AP® CHEMISTRY
2009 SCORING GUIDELINES (Form B)

Question 3 (10 points)

$$2\ H_2O_2(aq) \rightarrow 2\ H_2O(l) + O_2(g)$$

The mass of an aqueous solution of H_2O_2 is 6.951 g. The H_2O_2 in the solution decomposes completely according to the reaction represented above. The $O_2(g)$ produced is collected in an inverted graduated tube over water at 23.4°C and has a volume of 182.4 mL when the water levels inside and outside of the tube are the same. The atmospheric pressure in the lab is 762.6 torr, and the equilibrium vapor pressure of water at 23.4°C is 21.6 torr.

(a) Calculate the partial pressure, in torr, of $O_2(g)$ in the gas-collection tube.

$P_{atm} = P_{O_2} + P_{H_2O} \Rightarrow P_{O_2} = P_{atm} - P_{H_2O}$ $P_{O_2} = 762.6 \text{ torr} - 21.6 \text{ torr} = \mathbf{741.0 \text{ torr}}$	One point is earned for the correct answer.

(b) Calculate the number of moles of $O_2(g)$ produced in the reaction.

$PV = nRT \Rightarrow n = \frac{PV}{RT}$ $P = 741.0 \text{ torr} \times \frac{1 \text{ atm}}{760 \text{ torr}} = 0.9750 \text{ atm}$ $T = 273.15 + 23.4°C = 296.6 \text{ K}$ $V = 182.4 \text{ mL} \times \frac{1 \text{ L}}{1{,}000 \text{ mL}} = 0.1824 \text{ L}$ $n_{O_2} = \frac{PV}{RT} = \frac{(0.9750 \text{ atm})(0.1824 \text{ L})}{(0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1})(296.6 \text{ K})} = \mathbf{7.304 \times 10^{-3} \text{ mol}}$	One point is earned for the correct substitutions. One point is earned for the correct answer.

(c) Calculate the mass, in grams, of H_2O_2 that decomposed.

$(7.304 \times 10^{-3} \text{ mol } O_2) \times \frac{2 \text{ mol } H_2O_2}{1 \text{ mol } O_2} \times \frac{34.0 \text{ g } H_2O_2}{1 \text{ mol } H_2O_2} = \mathbf{0.497 \text{ g } H_2O_2}$	One point is earned for the conversion of mol O_2 to mol H_2O_2. One point is earned for the correct mass.

(d) Calculate the percent of H_2O_2, by mass, in the original 6.951 g aqueous sample.

$\frac{0.497 \text{ g } H_2O_2}{6.951 \text{ g sample}} \times 100 = \mathbf{7.15\%}$	One point is earned for the correct answer.

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Question 3 (continued)

(e) Write the oxidation number of the oxygen atoms in H_2O_2 and the oxidation number of the oxygen atoms in O_2 in the appropriate cells in the table below.

Substance	Oxidation Number of Oxygen Atoms
H_2O_2	
O_2	

In H_2O_2, the oxidation number of O is **–1**. In O_2, the oxidation number of O is **0**.	Two points are earned for the correct oxidation numbers (1 point each).

(f) Write the balanced oxidation half-reaction for the reaction.

$H_2O_2(aq) \rightarrow O_2(g) + 2\ H^+(aq) + 2\ e^-$	One point is earned for the correct reactant and products. One point is earned for correct balancing.

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3A

$$2\,H_2O_2(aq) \rightarrow 2\,H_2O(l) + O_2(g)$$

3. The mass of an aqueous solution of H_2O_2 is 6.951 g. The H_2O_2 in the solution decomposes completely according to the reaction represented above. The $O_2(g)$ produced is collected in an inverted graduated tube over water at 23.4°C and has a volume of 182.4 mL when the water levels inside and outside of the tube are the same. The atmospheric pressure in the lab is 762.6 torr, and the equilibrium vapor pressure of water at 23.4°C is 21.6 torr.

(a) Calculate the partial pressure, in torr, of $O_2(g)$ in the gas-collection tube.

(b) Calculate the number of moles of $O_2(g)$ produced in the reaction.

(c) Calculate the mass, in grams, of H_2O_2 that decomposed.

(d) Calculate the percent of H_2O_2, by mass, in the original 6.951 g aqueous sample.

(e) Write the oxidation number of the oxygen atoms in H_2O_2 and the oxidation number of the oxygen atoms in O_2 in the appropriate cells in the table below.

Substance	Oxidation Number of Oxygen Atoms
H_2O_2	-1
O_2	0

(f) Write the balanced oxidation half-reaction for the reaction.

6.951 g H_2O_2 O_2 V = 182.4 L when H_2O levels are same

762.6 torr 21.6 torr equil vp of H_2O

a) $P_{tot} = P_{O_2} + P_{H_2O}$

$762.6 \text{ torr} = P_{O_2} + 21.6 \text{ torr}$

$\boxed{P_{O_2} = 741 \text{ torr}}$

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ADDITIONAL PAGE FOR ANSWERING QUESTION 3

b) $PV = nRT$ $T = 296.4\ K$

$R = 62.4\ L\ torr\ mol^{-1}K^{-1}$

$V = 0.1824\ L$

$P = 741\ torr$

$(741)(.1824) = n(62.4)(296.4)$

$n = 0.00731$

$\boxed{n = 7.31 \times 10^{-3}\ mol\ O_2}$

c) $7.31 \times 10^{-3}\ mol\ O_2 \times \frac{2}{1} = .0146\ mol\ H_2O_2$

~~1.0 Hand~~

$.0146\ mol \cdot \frac{34\ g\ mol^{-1}}{1} = \boxed{.497\ g\ H_2O_2}$

d) $\frac{.497\ g\ H_2O_2}{6.951\ g\ (aq)} \times 100 = \boxed{7.15\%\ H_2O_2\ by\ mass}$

$2H_2O_2 \rightarrow 2H_2O + O_2$ ~~or~~ $H_2O_2 \rightarrow O_2 + 2e^- + 2H^+$

f) $\boxed{H_2O_2 \rightarrow O_2 + 2e^- + 2H^+}$

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$$2\,H_2O_2(aq) \rightarrow 2\,H_2O(l) + O_2(g)$$

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(a) Calculate the partial pressure, in torr, of $O_2(g)$ in the gas-collection tube.

