



AP[®] Chemistry 2005 Sample Student Responses

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ADDITIONAL PAGE FOR ANSWERING QUESTION 1.

$$1. a. K_a = \frac{[H^+][C_3H_5O_2^-]}{[HC_3H_5O_2]}$$

$$b. 1.34 \cdot 10^{-5} = \frac{x^2}{0.265} \quad x = [H^+] = 0.00188 \quad pH = -\log[H^+] = 2.725$$

$$c. i. \frac{0.496}{96} = 0.00517 \text{ moles} \quad [C_3H_5O_2^-] = \frac{0.00517}{0.05} = 0.103 \text{ M}$$

$$ii. 1.34 \cdot 10^{-5} = \frac{0.103x}{0.265} \quad x = [H^+] = 3.45 \cdot 10^{-5} \text{ M}$$

$$d. i. K_b = \frac{[4.18 \cdot 10^{-6}]^2}{[0.309]} = 5.65 \cdot 10^{-11}$$

$$ii. K_b = \frac{K_w}{K_a} \quad K_a = \frac{10^{-14}}{5.65 \cdot 10^{-11}} = 1.77 \cdot 10^{-4}$$

e. Methanoic acid is stronger. The K_a value of methanoic acid is higher than that of propanoic. Therefore, methanoic acid produces more H^+ when placed in aqueous solution. Thus, it is a stronger acid.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 1.

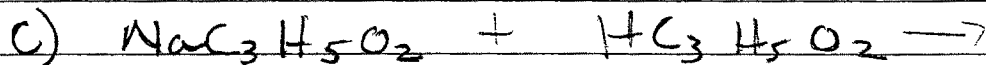
$$1. a) K_a = \frac{[H^+][C_3H_5O_2^-]}{[HC_3H_5O_2]} = 1.34 \times 10^{-5}$$

$$b) \frac{[H^+][C_3H_5O_2^-]}{(0.265 M - x)} = 1.34 \times 10^{-5}$$

$$x = [H^+] = [C_3H_5O_2^-] \quad x^2 = 3.55 \times 10^{-6}$$

$$[H^+] = \sqrt{3.55 \times 10^{-6}} = 0.0019$$

$$-\log [H^+] = \boxed{pH = 2.72}$$



$$Na = 23 \quad 0.005 \text{ mols}$$

$$0.013 \text{ mols}$$

$$\checkmark M = n \quad n = n \quad \checkmark$$

$$C = 12 \times 3 = 36$$

$$= 0.013 \text{ mols}$$

$$H = 1 \times 5 = 5$$

$$= i) \boxed{0.365 M C_3H_5O_2^-}$$

$$O = 16 \times 2 = 32$$

$$MW = 96$$

$$\frac{0.496}{96} = 0.005 \text{ mols } NaC_3H_5O_2$$

$$\frac{50 \text{ mL}}{1000} \times 0.265 M = 0.013 \text{ mols } HC_3H_5O_2$$

$$ii) 0.013 \text{ mols } HC_3H_5O_2 - 0.005 \text{ mols } NaC_3H_5O_2 = 0.008 \text{ mols } H^+$$

$$\boxed{= 0.16 M H^+}$$

$$d) i) K_b = \frac{[OH^-][HCO_2H]}{[HCO_2^-]} \quad x = [OH^-] = 4.18 \times 10^{-6} M = [HCO_2H]$$

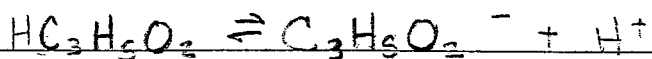
$$= \frac{(4.18 \times 10^{-6})^2}{0.309 - x} = \boxed{5.65 \times 10^{-11} = K_b}$$

$$ii) K_a = \frac{1 \times 10^{-14}}{5.65 \times 10^{-11}} = \boxed{1.77 \times 10^{-4} = K_a}$$

e) Propanoic acid is stronger because it has a lower pH

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1C

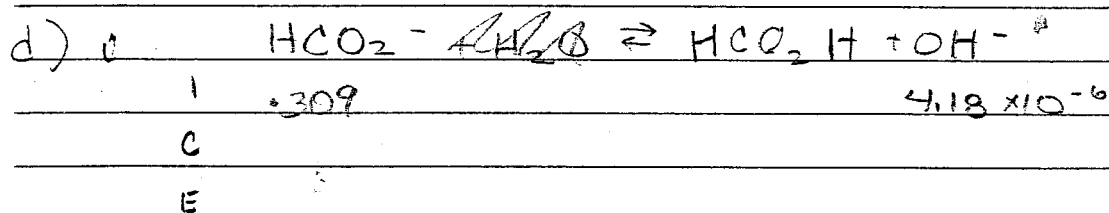
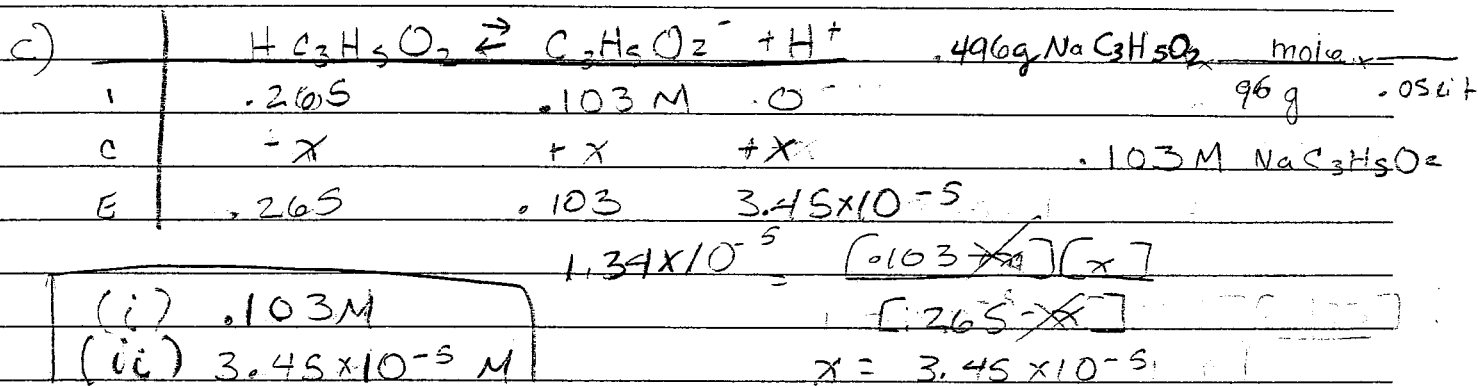


a)
$$\frac{[\text{C}_3\text{H}_5\text{O}_2^-][\text{H}^+]}{[\text{HC}_3\text{H}_5\text{O}_2]}$$

b)
$$\text{pH} = -\log[\text{HC}_3\text{H}_5\text{O}_2]$$

$$-\log[0.265]$$

$$\boxed{\text{pH} = 0.577}$$



$$K_b = \frac{[\text{OH}^-][\text{HB}^+]}{[\text{HA}]}$$

$$\text{pOH} = \text{p}K_b + \log [\text{HB}]$$

ii
$$\frac{1 \times 10^{-14}}{K_b} = K_a$$

e) methanoic acid is stronger because it has a greater pH.

GO ON TO THE NEXT PAGE.

Answer EITHER Question 2 below OR Question 3 printed on page 16. Only one of these two questions will be graded. If you start both questions, be sure to cross out the question you do not want graded. The Section II score weighting for the question you choose is 20 percent.

