Teacher

Look at pg. 1 problem #4
- This problem uses an ICE diagram for stoichiometry.

NATIONAL MATH + SCIENCE INITIATIVE

AP CHEMISTRY

Composition and Reaction Stoichiometry

2016 EDITION

Click on the following link or scan the QR code to complete the evaluation for the Study Session https://www.surveymonkey.com/r/S_SSS

Periodic Table of the Elements

1 H 1.0079																	2 He 4.0026
3 Li 6.941	4 Be 9.012											5 B 10.811	6 C 12.011	7 N 14.007	8 O 16.00	9 F 19.00	10 Ne 20.179
11 Na 22.99	12 Mg 24.30											13 Al 26.98	14 Si 28.09	15 P 30.974	16 S 32.06	17 Cl 35.453	18 Ar 39.948
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.938	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 93.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.75	52 Te 127.60	53 I 126.91	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57 *La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.85	75 Re 186.21	76 Os 190.2	77 Ir 192.2	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.02	89 †Ac 227.03	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 § (269)	111 § (272)	112 § (277)						

§Not yet named

*Lanthanide Series:	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.4	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.04	71 Lu 174.97
†Actinide Series:	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237.05	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

AP Chemistry Equations & Constants

Throughout the test the following symbols have the definitions specified unless otherwise noted.

L, mL	=	liter(s), milliliter(s)	mm Hg	=	millimeters of mercury
g	=	gram(s)	J, kJ	=	joule(s), kilojoule(s)
nm	=	nanometer(s)	V	=	volt(s)
atm	=	atmosphere(s)	mol	=	mole(s)

ATOMIC STRUCTURE

$E = h\nu$

$c = \lambda\nu$

E = energy

ν = frequency

λ = wavelength

Planck's constant, $h = 6.626 \times 10^{-34}$ J s

Speed of light, $c = 2.998 \times 10^{8}$ m s^{-1}

Avogadro's number $= 6.022 \times 10^{23}$ mol^{-1}

Electron charge, $e = -1.602 \times 10^{-19}$ coulomb

EQUILIBRIUM

$K_c = \dfrac{[C]^c[D]^d}{[A]^a[B]^b}$, where $a\,A + b\,B \rightleftarrows c\,C + d\,D$

$K_p = \dfrac{(P_C)^c(P_D)^d}{(P_A)^a(P_B)^b}$

$K_a = \dfrac{[H^+][A^-]}{[HA]}$

$K_b = \dfrac{[OH^-][HB^+]}{[B]}$

$K_w = [H^+][OH^-] = 1.0 \times 10^{-14}$ at 25°C

$\quad = K_a \times K_b$

$pH = -\log[H^+],\ pOH = -\log[OH^-]$

$14 = pH + pOH$

$pH = pK_a + \log\dfrac{[A^-]}{[HA]}$

$pK_a = -\log K_a,\ pK_b = -\log K_b$

Equilibrium Constants

K_c (molar concentrations)

K_p (gas pressures)

K_a (weak acid)

K_b (weak base)

K_w (water)

KINETICS

$\ln[A]_t - \ln[A]_0 = -kt$

$\dfrac{1}{[A]_t} - \dfrac{1}{[A]_0} = kt$

$t_{1/2} = \dfrac{0.693}{k}$

k = rate constant

t = time

$t_{1/2}$ = half-life

GASES, LIQUIDS, AND SOLUTIONS

$$PV = nRT$$

$$P_A = P_{total} \times X_A, \text{ where } X_A = \frac{\text{moles A}}{\text{total moles}}$$

$$P_{total} = P_A + P_B + P_C + \ldots$$

$$n = \frac{m}{M}$$

$$K = {}^\circ C + 273$$

$$D = \frac{m}{V}$$

$$KE \text{ per molecule} = \frac{1}{2}mv^2$$

$$\text{Molarity, } M = \text{moles of solute per liter of solution}$$

$$A = abc$$

P = pressure
V = volume
T = temperature
n = number of moles
m = mass
M = molar mass
D = density
KE = kinetic energy
v = velocity
A = absorbance
a = molar absorptivity
b = path length
c = concentration

Gas constant, $R = 8.314 \text{ J mol}^{-1}\text{ K}^{-1}$
$= 0.08206 \text{ L atm mol}^{-1}\text{ K}^{-1}$
$= 62.36 \text{ L torr mol}^{-1}\text{ K}^{-1}$
1 atm = 760 mm Hg
= 760 torr
STP = 0.00°C and 1.000 atm

