AP® CHEMISTRY
2013 SCORING GUIDELINES

Question 4
(15 points)

For each of the following three reactions, write a balanced equation for the reaction in part (i) and answer the question about the reaction in part (ii). In part (i), coefficients should be in terms of lowest whole numbers. Assume that solutions are aqueous unless otherwise indicated. Represent substances in solutions as ions if the substances are extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. You may use the empty space at the bottom of the next page for scratch work, but only equations that are written in the answer boxes provided will be scored.

EXAMPLE:

A strip of magnesium metal is added to a solution of silver(I) nitrate.

(i) Balanced equation:

$Mg + 2\,Ag^{+} \longrightarrow Mg^{2+} + 2\,Ag$

(ii) Which substance is oxidized in the reaction?

Mg is oxidized.

(a) A 20.0 mL sample of 0.10 *M* potassium phosphate is added to a 30.0 mL sample of 0.10 *M* calcium chloride.

(i) $3\,Ca^{2+} + 2\,PO_4^{3-} \rightarrow Ca_3(PO_4)_2$	2 points are earned for the correct reactants. 1 point is earned for the correct product. 1 point is earned for the correct balance of both mass and charge.

(ii) How many moles of product are formed?

$V \times M = (0.0200\text{ L})(0.10\ M) = 0.0020\text{ mol } PO_4^{3-}$ $V \times M = (0.0300\text{ L})(0.10\ M) = 0.0030\text{ mol } Ca^{2+}$ Therefore, 0.0010 mole of $Ca_3(PO_4)_2$ is formed.	1 point is earned for the correct number of moles with mathematical justification.

Question 4 (continued)

(b) Carbon dioxide gas is bubbled into freshly distilled water.

(i) $CO_2 + H_2O \rightarrow H^+ + HCO_3^-$ OR $CO_2 + 2\,H_2O \rightarrow H_3O^+ + HCO_3^-$ OR $CO_2 + H_2O \rightarrow H_2CO_3$	1 point is earned for the correct reactants. 2 points are earned for the correct product(s). 1 point is earned for the correct balance of both mass and charge.

(ii) The pH of the solution decreases as the reaction proceeds. Explain.

The reaction produces an acidic species. The solution pH decreases as $[H^+]$ increases.	1 point is earned for a correct explanation.

(c) A piece of zinc metal is placed in a 1.0 *M* solution of hydrochloric acid at 25°C.

(i) $Zn + 2\,H^+ \rightarrow Zn^{2+} + H_2$	1 point is earned for the correct reactants. 2 points are earned for the correct products. 1 point is earned for the correct balance of both mass and charge.

(ii) When a piece of zinc metal is placed in a 1.0 *M* solution of ethanoic (acetic) acid at 25°C, the rate of reaction is slower than when 1.0 *M* hydrochloric acid at 25°C is used. Explain.

Ethanoic acid is a weak acid while HCl is a strong acid, so $[H^+]$ will be less than it would be with HCl. The rate of reaction depends on $[H^+]$, so the rate will be slower in ethanoic acid than in hydrochloric acid.	1 point is earned for a correct explanation.

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CHEMISTRY

Part B

Time—40 minutes

NO CALCULATORS MAY BE USED FOR PART B.

Answer Question 4 below. The Section II score weighting for this question is 10 percent.

4. For each of the following three reactions, write a balanced equation for the reaction in part (i) and answer the question about the reaction in part (ii). In part (i), coefficients should be in terms of lowest whole numbers. Assume that solutions are aqueous unless otherwise indicated. Represent substances in solutions as ions if the substances are extensively ionized. Omit formulas for any ions or molecules that are unchanged by the reaction. You may use the empty space at the bottom of the next page for scratch work, but only equations that are written in the answer boxes provided will be scored.

EXAMPLE:

A strip of magnesium metal is added to a solution of silver(I) nitrate.

(i) Balanced equation:

$Mg + 2Ag^+ \longrightarrow Mg^{2+} + 2Ag$

(ii) Which substance is oxidized in the reaction?

Mg is oxidized.

(a) A 20.0 mL sample of 0.10 *M* potassium phosphate is added to a 30.0 mL sample of 0.10 *M* calcium chloride.

(i) Balanced equation:

$2PO_4^{3-} + 3Ca^{2+} \rightarrow Ca_3(PO_4)_2$

(ii) How many moles of product are formed?