2. Answer the following questions about a pure compound that contains only carbon, hydrogen, and oxygen.

- (a) A 0.7549 g sample of the compound burns in $O_2(g)$ to produce 1.9061 g of $CO_2(g)$ and 0.3370 g of $H_2O(g)$.
- Calculate the individual masses of C, H, and O in the 0.7549 g sample.
 - Determine the empirical formula for the compound.
- (b) A 0.5246 g sample of the compound was dissolved in 10.0012 g of lauric acid, and it was determined that the freezing point of the lauric acid was lowered by $1.68^\circ C$. The value of K_f of lauric acid is $3.90^\circ C m^{-1}$. Assume that the compound does not dissociate in lauric acid.
- Calculate the molality of the compound dissolved in the lauric acid.
 - Calculate the molar mass of the compound from the information provided.
- (c) Without doing any calculations, explain how to determine the molecular formula of the compound based on the answers to parts (a)(ii) and (b)(ii).
- (d) Further tests indicate that a 0.10 M aqueous solution of the compound has a pH of 2.6. Identify the organic functional group that accounts for this pH.

Question 2

$$a) (i) \text{ mass of C: } 1.9061 \text{ g } CO_2 \times \frac{1 \text{ mol } CO_2}{44.01 \text{ g } CO_2} \times \frac{1 \text{ mol C}}{1 \text{ mol } CO_2} \times \frac{12.01 \text{ g C}}{1 \text{ mol C}} \\ = 0.52016 \text{ g C}$$

$$\text{mass of H: } 0.3370 \text{ g } H_2O \times \frac{1 \text{ mol } H_2O}{18.02 \text{ g } H_2O} \times \frac{2 \text{ mol H}}{1 \text{ mol } H_2O} \times \frac{1.01 \text{ g H}}{1 \text{ mol H}} \\ = 0.03778 \text{ g H}$$

$$\text{mass of O} = 0.7549 \text{ g} - 0.52016 \text{ g} - 0.03778 \text{ g} \\ = 0.1970 \text{ g O}$$

$$(ii) \text{ moles C} = 0.52016 \text{ g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 0.043311 \text{ mol C} \\ \text{moles H} = 0.03778 \text{ g H} \times \frac{1 \text{ mol H}}{1.01 \text{ g H}} = 0.03741 \text{ mol H}$$

$$\text{moles O} = 0.1970 \text{ g O} \times \frac{1 \text{ mol O}}{16 \text{ g O}} = 0.01231 \text{ mol O}$$

$$C_{\left(\frac{0.043311}{0.01231}\right)} H_{\left(\frac{0.03741}{0.01231}\right)} O_{\left(\frac{0.01231}{0.01231}\right)} \Rightarrow C_{3.5} H_3 O \Rightarrow C_7 H_6 O_2$$

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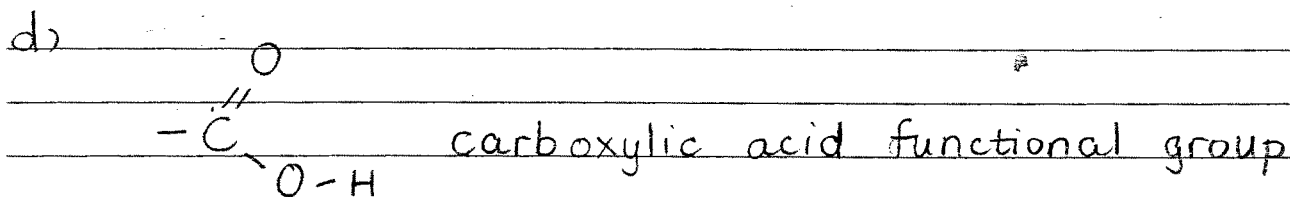
b) (i) $\Delta T = K_f m$

$1.68^\circ\text{C} = 3.90^\circ\text{C}/m (m)$

$m = 0.431 \text{ molality}$

(ii) $0.431 \frac{\text{mol}}{\text{kg}} = \frac{0.5246 \text{ g compound}}{10.0012 \text{ g lauric acid}} \times \frac{10^3 \text{ g lauric acid}}{1 \text{ kg lauric acid}} \times \frac{1 \text{ mol compound}}{x \text{ g compound}}$
 $x = 121.7 \text{ g/mol}$

c) Using the empirical formula from part (a) (ii), find the empirical formula mass. Then divide the molecular mass found in part (b) (ii) by this empirical formula mass. Multiply the empirical formula by this quotient to obtain the molecular formula.



Since the pH is less than 7, the solution is acidic.

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2B₁

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- Calculate the individual masses of C, H, and O in the 0.7549 g sample.
 - Determine the empirical formula for the compound.
- (b) A 0.5246 g sample of the compound was dissolved in 10.0012 g of lauric acid, and it was determined that the freezing point of the lauric acid was lowered by $1.68^\circ C$. The value of K_f of lauric acid is $3.90^\circ C m^{-1}$. Assume that the compound does not dissociate in lauric acid.
- Calculate the molality of the compound dissolved in the lauric acid.
 - Calculate the molar mass of the compound from the information provided.
- (c) Without doing any calculations, explain how to determine the molecular formula of the compound based on the answers to parts (a)(ii) and (b)(ii).
- (d) Further tests indicate that a 0.10 M aqueous solution of the compound has a pH of 2.6. Identify the organic functional group that accounts for this pH.

$$g C = (1.9061 g CO_2) \left(\frac{1 mol CO_2}{44.01 g CO_2} \right) \left(\frac{1 mol C}{1 mol CO_2} \right) \left(\frac{12.01 g C}{1 mol C} \right) = 0.5202 g C$$

$$g O = (1.9061 g CO_2) \left(\frac{1 mol CO_2}{44.01 g CO_2} \right) \left(\frac{2 mol O}{1 mol CO_2} \right) \left(\frac{16.00 g O}{1 mol O} \right) + (0.3370 g H_2O) \left(\frac{1 mol H_2O}{18.02 g H_2O} \right) \left(\frac{1 mol O}{1 mol H_2O} \right) \left(\frac{16.00 g O}{1 mol O} \right) = 1.685 g O$$

$$g H = (0.3370 g H_2O) \left(\frac{1 mol H_2O}{18.02 g H_2O} \right) \left(\frac{2 mol H}{1 mol H_2O} \right) \left(\frac{1.01 g H}{1 mol H} \right) = 0.03778 g H$$

$$i) \quad mol C = 0.5202 g \left(\frac{1 mol}{12.01 g/mol} \right) = 0.04331 mol C$$

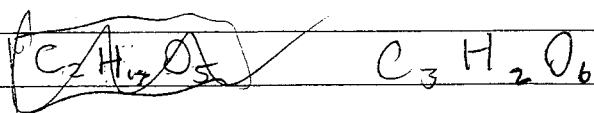
$$mol O = 1.685 g \left(\frac{1 mol}{16.00 g} \right) = 0.1053 mol O$$

$$mol H = 0.03778 g \left(\frac{1 mol}{1.01 g} \right) = 0.03741 mol H$$

divide all by 0.04331

$$\begin{aligned} \approx 1 mol C & \approx 1.5 mol C \\ \approx 2.5 mol O & \approx 3 mol O \\ \approx 0.6 mol H & \approx 1 mol H \end{aligned}$$

GO ON TO THE NEXT PAGE.



b) i) $\Delta T_{\text{cp}} = K_f \cdot m$
 $1.68^\circ\text{C} = 3.90^\circ\text{C} \cdot m (m)$
 $m = 0.431$

ii) $\frac{\text{mols sample}}{\text{kg acid}} = 0.431 \frac{\text{mols}}{\text{kg}}$

$\text{mols sample} = 0.431 \frac{\text{mols}}{\text{kg}} (10.0012 \text{ g}) \left(\frac{1 \text{ kg}}{1000 \text{ g}} \right)$
 $= 4.31 \times 10^{-3} \text{ mols}$

$\text{molar mass} = \frac{g}{\text{mol}}$

$= \frac{0.5246 \text{ g}}{4.31 \times 10^{-3} \text{ mol}} = 122 \text{ g/mol}$

c) Find the molar mass of the empirical formula

- Divide the molar mass determined in (b)(ii) by the molar mass of the empirical formula

- Multiply the result to # of carbon, hydrogen, and oxygen atoms in the empirical formula

d) -COOH group

- carboxyl group

GO ON TO THE NEXT PAGE.