THERMOCHEMISTRY/ ELECTROCHEMISTRY

$$q = mc\Delta T$$

$$\Delta S^\circ = \sum S^\circ \text{ products} - \sum S^\circ \text{ reactants}$$

$$\Delta H^\circ = \sum \Delta H_f^\circ \text{ products} - \sum \Delta H_f^\circ \text{ reactants}$$

$$\Delta G^\circ = \sum \Delta G_f^\circ \text{ products} - \sum \Delta G_f^\circ \text{ reactants}$$

$$\Delta G^\circ = \Delta H^\circ \quad T\Delta S^\circ$$

$$= -RT \ln K$$

$$= -nFE^\circ$$

$$I = \frac{q}{t}$$

q = heat
m = mass
c = specific heat capacity
T = temperature
S° = standard entropy
H° = standard enthalpy
G° = standard free energy
n = number of moles
E° = standard reduction potential
I = current (amperes)
q = charge (coulombs)
t = time (seconds)

Faraday's constant, F = 96,485 coulombs per mole of electrons

$$1 \text{ volt} = \frac{1 \text{ joule}}{1 \text{ coulomb}}$$

Composition and Reaction Stoichiometry

Warm-Up

1) A compound contains 40% calcium, 12% carbon, and 48% oxygen. What is the empirical formula for the compound?
(A) CaC_2O_4 (B) $CaCO_3$ (C) $CaCO_4$ (D) $CaCO_6$

2) A certain hydrocarbon was found to have an empirical formula of CH_3. Its molar mass was determined to be 30.0 g/mol. What is its molecular formula?
(A) CH_3 (B) C_2H_6 (C) C_3H_9 (D) C_4H_{12}

3) Which of the following compounds contains the greatest percentage of iron?
(A) $FeCl_2$ (B) FeO (C) $Fe_3(PO_4)_2$ (D) Fe_3O_4

4) Dinitrogen tetroxide is formed from its gaseous elements at STP. How many liters of each reactant are required to form 44.8 L of dinitrogen tetroxide?
(A) 22.4 L N_2 and 22.4 L O_2 (B) 22.4 L N_2 and 44.8 L O_2
(C) 44.8 L N_2 and 22.4 L O_2 (D) 44.8 L N_2 and 89.6 L O_2

$N_2 + 2O_2 \rightarrow N_2O_4$
−44.8 89.6 +44.8

5) For a reaction A +B → C, how many liters of C can be formed when 3 L of A and 4 L of B react at STP?
(A) 3 L of C (B) 4 L of C (C) 6 L of C (D) 7 L of C

For these, you can use a calculator

6) Combustion analysis of a hydrocarbon produced 33.01 g of CO_2 and 13.51 g of H_2O. Determine the empirical formula of the hydrocarbon.

7) A 1.50 g sample of Zn is combined with 250. mL of 0.110 *M* AgNO3 at 25°C. Identify the limiting reactant and determine the amount of Zn^{2+} produced.

$$2\,Ag^{+}(aq) + Zn(s) \rightarrow Zn^{2+}(aq) + 2\,Ag(s)$$

44.8
89.6

$N_2 + 2O_2 \rightarrow N_2O_4$ 44.8 L

44.8 L × 1/1 = 44.8 L
44.8 L × 2/1 = 89.6 L

Composition Stoichiometry

- Remember that when looking at a chemical formula the subscripts not only tell us a ratio of atoms but, more importantly, a ratio of MOLES OF ATOMS.

- Empirical formula problems then become an exercise in converting mass to moles and ultimately finding mole ratio of elements.

Rhyme Time: Remember, % to mass → mass to mole → divide by the smallest → make it whole

- In order to get a molecular formula you MUST have the molecular molar mass. $MM_{empirical}$ x _______ = $MM_{molecular}$ That factor is then applied to the subscripts of the empirical formula to produce the molecular formula.

- Combustion analysis simply adds one additional step in your calculation; you must use the mass of CO_2 and H_2O to determine the number of moles of C and H respectively.
  Remember that there is 1 mol C/1mol CO_2 and 2 mol H/1mol H_2O

- These problems are strong candidates for inclusion of laboratory data. Be on the lookout for these calculations in lab-based scenarios.

Turn and Talk

1) What if a volume of CO_2 was given in a combustion problem instead of a mass? How does that change the calculation of moles of C?

2) What if a third element was included in the combustion problem – like N, S, or P? What would you need to know in order to determine the moles of that element for comparison?

3) How does the process of determining the waters of hydration compare to the process of determining the empirical formula?

