AP® CHEMISTRY
2011 SCORING GUIDELINES

Question 2

A student is assigned the task of determining the mass percent of silver in an alloy of copper and silver by dissolving a sample of the alloy in excess nitric acid and then precipitating the silver as $AgCl$.

First the student prepares 50. mL of 6 M HNO_3.

(a) The student is provided with a stock solution of 16 M HNO_3, two 100 mL graduated cylinders that can be read to ±1 mL, a 100 mL beaker that can be read to ±10 mL, safety goggles, rubber gloves, a glass stirring rod, a dropper, and distilled H_2O.

(i) Calculate the volume, in mL, of 16 M HNO_3 that the student should use for preparing 50. mL of 6 M HNO_3.

moles before dilution = moles after dilution $M_i V_i = M_f V_f$ $(16\ M)(V_i) = (6\ M)(50.\ \text{mL})$ V_i = 19 mL or 20 mL (to one significant figure)	1 point is earned for the correct volume.

(ii) Briefly list the steps of an appropriate and safe procedure for preparing the 50. mL of 6 M HNO_3. Only materials selected from those provided to the student (listed above) may be used.

Wear safety goggles and rubber gloves. Then measure 19 mL of 16 M HNO_3 using a 100 mL graduated cylinder. Measure 31 mL of distilled H_2O using a 100 mL graduated cylinder. Transfer the water to a 100 mL beaker. Add the acid to the water with stirring.	1 point is earned for properly measuring the volume of 16 M HNO_3 and preparing a 6 M HNO_3 acid solution. 1 point is earned for wearing protective gear and for adding acid to water.

(iii) Explain why it is <u>not</u> necessary to use a volumetric flask (calibrated to 50.00 mL ±0.05 mL) to perform the dilution.

The graduated cylinders provide sufficient precision in volume measurement to provide two significant figures, making the use of the volumetric flask unnecessary.	1 point is earned for an acceptable explanation.

(iv) During the preparation of the solution, the student accidentally spills about 1 mL of 16 M HNO_3 on the bench top. The student finds three bottles containing liquids sitting near the spill: a bottle of distilled water, a bottle of 5 percent $NaHCO_3(aq)$, and a bottle of saturated $NaCl(aq)$. Which of the liquids is best to use in cleaning up the spill? Justify your choice.

$NaHCO_3(aq)$ should be used. The HCO_3^- ion will react as a base to neutralize the HNO_3.	1 point is earned for the correct choice with explanation.

Then the student pours 25 mL of the 6 M HNO_3 into a beaker and adds a 0.6489 g sample of the alloy. After the sample completely reacts with the acid, some saturated $NaCl(aq)$ is added to the beaker, resulting in the formation of an $AgCl$ precipitate. Additional $NaCl(aq)$ is added until no more precipitate is observed to form. The precipitate is filtered, washed, dried, and weighed to constant mass in a filter crucible. The data are shown in the table below.

Mass of sample of copper-silver alloy	0.6489 g
Mass of dry filter crucible	28.7210 g
Mass of filter crucible and precipitate (first weighing)	29.3587 g
Mass of filter crucible and precipitate (second weighing)	29.2599 g
Mass of filter crucible and precipitate (third weighing)	29.2598 g

(b) Calculate the number of moles of $AgCl$ precipitate collected.

mass of AgCl collected = (29.2598 – 28.7210) g = 0.5388 g $\frac{0.5388\ \text{g}}{(107.87 + 35.45)\ \text{g mol}^{-1}} = 3.759 \times 10^{-3}$ mol AgCl	1 point is earned for the correct mass of $AgCl$. 1 point is earned for the correct number of moles of $AgCl$ given with the correct number of significant figures.

(c) Calculate the mass percent of silver in the alloy of copper and silver.

3.759×10^{-3} mol Ag $\times \frac{107.87\ \text{g Ag}}{1\ \text{mol Ag}} = 0.4055$ g Ag $\frac{0.4055\ \text{g}}{0.6489\ \text{g}} \times 100\% = 62.49\%$ Ag	1 point is earned for the correct setup and the correct calculation of the mass of Ag. 1 point is earned for the correct percent of Ag.

2A1

2. A student is assigned the task of determining the mass percent of silver in an alloy of copper and silver by dissolving a sample of the alloy in excess nitric acid and then precipitating the silver as AgCl.

First the student prepares 50. mL of 6 *M* HNO_3.

(a) The student is provided with a stock solution of 16 *M* HNO_3, two 100 mL graduated cylinders that can be read to ±1 mL, a 100 mL beaker that can be read to ±10 mL, safety goggles, rubber gloves, a glass stirring rod, a dropper. and distilled H_2O.