2C₁

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- Calculate the molality of the compound dissolved in the lauric acid.
 - Calculate the molar mass of the compound from the information provided.
- (c) Without doing any calculations, explain how to determine the molecular formula of the compound based on the answers to parts (a)(ii) and (b)(ii).
- (d) Further tests indicate that a 0.10 M aqueous solution of the compound has a pH of 2.6. Identify the organic functional group that accounts for this pH.

a) i) $0.7549 \text{ g } C_xH_yO_z$

$$1.9061 \text{ g } CO_2 / 44 \text{ g/mol} = .0433 \text{ mol}$$

$$0.3370 \text{ g } H_2O / 18 \text{ g/mol} = .0187 \text{ mol}$$

$$.0433 \text{ mol } CO_2 \cdot 12 \text{ g/mol} = .5196 \text{ g C}$$

$$.0187 \text{ mol } H_2O \cdot 1 \text{ g/mol} = .0187 \text{ g H}$$

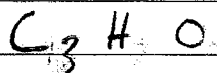
$$.7549 \text{ g} - (.5196 + .0187) = .2166 \text{ g O}$$

ii)

$$.5196 \text{ g C} / 12 \text{ g/mol} = .0433 \text{ mol C} / .0135 = 3.207 \approx 3$$

$$.0187 \text{ g H} / 1 \text{ g/mol} = .0187 \text{ mol H} / .0135 = 1.38 \approx 1$$

$$.2166 \text{ g O} / 16 \text{ g/mol} = .0135 \text{ mol O} / .0135 = 1 \approx 1$$



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ADDITIONAL PAGE FOR ANSWERING QUESTION 2.

$$b) i) m = \frac{\text{mol}}{\text{kg}} = \frac{\text{mol}}{.0100012 \text{ kg}}$$

$$\Delta T_f = K_f \cdot m$$

$$1.68 = 3.90 \cdot m$$

$$m = .4307$$

$$ii) .4307 = \frac{\text{mol}}{.0100012 \text{ kg}}$$

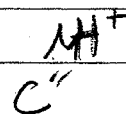
$$\text{mol} = .00431$$

$$\frac{.5246 \text{ g}}{.00431 \text{ mol}} = 121 \text{ g/mol}$$

c) To determine the molecular formula, the empirical formula and the molar mass would be used. When all the subscripts of the elements are multiplied by the same number, x , and their respective molar masses, it should equal the total molar mass of the comp.

$$d) \text{pH} = 2.6 \quad m = .1$$

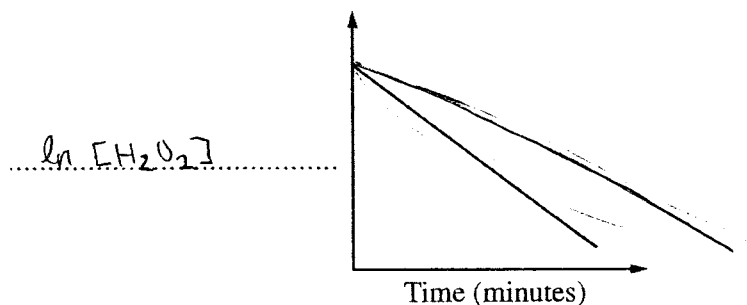
$$[\text{H}^+] = \text{antilog } -2.6 = .0025$$



Amine

GO ON TO THE NEXT PAGE.

(c) During the analysis of the data, the graph below was produced.



- Label the vertical axis of the graph.
- What are the units of the rate constant, k , for the decomposition of $\text{H}_2\text{O}_2(\text{aq})$?
- On the graph, draw the line that represents the plot of the uncatalyzed first-order decomposition of $1.00\text{ M H}_2\text{O}_2(\text{aq})$.

a. i) Experiment 1 vs 2

$$\left[\frac{.017}{.052}\right]^x = \frac{.156}{.476}$$

$$.327^x = .327 \quad x = 1$$

$[\text{I}^-]$ is first order

$$\text{ii) } .156 = k[.017]^1[.015]^y$$

$$.262 = 1.0625[.246]^y$$

$$.596 = k[.016]^1[.061]^y$$

$$.246 = .246^y \quad y = 1$$

$[\text{ClO}^-]$ is first order

b. i) $\text{Rate} = k[\text{I}^-]^1[\text{ClO}^-]^1$

$$\text{ii) } .156 = k[.017]^1[.015]^1$$

$$k = 611 \text{ M}^{-1}\text{s}^{-1}$$

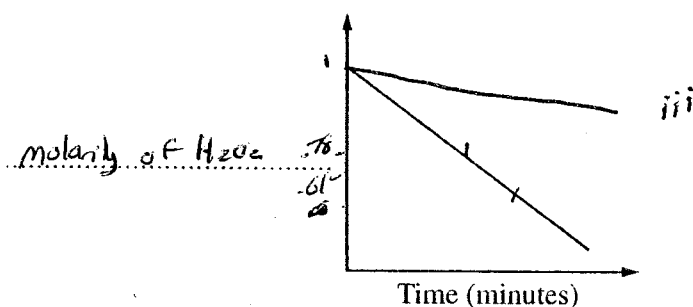
c. i) SEE GRAPH

ii) 1st order so units of k are s^{-1}

iii) SEE GRAPH

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(c) During the analysis of the data, the graph below was produced.



- Label the vertical axis of the graph.
- What are the units of the rate constant, k , for the decomposition of $\text{H}_2\text{O}_2(\text{aq})$?
- On the graph, draw the line that represents the plot of the uncatalyzed first-order decomposition of $1.00 \text{ M } \text{H}_2\text{O}_2(\text{aq})$.

(a) i I^- Tripling the concentration of I^- in experiment 1 and 2 triples the rate of the reaction, thus its rate order is 1.

ii ClO^- Quadrupling the concentration of ClO^- in experiment 1 and 3 raises the rate by about 4 times. Thus rate order equals $4^x = 3.82$, $x \log 4 = \log 3.82$, $x = .967$ Since decreasing

Since $[\text{I}^-]$ is decreased by .01, it decreases the initial rate by small extent, rate order for ClO^- is about 1

(b) i rate = $k[\text{I}^-]^1[\text{ClO}^-]^1$

ii $k = \frac{[.017\text{M}][.015\text{M}]}{.156 \text{ L}^{-1}\text{s}^{-1}} = k = 0.002 \text{ M}^{-1}\text{s}^{-1}$

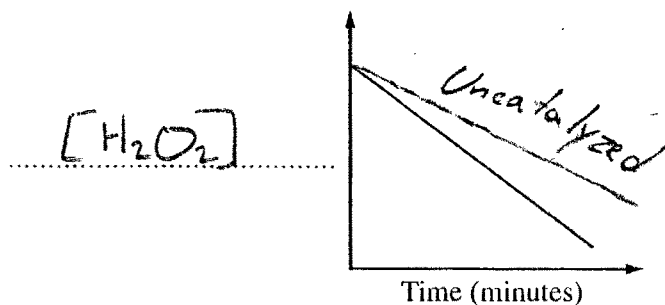
(c) ii $k = \text{s}^{-1}$

iii see graph

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3C,

(c) During the analysis of the data, the graph below was produced.