Deconstruction Exercise, an oldie but goodie, 1990

An experiment is performed to determine the empirical formula of a copper iodide formed by direct combination of elements. A clean strip of copper metal is weighed accurately. It is suspended in a test tube containing iodine vapor generated by heating solid iodine. A white compound forms on the strip of copper, coating it uniformly. The strip with the adhering compound is weighed. Finally, the compound is washed completely from the surface of the metal and the clean strip is dried and reweighed.

Mass of clean copper strip	1.2789 grams
Mass of copper strip and compound	1.2874 grams
Mass of copper strip after washing	1.2748 grams

Determine:
(a) The number of moles of iodine that reacted
(b) The number of moles of copper that reacted
(c) The empirical formula for the copper iodide.

First, in the prompt, circle what we are asked to determine.

As soon as you see "empirical formula" think "I'll need moles." Next, think about all the ways we can find moles – from grams? From PV=nRT? From molarity and volume?
What information do we have?

Strategy Hint:
When you see a data table that has masses with/without or before/after there's probably a good chance you are going to need to subtract values to get something useful.

Look at the three values given in the data table – which differences would give us useful information?
(1) and (2)? (2) and (3)? (1) and (3)? Calculate each and label what they represent:

Now, tackle determining the number of moles, parts (a) and (b).

Once you have moles of each, determine the mole ratio and the empirical formula (c).

Independent Practice Hydrate Lab 2008 Q2, parts (a), (b) and (c)

In the first of two experiments, a student is assigned the task of determining the number of moles of water in one mole of $MgCl_2 \cdot n\ H_2O$. The student collects the data shown in the following table.

Mass of empty container	22.347 g
Initial mass of sample and container	25.825 g
Mass of sample and container after first heating	23.982 g
Mass of sample and container after second heating	23.976 g
Mass of sample and container after third heating	23.977 g

(a) Explain why the student can correctly conclude that the hydrate was heated a sufficient number of times in the experiment.

(b) Use the data above to

(i) calculate the total number of moles of water lost when the sample was heated, and

(ii) determine the formula of the hydrated compound.

(c) A different student heats the hydrate in an uncovered crucible, and some of the solid spatters out of the crucible. This spattering will have what effect on the calculated mass of the water lost by the hydrate? Justify your answer.

Reaction Stoichiometry

Mental Math Mole Ratios

The mole:mole ratio is at the heart of reaction stoichiometry problems. Many of you use Dimensional Analysis to solve stoichiometry problems, but for the sake of solidifying your conceptual understanding, complete the following exercise using only mental math – no calculators or scratch work allowed. Plus, it's good practice for the multiple choice section!

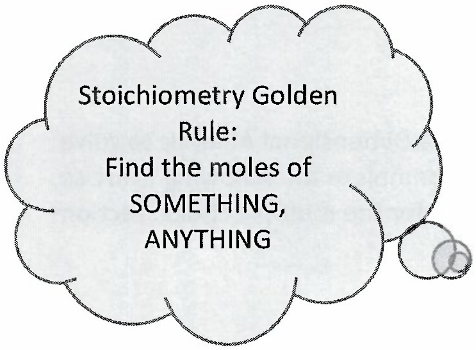
C_3H_8	5 O_2	→	3 CO_2	4 H_2O
0.10 mol		→		
0.5 mol		→		
	1.0 mol	→		
	2.0 mol	→		

2 $KMnO_4$	5 H_2SO_3	→	2 $MnSO_4$	K_2SO_4	2H_2SO_4
	0.10 mol	→			
0.5 mol		→			
		→		1.0 mol	
		→			1.0 mol

4Al	3O_2	→	2Al_2O_3
	0.10 mol	→	
0.5 mol		→	
		→	1.0 mol
	2.0 mol	→	

Can you extend this idea to limiting reactant problems?

	2 HCl	Mg	→	$MgCl_2$	H_2	
Available	0.10 mol	0.10 mol	→			
used			→			made
Available	0.02 mol	0.10 mol	→			
used			→			made