$.10M = \frac{x\ mol\ PO_4^{3-}}{.02L} \rightarrow x = .002\ mol,\ .10M\ Ca^{2+} = \frac{y\ mol}{.03L} = .003\ mol$

$.002\ mol\ /2 = .001\ mol\ product$

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B B B B B B B B B B B B B B 4A 2

(b) Carbon dioxide gas is bubbled into freshly distilled water.

(i) Balanced equation:

$CO_2 + H_2O \rightarrow H_2CO_3$

(ii) The pH of the solution decreases as the reaction proceeds. Explain.

The product, H_2CO_3, is an acid because a nonmetallic oxide is being added to water. The pH goes down because the product is acidic.

(c) A piece of zinc metal is placed in a 1.0 *M* solution of hydrochloric acid at 25°C.

(i) Balanced equation:

$Zn + 2H^+ \rightarrow Zn^{2+} + H_2$

(ii) When a piece of zinc metal is placed in a 1.0 *M* solution of ethanoic (acetic) acid at 25°C, the rate of reaction is slower than when 1.0 *M* hydrochloric acid at 25°C is used. Explain.

Acetic acid is a weaker acid than HCl and has a lower concentration of H^+. Since the concentration of the reactants is lower, the reaction proceeds more slowly.

YOU MAY USE THE SPACE BELOW FOR SCRATCH WORK, BUT ONLY EQUATIONS THAT ARE WRITTEN IN THE ANSWER BOXES PROVIDED WILL BE SCORED.

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CHEMISTRY

Part B

Time—40 minutes

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(i) Balanced equation:

$Mg + 2Ag^+ \longrightarrow Mg^{2+} + 2Ag$

(ii) Which substance is oxidized in the reaction?

Mg is oxidized.

(a) A 20.0 mL sample of 0.10 *M* potassium phosphate is added to a 30.0 mL sample of 0.10 *M* calcium chloride.

(i) Balanced equation:

$2PO_3^- + Ca^{+2} \longrightarrow Ca(PO_3)_2$

(ii) How many moles of product are formed?

.001 mol $Ca(PO_3)_2$

$2K^+ + 2PO_3^- + Ca^{+2} + 2Cl^- \longrightarrow 2K^+ + 2Cl^- + Ca(PO_3)_2$

KPO_3 : $.1 = \frac{mol}{.020}$ $\quad CaCl_2$ $.1 = \frac{mol}{.030}$

.002 mol $\quad$ .003 mol

$\frac{.002\ mol}{} \left| \frac{1\ mol\ Ca(PO_3)_2}{2\ mol} \right.$ $\quad \frac{.003\ mol}{} \left| \frac{1\ mol\ Ca(PO_3)_2}{1\ mol} \right. = .003\ mol$

$= .001\ mol$

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4Ba

B B B B B B B B B B B B B B

(b) Carbon dioxide gas is bubbled into freshly distilled water. $CO_2 + H-OH$

(i) Balanced equation:

$$CO_2 + H_2O \longrightarrow CO_3^- + 2H^+$$

(ii) The pH of the solution decreases as the reaction proceeds. Explain.

The reaction increases the amount of H^+ in the solution making it more acidic ∴ pH↓

(c) A piece of zinc metal is placed in a 1.0 *M* solution of hydrochloric acid at 25°C.

(i) Balanced equation:

$$Zn + 2H^+ \longrightarrow Zn^{+2} + H_2$$

(ii) When a piece of zinc metal is placed in a 1.0 *M* solution of ethanoic (acetic) acid at 25°C, the rate of reaction is slower than when 1.0 *M* hydrochloric acid at 25°C is used. Explain.

HCl is a strong acid so it ionizes quicker than ethanoic acid.

YOU MAY USE THE SPACE BELOW FOR SCRATCH WORK, BUT ONLY EQUATIONS THAT ARE WRITTEN IN THE ANSWER BOXES PROVIDED WILL BE SCORED.

$CO_3^{-2} + H^+$

$Zn + H^+ + Cl^- \longrightarrow ZnCl_2$

$Zn^{+2} + Cl^- + H_2$

$C_nH_{2n+2}O$ anol

$C_nH_{2n}O_2$ anal

$C_2H_4O_2$

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4C1

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CHEMISTRY

Part B

Time—40 minutes

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A strip of magnesium metal is added to a solution of silver(I) nitrate.