- Label the vertical axis of the graph.
- What are the units of the rate constant, k , for the decomposition of $\text{H}_2\text{O}_2(\text{aq})$?
- On the graph, draw the line that represents the plot of the uncatalyzed first-order decomposition of $1.00 \text{ M } \text{H}_2\text{O}_2(\text{aq})$.

3. @ (i) I^- is first order because as the concentration of I^- triples the rate triples as well.

(ii) ClO^- rate = $\frac{[\text{I}^-]^1 [\text{ClO}^-]^x}{[\text{I}^-]^1 [\text{ClO}^-]^x}$ ClO^- is 0 order has no effect on the rate like

$$\frac{.476}{.596} = \frac{(.052)^1 \times (.015)^x}{(.016)^1 \times (.061)^x}$$

$$\frac{.799}{3.25} = \frac{3.25}{3.25} \times \frac{(.015)^x}{(.061)^x}$$

$$.246 = \frac{(.015)^x}{(.061)^x} \quad .246 = .246 (x-x) = 0$$

(b)(i) rate = $k[\text{ClO}^-]^0[\text{I}^-]^1$

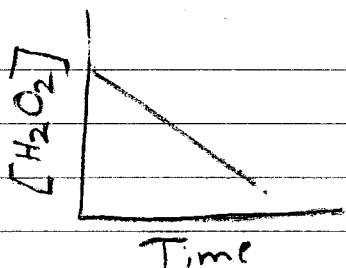
(ii) $\frac{.476 \text{ mol/L} \cdot \text{s}}{.052 \text{ mol/L}^2} = k(1)(.052) \text{ mol/L}^2$

$$k = 9.15 \text{ L/mol} \cdot \text{s}$$

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ADDITIONAL PAGE FOR ANSWERING QUESTION 3.

C(i)



(ii) mol/L·min

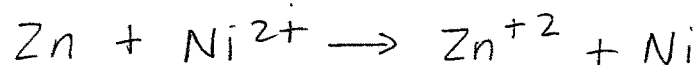
(iii) on graph in front of page

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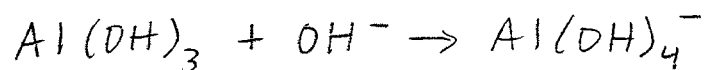
USE THIS PAGE FOR ANSWERING QUESTION 4.

PLEASE WRITE THE LETTER FOR THE REACTION IN THE SQUARE AT THE LEFT END OF EACH BOX. ONLY THE ANSWERS IN THE BOXES WILL BE SCORED.

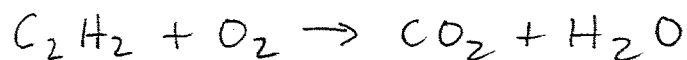
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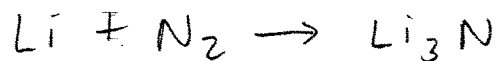
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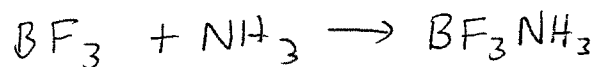
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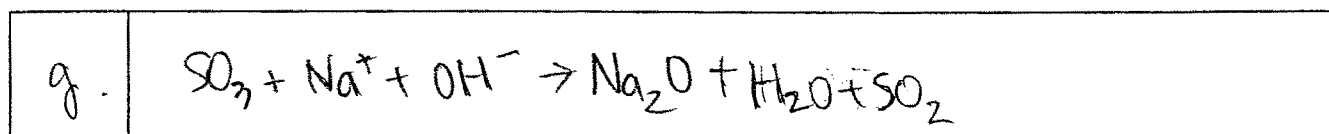
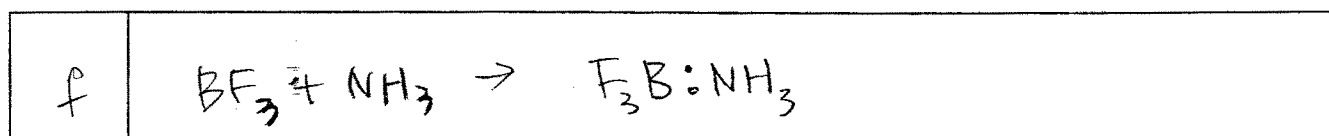
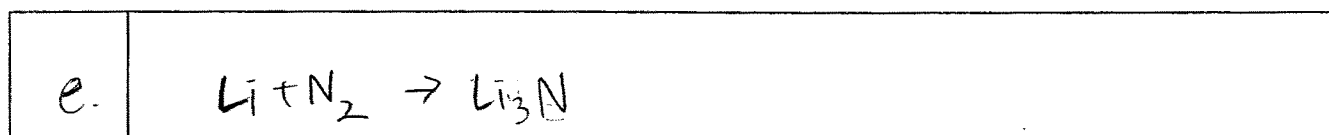
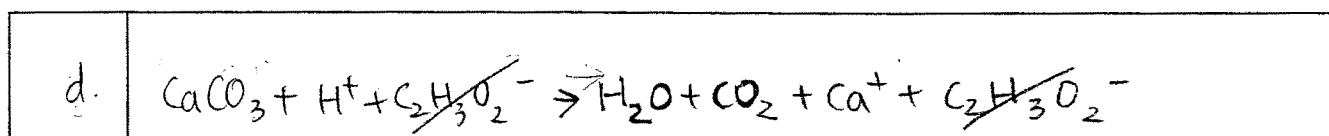
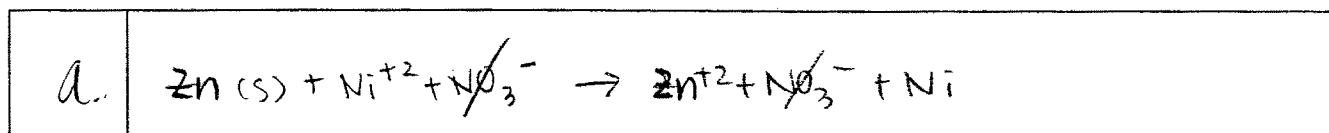
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PLEASE WRITE THE LETTER FOR THE REACTION IN THE SQUARE AT THE
LEFT END OF EACH BOX. ONLY THE ANSWERS IN THE BOXES WILL BE SCORED.