(i) Calculate the volume, in mL, of 16 *M* HNO_3 that the student should use for preparing 50. mL of 6 *M* HNO_3.

(ii) Briefly list the steps of an appropriate and safe procedure for preparing the 50. mL of 6 *M* HNO_3. Only materials selected from those provided to the student (listed above) may be used.

(iii) Explain why it is <u>not</u> necessary to use a volumetric flask (calibrated to 50.00 mL ±0.05 mL) to perform the dilution.

(iv) During the preparation of the solution, the student accidentally spills about 1 mL of 16 *M* HNO_3 on the bench top. The student finds three bottles containing liquids sitting near the spill: a bottle of distilled water, a bottle of 5 percent $NaHCO_3(aq)$, and a bottle of saturated $NaCl(aq)$. Which of the liquids is best to use in cleaning up the spill? Justify your choice.

Then the student pours 25 mL of the 6 *M* HNO_3 into a beaker and adds a 0.6489 g sample of the alloy. After the sample completely reacts with the acid, some saturated $NaCl(aq)$ is added to the beaker, resulting in the formation of an AgCl precipitate. Additional $NaCl(aq)$ is added until no more precipitate is observed to form. The precipitate is filtered, washed, dried, and weighed to constant mass in a filter crucible. The data are shown in the table below.

Mass of sample of copper-silver alloy	0.6489 g
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Mass of filter crucible and precipitate (first weighing)	29.3587 g
Mass of filter crucible and precipitate (second weighing)	29.2599 g
Mass of filter crucible and precipitate (third weighing)	29.2598 g

(b) Calculate the number of moles of AgCl precipitate collected.

(c) Calculate the mass percent of silver in the alloy of copper and silver.

a) ① $18.8\ mL\ HNO_3 = .050\ L\ HNO_3 \left|\frac{6\ mol}{1\ L}\right| \frac{1\ mol}{1\ mol} \left|\frac{1\ L}{16\ mol}\right| \frac{1000\ mL}{1\ L}$ 18.75

ADDITIONAL PAGE FOR ANSWERING QUESTION 2

(II) While wearing safety goggles, the student should measure out 19 mL of 16M HNO_3 into one of the 100. mL graduated cylinders and 31 mL of distilled water into the other 100 mL graduated cylinder. Then, pour the distilled H_2O into the 100 mL beaker. Add the 19 mL of HNO_3 to the beaker of distilled H_2O and mix with the stirring rod.

(III) Because the molarity does not have to be exact. The acid is only used to dissolve the alloy and the molarity will not affect the results.

(IV) $NaHCO_3$ is baking soda which will neutralize the HNO_3.

b) $29.2598\text{ g} - 28.7210\text{ g} = .5388\text{ g AgCl}$

$3.759\times10^{-3}\text{ mol AgCl} = .5388\text{ g AgCl} \left| \frac{1\text{ mol}}{143.32\text{ g}} \right.$

c) $.4055\text{ g Ag} = .5388\text{ g AgCl} \left| \frac{1\text{ mol}}{143.32\text{ g}} \right| \frac{1\text{ mol Ag}}{1\text{ mol AgCl}} \left| \frac{107.87\text{ g}}{1\text{ mol Ag}} \right.$

$\left(\frac{.4055\text{ g Ag}}{.6489\text{ g sample of alloy}} \right) 100 = 62.49\%$

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ADDITIONAL PAGE FOR ANSWERING QUESTION 2

2-a-i. $V_1 M_1 = V_2 M_2$

$V_1 (16\,M) = (50.\,mL)(6\,M)$

$\boxed{V_1 = 19\,mL}$

ii. The student should slowly pour the 16 M solution of HNO_3 into a graduated cylinder to the 19 mL line. Then the student should pour the solution into the beaker. A second graduated cylinder should be filled with distilled H_2O to 31 mL. The H_2O should then be added to the solution in the beaker. Finally, the solution should be stirred with the stirring rod.

iii. Since the volumes of solution and H_2O are additive, the two graduated cylinders can be used to properly measure out a sum of 50 mL of solution.

iv. The bottle of $NaHCO_3$ should be used because it is a weak base and can neutralize the HNO_3.

b. $29.2598\,g - 28.7210\,g = .5388\,g\ ppt \times \frac{1\ mol\ AgCl}{143.32\,g\ AgCl} = \boxed{.003759\ mol\ AgCl}$

c. $.003759\ mol\ AgCl \times \frac{1\ mol\ Ag}{1\ mol\ AgCl} \times \frac{107.8\,g\ Ag}{1\ mol\ Ag} = .4055\,g\ Ag$