(i) Balanced equation:

$Mg + 2Ag^+ \longrightarrow Mg^{2+} + 2Ag$

(ii) Which substance is oxidized in the reaction?

Mg is oxidized.

(a) A 20.0 mL sample of 0.10 *M* potassium phosphate is added to a 30.0 mL sample of 0.10 *M* calcium chloride.

(i) Balanced equation:

$2KPO_3 + CaCl_2 \rightarrow 2KCl + Ca(PO_3)_2$

(ii) How many moles of product are formed?

.002 mol potassium phosphate + .003 mol calcium chloride = (.005 mol)(2) = .01 moles product

$.005 \times 2 = .010$

2+	K	+2
2+	PO_3	2
1	Ca	1
2	Cl	+2

$\frac{.1\ mol}{L} \times .02\ L = .002\ mol$

$.02 \times .1 = .002$

$\frac{.1\ mol}{L} \times .03\ L = .003\ mol$

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4C 2

B B B B B B B B B B B B B

(b) Carbon dioxide gas is bubbled into freshly distilled water.

(i) Balanced equation:

$CO_2 + H_2O \rightarrow CO_3 + H_2$

1	C	1
1+2	O	3
2	H	2

(ii) The pH of the solution decreases as the reaction proceeds. Explain.

Becomes more acidic because protons are a product. H^+ makes things more acidic.

(c) A piece of zinc metal is placed in a 1.0 *M* solution of hydrochloric acid at 25°C.

(i) Balanced equation:

$Zn + 2HCl \rightarrow ZnCl_2 + H_2$

1	Zn	1
1	H	2
1	Cl	2

(ii) When a piece of zinc metal is placed in a 1.0 *M* solution of ethanoic (acetic) acid at 25°C, the rate of reaction is slower than when 1.0 *M* hydrochloric acid at 25°C is used. Explain.

Zn doesn't react as well with acetic acid as it does with HCl. Plus, the initial breakage of bonds between HCl is easier than acetic acid.

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AP® CHEMISTRY
2013 SCORING COMMENTARY

Question 4

Overview

This question tested students' ability to convert the names of substances into chemical formulas, predict the products from a given set of reactants, and write balanced net-ionic equations. A follow-up question to each part assessed knowledge and understanding of fundamental concepts from the classroom and laboratory, namely performing solution stoichiometry calculations, rationalizing changes in solution pH, and justifying a difference in reaction rate.

Sample: 4A
Score: 15

This response earned the maximum score possible. All equations are correct and balanced, and the required mathematical work in part (a)(i) is shown clearly. The answer to part (c)(ii) correctly connects the rate of a chemical reaction to the concentration of a reactant.

Sample: 4B
Score: 11

This response incorrectly describes the phosphate ion as PO_3^- in part (a)(i) and therefore earned 1 of the 2 reactant points. However, because this error is subsequently applied correctly and consistently, all 3 remaining points in part (a) were earned. In part (b)(i) the reactant point was earned, but CO_3^- is neither carbonate ion nor bicarbonate ion and thus did not earn a product point. H^+ is a correct product and earned 1 point. The balancing point was not earned because the equation was not balanced for charge. The response for part (b)(ii) earned 1 point. All 4 points available for part (c)(i) were earned, but the point in (c)(ii) was not earned because comparing the rates of dissociation of hydrochloric and acetic acid is not a sufficient explanation of the difference in reaction kinetics.

Sample: 4C
Score: 6

The full molecular equation in part (a)(i) does not follow the instructions to omit formulas for any ions or molecules that are unchanged by the reaction. The formula and charge of phosphate ion are both incorrect but are then are applied correctly and consistently in predicting $Ca(PO_3)_2$ as a product. The balancing point was also earned. The mathematical response to part (a)(ii) begins with a valid calculation of molar amounts of reactants, but does not arrive at a consistent answer. The equation in part (b)(i) earned 1 point for the correct reactants and 1 point for balancing, but the formation of CO_3 and H_2 as products is incorrect. In part (b)(ii) the explanation of the lower solution pH is invalid because no acidic species appear as a product in the reaction as written. In part (c)(i) 1 point was earned for the correct product H_2 and 1 point was earned for balancing for mass and charge. Invoking bond strength in (c)(ii) did not earn the point.