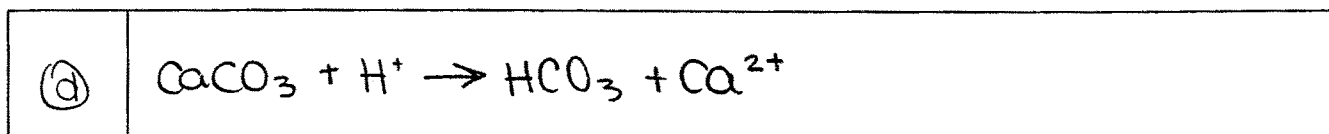
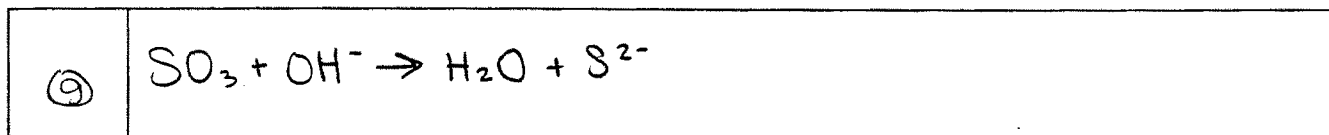
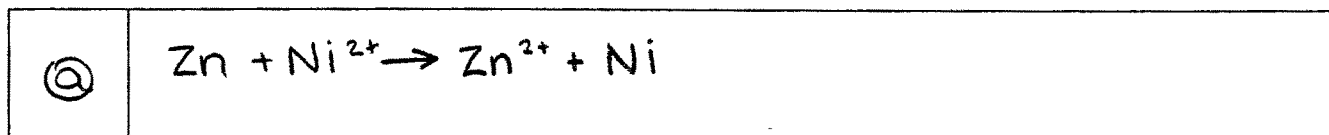


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4C

USE THIS PAGE FOR ANSWERING QUESTION 4.
PLEASE WRITE THE LETTER FOR THE REACTION IN THE SQUARE AT THE
LEFT END OF EACH BOX. ONLY THE ANSWERS IN THE BOXES WILL BE SCORED.



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Your responses to the rest of the questions in this part of the examination will be graded on the basis of the accuracy and relevance of the information cited. Explanations should be clear and well organized. Examples and equations may be included in your responses where appropriate. Specific answers are preferable to broad, diffuse responses.

Answer BOTH Question 5 below AND Question 6 printed on page 24. Both of these questions will be graded. The Section II score weighting for these questions is 30 percent (15 percent each).

5. Answer the following questions that relate to laboratory observations and procedures.

- (a) An unknown gas is one of three possible gases: nitrogen, hydrogen, or oxygen. For each of the three possibilities, describe the result expected when the gas is tested using a glowing splint (a wooden stick with one end that has been ignited and extinguished, but still contains hot, glowing, partially burned wood).
- (b) The following three mixtures have been prepared: CaO plus water, SiO₂ plus water, and CO₂ plus water. For each mixture, predict whether the pH is less than 7, equal to 7, or greater than 7. Justify your answers.
- (c) Each of three beakers contains a 0.1 M solution of one of the following solutes: potassium chloride, silver nitrate, or sodium sulfide. The three beakers are labeled randomly as solution 1, solution 2, and solution 3. Shown below is a partially completed table of observations made of the results of combining small amounts of different pairs of the solutions.

		AgNO ₃	Na ₂ S	KCl
		Solution 1	Solution 2	Solution 3
AgNO ₃	Solution 1		Ag ₂ S black precipitate	AgCl
Na ₂ S	Solution 2			no reaction
KCl	Solution 3			

KCl
AgNO₃
Na₂S

- (i) Write the chemical formula of the black precipitate.
- (ii) Describe the expected results of mixing solution 1 with solution 3.
- (iii) Identify each of the solutions 1, 2, and 3.

a) The splint would extinguish in nitrogen gas, burn nicely in oxygen gas, or make a popping noise in hydrogen gas.

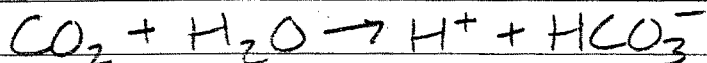
b) $\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 \rightarrow \text{Ca}^{2+} + 2\text{OH}^-$
CaO would have a pH greater than 7 since metal oxides form bases in water

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

ADDITIONAL PAGE FOR ANSWERING QUESTION 5.

SiO_2 (sand/quartz) is not dissolvable in water.
Therefore, the pH would not change and remain neutral at 7



Carbon dioxide can hydrolyze in water to form H_2CO_3 , which can then dissociate to form an acid with a pH less than 7.

c.i Ag_2S

ii A ^{white?} precipitate would form due to:
 $\text{Ag}^+ + \text{Cl}^- \rightarrow \text{AgCl}$

iii. I - AgNO_3
II - Na_2S
III - KCl

GO ON TO THE NEXT PAGE.

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Na_2S

		AgNO_3	Na_2S	KCl
		Solution 1	Solution 2	Solution 3
AgNO_3	Solution 1		black precipitate	
Na_2S	Solution 2			no reaction
KCl	Solution 3	$\text{AgCl}(\text{s})$		

- (i) Write the chemical formula of the black precipitate.
- (ii) Describe the expected results of mixing solution 1 with solution 3.
- (iii) Identify each of the solutions 1, 2, and 3.

5. a) If the gas were oxygen, the stick would glow brighter. If the gas were hydrogen, a loud pop would be heard. If the gas were nitrogen, nothing would occur.

b) $\text{CaO} \Rightarrow \text{pH} > 7$ CaOH is a strong base and thus this mixture is basic.

$\text{SiO}_2 \Rightarrow$ equal to 7 silicon dioxide is neither acidic nor basic and thus the pH would be unaffected. pH of water is 7 because it is neutral.

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B B B B

B B B B

5B₂

ADDITIONAL PAGE FOR ANSWERING QUESTION 5.

$\text{CO}_2 \Rightarrow \text{pH} < 7$ Acids react with carbonates to form carbon dioxide gas; and therefore CO_2 is a conjugate base. The solution therefore would be acidic.

© (i) Ag_2S

(ii) A precipitate would form (silver chloride) $\text{AgCl}_{(s)}$

(iii) solution 1 = AgNO_3

solution 2 = Na_2S

solution 3 = KCl

GO ON TO THE NEXT PAGE.

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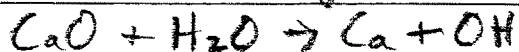
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	Solution 1	Solution 2	Solution 3
Solution 1		black precipitate	
Solution 2			no reaction
Solution 3			

- (i) Write the chemical formula of the black precipitate.
- (ii) Describe the expected results of mixing solution 1 with solution 3.
- (iii) Identify each of the solutions 1, 2, and 3.

① For Nitrogen, the glowing splint will go out.
For Hydrogen and Oxygen, the splint will glow brighter.

② CaO will be greater than 7 because



CO_2 will be less than 7 because H_2CO_3 is an acid.

SiO_2 will be equal to 7 because it is neutral and does

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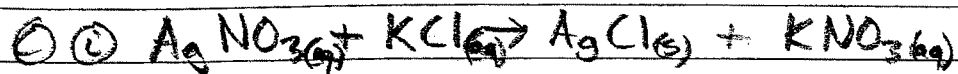
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5C₂

ADDITIONAL PAGE FOR ANSWERING QUESTION 5.

not react with water.



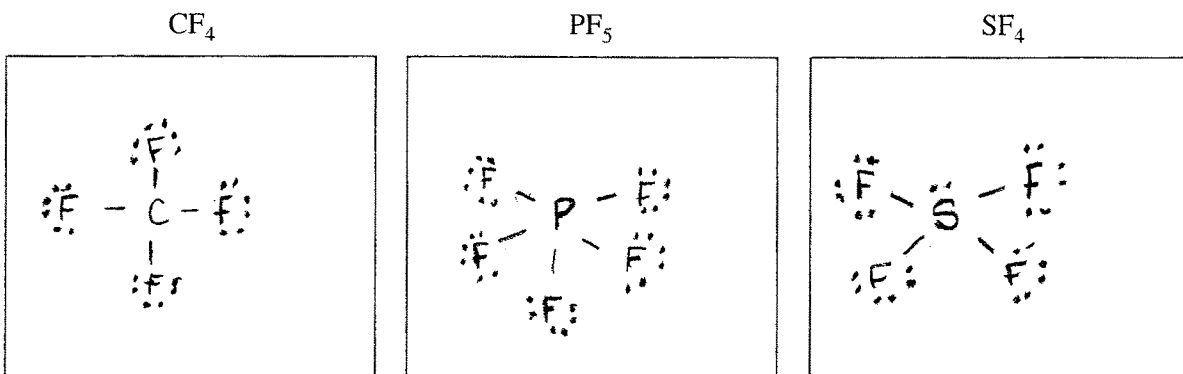
$\textcircled{\text{D}}$ you would get K_2S and Na^+ and Cl^- ions

$\textcircled{\text{LII}}$ 1 = KCl
2 = AgNO_3
3 = Na_2S

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6. Answer the following questions that relate to chemical bonding.