(b) Calculate the number of moles of $O_2(g)$ produced in the reaction.

(c) Calculate the mass, in grams, of H_2O_2 that decomposed.

(d) Calculate the percent of H_2O_2, by mass, in the original 6.951 g aqueous sample.

(e) Write the oxidation number of the oxygen atoms in H_2O_2 and the oxidation number of the oxygen atoms in O_2 in the appropriate cells in the table below.

Substance	Oxidation Number of Oxygen Atoms
H_2O_2	−1
O_2	0

(f) Write the balanced oxidation half-reaction for the reaction.

a) $P_{O_2} = \frac{762.6 + 21.6}{2} = 392 \text{ torr} = 0.516 \text{ atm}$

b) $PV = nRT \Rightarrow 0.516 \times 0.1824 = n \times 0.082 \times 296.4$

$n = 0.00387 \text{ moles } O_2$

c) $\text{mass } H_2O_2 = 0.00387 \text{ moles } O_2 \times \frac{2 \text{ mol } H_2O_2}{1 \text{ mol } O_2} \times \frac{14.016 \text{ g } H_2O_2}{1 \text{ mol } H_2O_2}$

$= 0.108 \text{ g } H_2O_2$

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ADDITIONAL PAGE FOR ANSWERING QUESTION 3

d) % by mass = $\frac{\text{amount decomposed}}{\text{original amount}} \times 100$

$= \frac{0.108}{6.951} \times 100 = 1.55\%$

f) $H_2O_2 \longrightarrow O_2$ Oxidation half reaction

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(a) Calculate the partial pressure, in torr, of $O_2(g)$ in the gas-collection tube.

(b) Calculate the number of moles of $O_2(g)$ produced in the reaction.

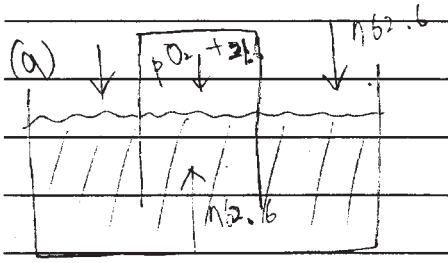
(c) Calculate the mass, in grams, of H_2O_2 that decomposed.

(d) Calculate the percent of H_2O_2, by mass, in the original 6.951 g aqueous sample.

(e) Write the oxidation number of the oxygen atoms in H_2O_2 and the oxidation number of the oxygen atoms in O_2 in the appropriate cells in the table below.

Substance	Oxidation Number of Oxygen Atoms
H_2O_2	−1
O_2	0

(f) Write the balanced oxidation half-reaction for the reaction.

(a) 

762.6 − 21.6 = 741.0

ans) 741.0 (torr)

(b) 1 mole of O_2 = 22.4 L

0.1824 L O_2 = 0.1824 × $\frac{1}{22.4}$ mol O_2

= 0.008 mol O_2

ans) 0.008 mol

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ADDITIONAL PAGE FOR ANSWERING QUESTION 3

(c) 2 moles of H_2O_2 react to produce 1 mole of O_2

$\rightarrow 2 \times 0.005 = 0.016$ (mol)

ans) 0.016 (mol)

(d) Molar mass $H_2O_2 = 18.016$ g/mol.

Total mass of H_2O_2 in solution = 18.0169/mol × 0.016 mol

= 0.288 g ans) 0.2889

(e)

(f) $O^- \rightarrow \frac{1}{2}O_2 + e^-$

ans) $2O^- \rightarrow O_2 + 2e^-$

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AP® CHEMISTRY
2009 SCORING COMMENTARY (Form B)

Question 3

Sample: 3A
Score: 10

This response earned all 10 points: 1 for part (a), 2 for part (b), 2 for part (c), 1 for part (d), 2 for part (e), and 2 for part (f).

Sample: 3B
Score: 6

This response earned 6 of the possible 10 points. In part (a) the point was not earned because the partial pressure of the dry O_2 gas is incorrectly determined as the average of the two pressures provided. In part (b) both points were earned for using the incorrect pressure calculated in part (a) to correctly determine the number of moles of O_2. In part (c) only 1 of the 2 points was earned; the incorrect number of moles of O_2 is used consistently, but the molar mass of H_2O_2 is incorrect. In part (d) 1 point was earned for calculating a percent by mass in the original sample consistent with the mass calculated in part (c), with an acceptable number of significant figures. In part (e) 2 points were earned for the correct oxidation number of the oxygen atoms in each substance. In part (f) no points were earned because a balanced oxidation half-reaction is not given.

Sample: 3C
Score: 4

This response earned 4 of the possible 10 points. In part (a) 1 point was earned for the correct partial pressure of the dry O_2 gas with an acceptable number of significant figures. In part (b) neither point was earned because the number of moles of O_2 gas is determined by using the molar volume at STP. In part (c) 1 point was earned for multiplying the number of moles determined in part (b) by the correct mole ratio. The second point was not earned because the mass is not determined. The point was not earned in part (d). In part (e) 2 points were earned for the correct oxidation number of the oxygen atoms in each substance. In part (f) no points were earned because a correctly balanced oxidation half-reaction is not given.

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