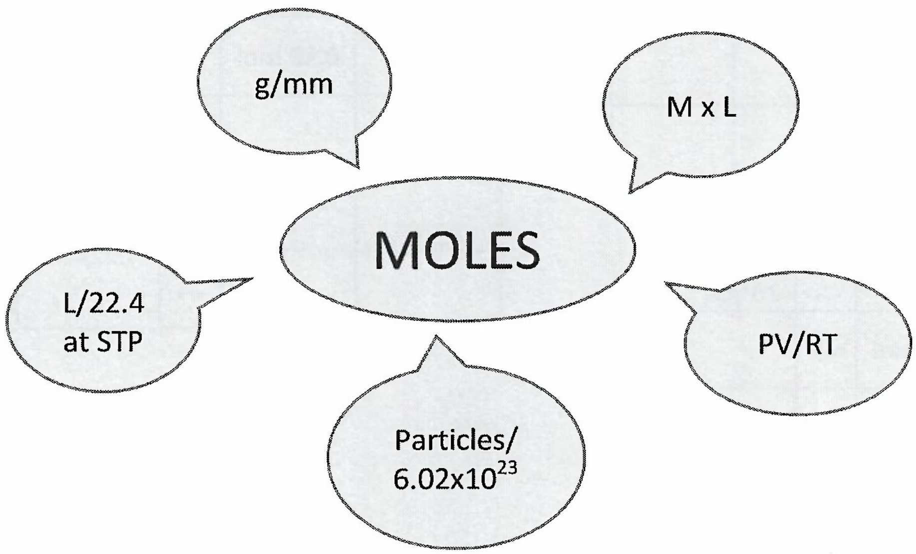


Stoichiometry questions are likely to pop up anywhere on the test. Any time there is a chemical reaction involved, stoichiometry is a possibilty.

The basic premise of all stoichiometry problems is this:

Find moles of something $\rightarrow$ use it to find moles of something else $\rightarrow$ do something with your new mole value

Consider some of the ways to get to moles in a problem:



Turn and Talk

Match each of these prompts to one of the approaches in the figure above:

1) What mass of hydrochloric acid can 3.0 g of sodium bicarbonate neutralize?
2) What volume of 0.10 M silver nitrate solution would be necessary to precipitate all of the Cl^- from a mixture of 0.10 L of 0.15 M sodium chloride and 0.25 L of 0.20 *M* $MgCl_2$ solutions?
3) Given the decomposition of liquid water into gaseous oxygen and hydrogen, what mass of water is necessary to form 1.5 L of O_2 at 315 K and 0.957 atm?
4) What mass of Lithium, in grams, reacts completely with 50.0 mL of nitrogen gas at STP?
5) What mass of water is produced from the reaction of 3.0×10^{23} molecules of hydrogen with excess oxygen?

Deconstruction Exercise 2008 Q2 parts (d) and (e)

In the second experiment, a student is given 2.94 g of a mixture containing anhydrous $MgCl_2$ and KNO_3 . To determine the percentage by mass of $MgCl_2$ in the mixture, the student uses excess $AgNO_3(aq)$ to precipitate the chloride ion as $AgCl(s)$.

(d) Starting with the 2.94 g sample of the mixture dissolved in water, briefly describe the steps necessary to quantitatively determine the mass of the AgCl precipitate.

(e) The student determines the mass of the AgCl precipitate to be 5.48 g. On the basis of this information, calculate each of the following.

(i) The number of moles of $MgCl_2$ in the original mixture

(ii) The percent by mass of $MgCl_2$ in the original mixture

Consider the scenario they are describing. Is a chemical reaction involved in the precipitation of AgCl?
Write the reaction that is occurring to precipitate the AgCl from the mixture.

Part (d) asks us to describe a procedure to determine how much AgCl is precipitated. Think about reactions you've seen in lab that produced a precipitate. You mix solution A with solution B and something cloudy happens. Then what? How do you retrieve the solid? What data do you need to record? Write down your steps here:

Part (e) assumes that the student successfully followed a procedure similar to the one you proposed, and is now ready to do the two calculations for (i) moles and (ii) percent.

Remember the golden rule of stoichiometry? FIND THE MOLES OF SOMETHING. We have 2 mass values that would be good candidates. (1) the mass of the mixture, 2.94 g and (2) the mass of pure AgCl collected, 5.48 g. The AgCl should be the obvious choice since we can determine and use the molar mass of AgCl.

Now, calculate the number of moles of AgCl in the 5.48 grams.

What is the mole ratio between AgCl and $MgCl_2$ from your balanced equation? Use it to convert moles of AgCl to moles of $MgCl_2$ to get the answer for (i).

Strategy Hint: Since we were given a mass of AgCl but asked about an amount of $MgCl_2$ – stoichiometry is in our future. The mole:mole ratio will be key.

Strategy Hint: Always think of percentages as PART over WHOLE x 100, then identify what PART and WHOLE represent in the given context.

Part (ii) asks for the percent by mass of $MgCl_2$ in the original mixture.

In this case, the PART is

____

and the WHOLE is

____

Since we need a percent by mass, we'll need the mass of $MgCl_2$ present. Easy enough, we just calculated moles of $MgCl_2$ in (i) so a simple conversion with molar mass should do the trick.

(ii) Now, set up the percent fraction, PART over WHOLE x 100, and solve.