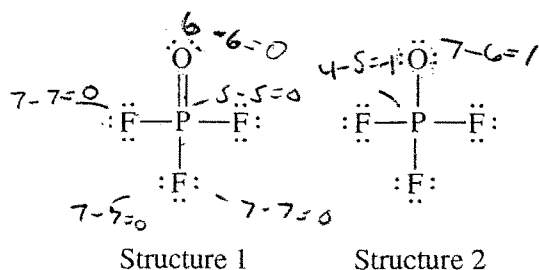
- (a) In the boxes provided, draw the complete Lewis structure (electron-dot diagram) for each of the three molecules represented below.



- (b) On the basis of the Lewis structures drawn above, answer the following questions about the particular molecule indicated.

- (i) What is the F-C-F bond angle in CF₄?
- (ii) What is the hybridization of the valence orbitals of P in PF₅?
- (iii) What is the geometric shape formed by the atoms in SF₄?

- (c) Two Lewis structures can be drawn for the OPF₃ molecule, as shown below.



- (i) How many sigma bonds and how many pi bonds are in structure 1?
- (ii) Which one of the two structures best represents a molecule of OPF₃? Justify your answer in terms of formal charge.

b) i) 109.4

ii) sp³d

iii) see-saw

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6A₂

ADDITIONAL PAGE FOR ANSWERING QUESTION 6.

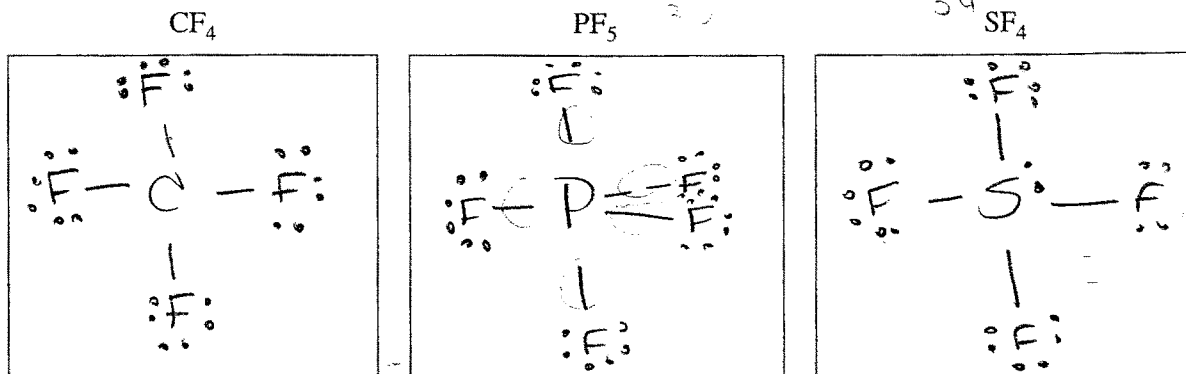
c.) i) There are 4 sigma bonds and one pi bond

ii) Structure 1 best represents a molecule of OPF_3 because all of its components have a formal charge of 0 while the Oxygen and Phosphorus in structure 2 have charges of 1 and -1 respectively.

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6. Answer the following questions that relate to chemical bonding.

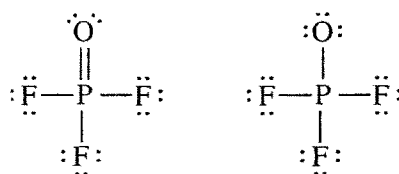
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- (b) On the basis of the Lewis structures drawn above, answer the following questions about the particular molecule indicated.

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- (ii) What is the hybridization of the valence orbitals of P in PF₅?
- (iii) What is the geometric shape formed by the atoms in SF₄?

- (c) Two Lewis structures can be drawn for the OPF₃ molecule, as shown below.



Structure 1

Structure 2

- (i) How many sigma bonds and how many pi bonds are in structure 1?
- (ii) Which one of the two structures best represents a molecule of OPF₃? Justify your answer in terms of formal charge.

(b) (i) 90°
 (ii) sp³d
 (iii) see-saw

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ADDITIONAL PAGE FOR ANSWERING QUESTION 6.

(c)

(i) 4 sigma bonds
1 pi bond

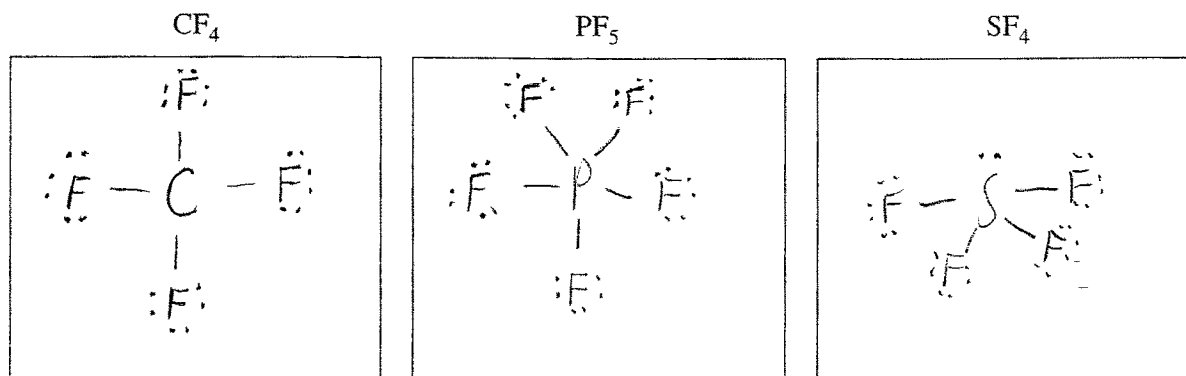
(ii) structure I, due to its
stable formal charge of
0.

central atom: P total
valence = 5
 $5 - 5 = 0$

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6. Answer the following questions that relate to chemical bonding.

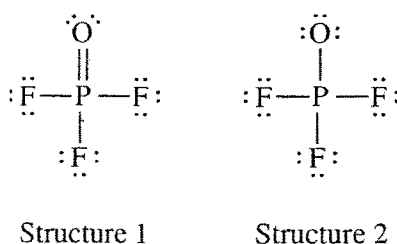
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- (b) On the basis of the Lewis structures drawn above, answer the following questions about the particular molecule indicated.

- (i) What is the $\text{F}-\text{C}-\text{F}$ bond angle in CF_4 ?
- (ii) What is the hybridization of the valence orbitals of P in PF_5 ?
- (iii) What is the geometric shape formed by the atoms in SF_4 ?

- (c) Two Lewis structures can be drawn for the OPF_3 molecule, as shown below.



- (i) How many sigma bonds and how many pi bonds are in structure 1 ?
- (ii) Which one of the two structures best represents a molecule of OPF_3 ? Justify your answer in terms of formal charge.

b) (i) planer molecule so bond angle = 90°
 (ii) $2s^2 p^6$ P^{+5} no electrons on 3rd level
 (iii) This molecule is square pyramidal, due to the unshared electron pair

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6C₂

ADDITIONAL PAGE FOR ANSWERING QUESTION 6.

c) (i) In structure one, there are four sigma and one pi bond, because there are 3 single and 1 double bonds

(ii) Due to the symmetry of structure 2, it has a formal charge of zero. Therefore, it best represents a molecule of OPF_3 .