$\frac{.4055\,g\ Ag}{.6489\,g\ alloy} \times 100\% = \boxed{62.49\%}$

ADDITIONAL PAGE FOR ANSWERING QUESTION 2

a) i) $6\,M \times 0.05\,L = 0.3\ mol\ HNO_3$

$16\,M \times V\,L = 0.3\ mol\ HNO_3$

$V = 0.01875\,L$

$\boxed{V = 19\,mL}$

ii) • Put on safety goggles and rubber gloves
• Measure 19 mL of 16 M HNO_3 into one of the graduated cylinders using a dropper
• Measure 31 mL of DI H_2O into the other graduated cylinder
• Pour the contents of both graduated cylinders into the beaker
• Stir the resulting solution with the glass stirring rod.

iii) There is no solid to be dissolved/ionized and therefore no volumetric flask is needed

iv) The bottle of 5% $NaHCO_3$
$NaHCO_3$ can be used as a weak base to neutralize the acid unlike the other liquids

b) $29.2528 - 28.7210 = 0.5318\,g$

$107.87\,g/mol\ Ag$
$35.45\,g/mol\ Cl$

$0.5318\,g \times \frac{1\,mol}{143.32\,g} = \boxed{3.7106 \times 10^{-3}\ mol\ AgCl}$

c) $3.7106 \times 10^{-3}\ mol\ Ag$

$3.7106 \times 10^{-3}\ mol\ Ag \times 107.87\,g/mol = 0.4003\,g\ Ag$

$\frac{0.4003\,g\ Ag}{0.6489\,g\ Cu\text{-}Ag} \times 100 = \boxed{61.683\%\ Ag\ by\ mass}$

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AP® CHEMISTRY
2011 SCORING COMMENTARY

Question 2

Overview

This question assessed students' knowledge and skills pertaining to a laboratory experience involving the determination of the mass percent of silver in a copper-silver alloy. The question consisted of both mathematical and conceptual applications of chemistry. Part (a) was primarily concerned with the laboratory process itself: diluting an acid (a mathematical determination and an experimental process in which students are provided with a specific list of equipment), comparing/contrasting appropriate glassware based on the level of precision of the dilution, and cleaning up an acid spill. Parts (b) and (c) focused on the manipulation of experimental data: students determined the number of moles of AgCl precipitate and the mass percent of Ag in the Cu-Ag alloy.

Sample: 2A
Score: 9

This response earned all available points. Part (a)(i) earned 1 point for the correct determination of the volume of 16 *M* HNO_3 required to prepare a 6 *M* solution. Part (a)(ii) earned 2 points: 1 procedure point for correctly measuring the required volumes of water and HNO_3 in graduated cylinders, and 1 safety point for indicating the use of the personal protective equipment and correctly adding the acid to the water. Part (a)(iii) earned 1 point. Part (a)(iv) earned 1 point for the selection of sodium hydrogen carbonate to clean up the spill, with a correct justification that the base can neutralize the HNO_3. Part (b) earned 2 points. The first point was earned for correctly determining the mass of dried AgCl precipitate, and the second point was earned for correctly converting from grams of AgCl to moles and reporting this value with the accepted number of significant figures. Part (c) earned 2 points: The first point was earned for correctly determining the mass of Ag in the AgCl precipitate, and the second point was earned for correctly determining the mass percent of Ag in the alloy.

Sample: 2B
Score: 7

Part (a)(ii) earned 1 of 2 available points: The procedure point was earned for correctly using graduated cylinders to measure out the required volumes of HNO_3 and water. The safety point was not earned because the use of the provided personal protective equipment is omitted, and the student indicates that water was being added to the acid. Part (a)(iii) did not earn the point because the student does not correlate the relative precision of the glassware to the level of precision required to prepare the 6 *M* acid solution.

Sample: 2C
Score: 5

Part (a)(ii) earned 1 of 2 possible points: The procedure point was earned for using graduated cylinders to measure the required volumes of acid and water. Although goggles and gloves are mentioned, the safety point was not earned because the student does not specify that the acid should be poured into the water. Part (a)(iii) did not earn the point because the student does not correlate the relative precision of the glassware to the level of precision required to prepare the 6 *M* acid solution. Part (b) did not earn points. The first point was not earned because there is a mathematical error in the determination of the mass of the AgCl precipitate.

Question 2 (continued)

The response would have earned the second point for correctly calculating the moles of AgCl based on the incorrect mass of the precipitate, but the answer is recorded with an incorrect number of significant figures for the reported number of moles of AgCl. Part (c) earned 2 points: the first point for correctly converting from moles of AgCl (found in part (b)) to grams of Ag in the precipitate, and the second point for correctly calculating a consistent mass percent of Ag in the alloy.