In part (c) the point was not earned because the response incorrectly states that the pH of the second buffer is less than the pH of the first buffer.

Sample: 4C
Score: 1

This response earned 1 point. In part (a) the point was not earned. Even though the correct mass of CH_3NH_3Cl is provided, insufficient supportive work is shown to justify the calculation. In part (b) the first point was not earned because the response does not include the equipment needed to measure the mass of CH_3NH_3Cl (electronic balance). The second point was not earned because the buret is not first rinsed with CH_3NH_2 before being filled. In part (c) the point was earned for correctly claiming that the pH of the first buffer is equal to the pH of the second buffer with supporting justification using the consistent ratios of conjugate acid to base.