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Answer EITHER Question 7 below OR Question 8 printed on page 28. Only one of these two questions will be graded. If you start both questions, be sure to cross out the question you do not want graded. The Section II score weighting for the question you choose is 15 percent.

7. Use principles of atomic structure, bonding, and/or intermolecular forces to respond to each of the following. Your responses must include specific information about all substances referred to in each question.

(a) At a pressure of 1 atm, the boiling point of $\text{NH}_3(l)$ is 240 K, whereas the boiling point of $\text{NF}_3(l)$ is 144 K.

- Identify the intermolecular force(s) in each substance.
- Account for the difference in the boiling points of the substances.

(b) The melting point of $\text{KCl}(s)$ is 776°C , whereas the melting point of $\text{NaCl}(s)$ is 801°C .

- Identify the type of bonding in each substance.
- Account for the difference in the melting points of the substances.

(c) As shown in the table below, the first ionization energies of Si, P, and Cl show a trend.

Element	First Ionization Energy (kJ mol^{-1})
Si	786
P	1,012
Cl	1,251

- For each of the three elements, identify the quantum level (e.g., $n = 1$, $n = 2$, etc.) of the valence electrons in the atom.
 - Explain the reasons for the trend in first ionization energies.
- (d) A certain element has two stable isotopes. The mass of one of the isotopes is 62.93 amu and the mass of the other isotope is 64.93 amu.
- Identify the element. Justify your answer.
 - Which isotope is more abundant? Justify your answer.

a) i. NH_3 : London dispersion, dipole/dipole, hydrogen bonding
 NF_3 : London dispersion, dipole/dipole

ii. NH_3 can enter into hydrogen bonds which are the strongest intermolecular force. The strongest intermolecular force of NF_3 is dipole/dipole. More energy is needed to overcome the intermolecular forces in NH_3 than NF_3 so it has a higher boiling point.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 7.

b) i. Both Substances (KCl and NaCl) are ionic substances. The cations and anions are held together in a lattice by ionic bonds

ii. the strength of an ionic bond depends on the magnitude of the charge as well as the distance between nuclei. Both KCl and NaCl have the same magnitude of charges (+1, -1), but Na^+ has a smaller radius than K^+ so the Na^+ and Cl^- ions can get closer together + form a stronger bond. Therefore more energy is needed to overcome the attractive force in NaCl which is why it has a higher melting point than KCl.

c) i. All 3 elements have valence electrons with the quantum level $n=3$.

ii. As you move across the periodic table from left to right the atomic radius of each element decreases.

For Si, P, and Cl the radii decrease in that order. The effective nuclear shielding remains the same but the nuclear charge increases which creates a stronger pull on the valence electrons. The first ionization energies increase from Si to P to Cl because the nucleus of each pulls more strongly on the valence electrons than the previous element. Therefore it takes the most energy to free a Cl electron, a bit less for a P electron and least for an Si electron.

d) i. Cu; Copper The atomic mass on the periodic table is an average mass of all the elements isotopes based on their abundance. Copper's periodic table mass is 63.55 amu which is the only element with a mass between 62.93 amu + 64.93 amu. 63.55 amu

ii. 62.93 isotope because copper's periodic table mass is closer to 62.93 than it is to 64.93. Atomic mass = (mass isotope 1 \times % abundance) + (mass isotope 2 \times % abund.)

GO ON TO THE NEXT PAGE.

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- (d) A certain element has two stable isotopes. The mass of one of the isotopes is 62.93 amu and the mass of the other isotope is 64.93 amu.
- Identify the element. Justify your answer.
 - Which isotope is more abundant? Justify your answer.

a) i) NH_3 - Hydrogen bonding, dipole-dipole forces

NF_3 - London dispersion forces, dipole-dipole forces

ii) The intermolecular forces in NH_3 are stronger than those in NF_3 , it takes more energy to break the intermolecular forces in NH_3 than in NF_3 .

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ADDITIONAL PAGE FOR ANSWERING QUESTION 7.

b) i) KCl - ionic

NaCl - ionic

ii) The valence electrons in Na^+ and Cl^- are on the same orbital, so there is less distance between the two elements in NaCl than in KCl, where K^+ and Cl^- are on different orbitals.

c) i)

the valence electrons on

Since Na^+ and Cl^- are closer in NaCl than K^+ and Cl^- in KCl, there is more attraction between the nucleus and the electrons in NaCl than in KCl and NaCl is more reluctant to separate.

c) i) Si: $n=3$ P: $n=3$ Cl: $n=3$

ii) The first ionization energy increases from left to right of a period because number of protons increase from left to right while the electrons are at the same quantum level. As the elements become more positive, it attracts the electrons more strongly, so it becomes increasingly difficult to remove an electron.

d) i) Copper. The average mass of the isotopes is between 62.93 amu and 64.93 amu. Copper is the only element that meets this restraint.

ii) The isotope with the mass of 64.93 is more abundant. Its mass is closer to the average mass.

GO ON TO THE NEXT PAGE.

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(ii) Explain the reasons for the trend in first ionization energies.

(d) A certain element has two stable isotopes. The mass of one of the isotopes is 62.93 amu and the mass of the other isotope is 64.93 amu.

- Identify the element. Justify your answer.
- Which isotope is more abundant? Justify your answer.

(a) i The intermolecular forces in NH_3 are dispersion forces, dipole-dipole forces, and hydrogen bonds. The intermolecular forces in NF_3 are dispersion forces and dipole-dipole forces.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 7.

ii Both substances contain dispersion forces and dipole-dipole forces, but NH_3 contains hydrogen bonds. These bonds are much stronger than the dispersion or dipole forces. Therefore, they would require more energy to break, and for NH_3 , the boiling point would have to be higher to overcome these forces. NF_3 does not have such strong bonds.

(b) i Both KCl and NaCl have ionic bonds.

ii The compound NaCl is more electronegative than KCl. Therefore, the bonds in NaCl are more ionic and stronger. They would require more energy to break than those of KCl.

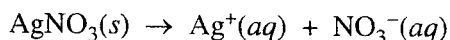
(c) i For all three elements, $n = 3$.

ii Si has 4 valence electrons, P has 5, and Cl has 7. Chlorine is the closest to having eight electrons, which would make it completely stable. It is the most stable of all three elements listed, so it would require the most energy to remove an electron. Silicon is the least stable element listed, so it would require the least energy to remove an electron. Phosphorus is in between the other two, so its ionization energy should be like that as well.

(d) i The element is Copper. The two atomic masses average to about 63. The atomic mass of Copper is 63.55.

ii The 62.93 isotope is more abundant. The mass of this isotope is closest to the average atomic mass of Copper, 63.55. Therefore, it has the highest percentage.

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8. The dissolving of $\text{AgNO}_3(s)$ in pure water is represented by the equation above.

- (a) Is ΔG for the dissolving of $\text{AgNO}_3(s)$ positive, negative, or zero? Justify your answer.
- (b) Is ΔS for the dissolving of $\text{AgNO}_3(s)$ positive, negative, or zero? Justify your answer.
- (c) The solubility of $\text{AgNO}_3(s)$ increases with increasing temperature.
- (i) What is the sign of ΔH for the dissolving process? Justify your answer.
- (ii) Is the answer you gave in part (a) consistent with your answers to parts (b) and (c) (i) ? Explain.