Independent Practice Gravimetric Analysis 2014 Q1

Mass of KI tablet	0.425 g
Mass of thoroughly dried filter paper	1.462 g
Mass of filter paper + precipitate after first drying	1.775 g
Mass of filter paper + precipitate after second drying	1.699 g
Mass of filter paper + precipitate after third drying	1.698 g

A student is given the task of determining the I^- content of tablets that contain KI and an inert, water-soluble sugar as a filler. A tablet is dissolved in 50.0 mL of distilled water, and an excess of 0.20 M $Pb(NO_3)_2(aq)$ is added to the solution. A yellow precipitate forms, which is then filtered, washed, and dried. The data from the experiment are shown in the table above.

(a) For the chemical reaction that occurs when the precipitate forms,

(i) write a balanced, net-ionic equation for the reaction, and

(ii) explain why the reaction is best represented by a net-ionic equation.

(b) Explain the purpose of drying and weighing the filter paper with the precipitate three times.

(c) In the filtrate solution, is $[K^+]$ greater than, less than, or equal to $[NO_3^-]$? Justify your answer.

(d) Calculate the number of moles of precipitate that is produced in the experiment.

(e) Calculate the mass percent of I^- in the tablet.

(f) In another trial, the student dissolves a tablet in 55.0 mL of water instead of 50.0 mL of water. Predict whether the experimentally determined mass percent of I^- will be greater than, less than, or equal to the amount calculated in part (e). Justify your answer.

Multiple Choice Practice

Remember NO CALCULATOR – mental math only!

(1)	$2\ H_2O_{(l)} + 4\ MnO_4^-{}_{(aq)} + 3\ ClO_2^-{}_{(aq)} \rightarrow 4\ MnO_{2(s)} + 3\ ClO_4^-{}_{(aq)} + 4\ OH^-{}_{(aq)}$ According to the balanced equation above, how many moles of $ClO_2^-{}_{(aq)}$ are needed to react completely with 20. mL of 0.20 M $KMnO_4$ solution? (A) 0.0030 mol (B) 0.0053 mol (C) 0.0075 mol (D) 0.030 mol
(2)	$2\ N_2H_{4(g)} + N_2O_{4(g)} \rightarrow 3N_{2(g)} + 4\ H_2O_{(g)}$ When 8.0 g of N_2H_4 (32 g mol^{-1}) and 92 g of N_2O_4 (92 g mol^{-1}) are mixed together and react according to the equation above, what is the maximum mass of H_2O that can be produced? (A) 9.0 g (B) 18 g (C) 36 g (D) 72 g
(3)	$CS_{2(l)} + 3\ O_{2(g)} \rightarrow CO_{2(g)} + 2\ SO_{2(g)}$ What volume of $O_{2(g)}$ is required to react with excess $CS_{2(l)}$ to produce 4.0 L of $CO_{2(g)}$? (Assume all gases are measured at 0°C and 1 atm.) (A) 12 L (B) 22.3 L (C) 1/3 x 22.4 L (D) 2 x 22.4 L
(4)	A compound contains 1.10 mol of K, 0.55 mol of Te, and 1.65 mol of O. What is the simplest formula of this compound? (A) KTeO (B) KTe_2O (C) K_2TeO_3 (D) K_2TeO_6
(5)	$10\ HI + 2\ KMnO_4 + 3\ H_2SO_4 \rightarrow 5\ I_2 + 2\ MnSO_4 + K_2SO_4 + 8\ H_2O$ According to the balanced equation above, how many moles of HI would be necessary to produce 2.5 mol of I_2, starting with 4.0 mol of $KMnO_4$ and 3.0 mol of H_2SO_4? (A) 20 (B) 10 (C) 8.0 (D) 5.0
(6)	When a 1.25-gram sample of limestone was dissolved in acid, 0.44 gram of CO_2 was generated. If the rock contained no carbonate other than $CaCO_3$, what was the percent of $CaCO_3$ by mass in the limestone? ($CaCO_3$, 100 g mol^{-1}) (A) 35% (B) 44% (C) 67% (D) 80%
(7)	A 27.0-gram sample of an unknown hydrocarbon was burned in excess oxygen to form 88.0 grams of carbon dioxide and 27.0 grams of water. What is a possible molecular formula of the hydrocarbon? (A) CH_4 (B) C_2H_2 (C) C_4H_3 (D) C_4H_6

More Practice 2009B Q3

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

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.

(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.

(d) 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	

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

- Problem #4 page 1 - Do in class

- Animation of Electrochemistry
  Electrochemistry
  Electrochemistry lecture notes pg. 3
  (Good video)

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