The compound NaI dissolves in pure water according to the equation $\text{NaI}(s) \rightarrow \text{Na}^+(aq) + \text{I}^-(aq)$. Some of the information in the table of standard reduction potentials given below may be useful in answering the questions that follow.

Half-reaction	E° (V)
$\text{O}_2(g) + 4 \text{H}^+ + 4 e^- \rightarrow 2 \text{H}_2\text{O}(l)$	1.23
$\text{I}_2(s) + 2 e^- \rightarrow 2 \text{I}^-$	0.53
$2 \text{H}_2\text{O}(l) + 2 e^- \rightarrow \text{H}_2(g) + 2 \text{OH}^-$	-0.83
$\text{Na}^+ + e^- \rightarrow \text{Na}(s)$	-2.71

- (d) An electric current is applied to a 1.0 M NaI solution.
- (i) Write the balanced oxidation half-reaction for the reaction that takes place.
- (ii) Write the balanced reduction half-reaction for the reaction that takes place.
- (iii) Which reaction takes place at the anode, the oxidation reaction or the reduction reaction?
- (iv) All electrolysis reactions have the same sign for ΔG° . Is the sign positive or negative? Justify your answer.

(a) ΔG for the dissolving of $\text{AgNO}_3(s)$ is negative because $\text{AgNO}_3(s)$ is very soluble and the dissolving process is spontaneous.

b) ΔS for the dissolving of $\text{AgNO}_3(s)$ is positive since the two products which are Ag^+ and NO_3^- aqueous ions have more entropy than

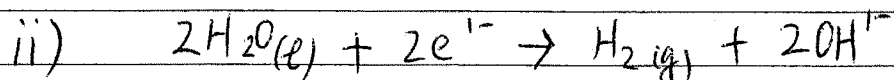
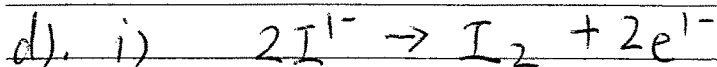
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ADDITIONAL PAGE FOR ANSWERING QUESTION 8.

the product which is a solid ($\text{AgNO}_3(\text{s})$). ΔS is positive since entropy increased.

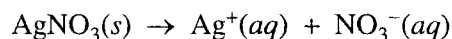
c) i) ΔH is positive since the solubility increased as temperature increased. the increase in temperature shift the equation to the right which means the forward reaction must be endothermic. If the ~~reverse~~ forward reaction is endothermic then ΔH is positive.

ii) The answers are consistent. Since $\Delta G = \Delta H - T\Delta S$ ~~Even~~ Even though ΔH is positive ΔG could still be a negative ~~number~~ number because ΔS could be a more important factor than ~~the~~ ΔH . As $T\Delta S$ increases as temperature increases and this increase offsets the enthalpy term.



iii) The oxidation reaction takes place at the anode.

iv) All electrolysis reactions have a positive ΔG° because electric energy must be supplied for the reaction to happen. ~~The~~ The reaction is non-spontaneous ~~the~~ thus ΔG° is positive.



8. The dissolving of $\text{AgNO}_3(s)$ in pure water is represented by the equation above.

- (a) Is ΔG for the dissolving of $\text{AgNO}_3(s)$ positive, negative, or zero? Justify your answer.
- (b) Is ΔS for the dissolving of $\text{AgNO}_3(s)$ positive, negative, or zero? Justify your answer.
- (c) The solubility of $\text{AgNO}_3(s)$ increases with increasing temperature.
 - (i) What is the sign of ΔH for the dissolving process? Justify your answer.
 - (ii) Is the answer you gave in part (a) consistent with your answers to parts (b) and (c) (i) ? Explain.

The compound NaI dissolves in pure water according to the equation $\text{NaI}(s) \rightarrow \text{Na}^+(aq) + \text{I}^-(aq)$. Some of the information in the table of standard reduction potentials given below may be useful in answering the questions that follow.

Half-reaction	E° (V)
$\text{O}_2(g) + 4 \text{H}^+ + 4 e^- \rightarrow 2 \text{H}_2\text{O}(l)$	1.23
$\text{I}_2(s) + 2 e^- \rightarrow 2 \text{I}^-$	0.53
$2 \text{H}_2\text{O}(l) + 2 e^- \rightarrow \text{H}_2(g) + 2 \text{OH}^-$	-0.83
$\text{Na}^+ + e^- \rightarrow \text{Na}(s)$	-2.71

- (d) An electric current is applied to a 1.0 M NaI solution.
 - (i) Write the balanced oxidation half-reaction for the reaction that takes place.
 - (ii) Write the balanced reduction half-reaction for the reaction that takes place.
 - (iii) Which reaction takes place at the anode, the oxidation reaction or the reduction reaction?
 - (iv) All electrolysis reactions have the same sign for ΔG° . Is the sign positive or negative? Justify your answer.

(a). ΔG for the dissolving of $\text{AgNO}_3(s)$ is negative because it is a favorable reaction; compounds containing NO_3 are very soluble.

(b). ΔS for the dissolving of $\text{AgNO}_3(s)$ is positive because the disorder is increased, as it is for any dissolving.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 8.

reaction.

(c). ΔH is positive because ~~the~~ breaking the bonds in AgNO_3 needs energy.

My answer to part (a) is consistent with those to (b) and (c)(i); $\Delta G = \Delta H + T\Delta S$ and though ΔH may be positive, the negative $T\Delta S$ term has a greater impact because when the temperature rises, the reaction becomes more favorable. Therefore, ΔG would still be negative.

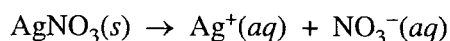
(d). oxidation reaction: $2\text{I}^- \rightarrow \text{I}_2(\text{s}) + 2\text{e}^-$

reduction reaction: $\text{Na}^+ + \text{e}^- \rightarrow \text{Na}(\text{s})$

The oxidation reaction takes place at the anode.

All electrolysis reactions ~~are~~ have a positive ΔG ;

$\Delta G^\circ = -nF\mathcal{E}^\circ$ and \mathcal{E}° is always negative for electrolysis reactions - ~~therefore~~ voltage must be applied for the cell to function.



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(i) What is the sign of ΔH for the dissolving process? Justify your answer.

(ii) Is the answer you gave in part (a) consistent with your answers to parts (b) and (c) (i)? Explain.

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(iii) Which reaction takes place at the anode, the oxidation reaction or the reduction reaction?

(iv) All electrolysis reactions have the same sign for ΔG° . Is the sign positive or negative? Justify your answer.

@ ΔG is negative NO_3 is always soluble in water because of that when placed in water it will spontaneously break its bonds with the silver.

@ ΔS is positive because as the AgNO_3 dissociates the randomness of the ions' positions and collisions will increase.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 8.

Ⓒ i: when dissolving ΔH for AgNO_3 ~~will be~~^{is} + because the molecule dissolves more with more heat therefore it must be endothermic

ii: The answer in part a is consistent because ~~when~~^{although} ΔH is positive* if ΔS is much greater in magnitude than ΔH , ΔG can still be negative and the reaction can still be spontaneous - especially if the temperature is raised.

* according to the equation $\Delta G = \Delta H - T\Delta S$

Ⓓ i $\text{Na} \rightarrow \text{Na}^+ + e^-$

ii $\text{I} + e^- \rightarrow \text{I}^-$

iii the reduction half of the reaction takes place at the anode

iv all electrolysis reactions would have a positive sign for ΔG because they all require energy to be put into the system in order to go forward with the reaction