



AP[®] Chemistry 2001 Sample Student Responses

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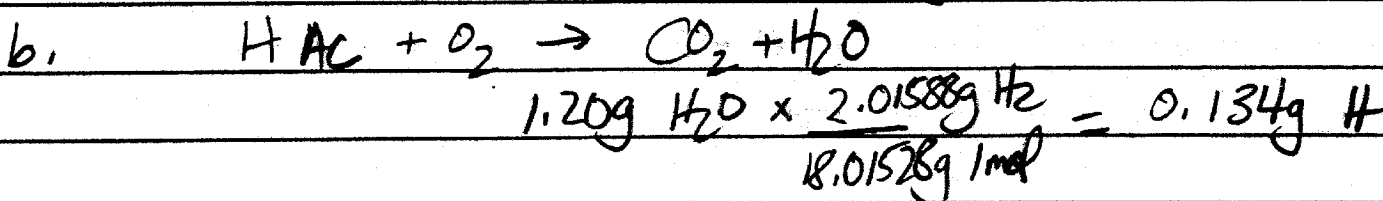
3A

3. Answer the following questions about acetylsalicylic acid, the active ingredient in aspirin.

- (a) The amount of acetylsalicylic acid in a single aspirin tablet is 325 mg, yet the tablet has a mass of 2.00 g. Calculate the mass percent of acetylsalicylic acid in the tablet.
- (b) The elements contained in acetylsalicylic acid are hydrogen, carbon, and oxygen. The combustion of 3.000 g of the pure compound yields 1.200 g of water and 3.72 L of dry carbon dioxide, measured at 750. mm Hg and 25°C. Calculate the mass, in g, of each element in the 3.000 g sample.
- (c) A student dissolved 1.625 g of pure acetylsalicylic acid in distilled water and titrated the resulting solution to the equivalence point using 88.43 mL of 0.102 M NaOH(aq). Assuming that acetylsalicylic acid has only one ionizable hydrogen, calculate the molar mass of the acid.
- (d) A 2.00×10^{-3} mole sample of pure acetylsalicylic acid was dissolved in 15.00 mL of water and then titrated with 0.100 M NaOH(aq). The equivalence point was reached after 20.00 mL of the NaOH solution had been added. Using the data from the titration, shown in the table below, determine
- the value of the acid dissociation constant, K_a , for acetylsalicylic acid and
 - the pH of the solution after a total volume of 25.00 mL of the NaOH solution had been added (assume that volumes are additive).

Volume of 0.100 M NaOH Added (mL)	pH
0.00	2.22
5.00	2.97
10.00	3.44
15.00	3.92
20.00	8.13
25.00	?

$$a. \frac{\text{Acid}}{\text{Tablet}} \quad 325 \text{ mg} = 0.325 \text{ g} \quad \frac{0.325 \text{ g}}{2.00 \text{ g}} \times 100\% = 16.3\%$$



$$PV = nRT \quad n = \frac{750}{760} \text{ atm} \cdot \frac{3.72 \text{ L mol K}}{298 \text{ K} \cdot 0.0821 \text{ L atm}} = 0.150 \text{ mol CO}_2$$

$$n = \frac{PV}{RT}$$

next (ctd.)

ADDITIONAL PAGE FOR ANSWERING QUESTION 3.

$$0.150 \text{ mol CO}_2 \times \frac{44 \text{ g CO}_2}{1 \text{ mol CO}_2} \times \frac{12 \text{ g C}}{44 \text{ g CO}_2} = 1.80 \text{ g C}$$

$$3.00 \text{ g H}_x \text{O}_y \text{C}_z - 1.80 \text{ g C} - 0.134 \text{ g H} = 1.066 \text{ g O}$$

$$\underline{1.80 \text{ g Carbon} \quad 0.134 \text{ g Hydrogen} \quad 1.07 \text{ g O}}$$

c. $88.43 \text{ mL} \times 0.102 \text{ M} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 0.00902 \text{ mol NaOH}$

1 mol NaOH neutralizes 1 mol acetylsalicylic acid

$$\text{MM} = \frac{\text{g}}{\text{mol}} = \frac{1.625 \text{ g}}{0.00902 \text{ mol}} = \frac{180.2 \text{ g}}{\text{mol}}$$

d. i. $\text{pH} = \text{pKa}$ at $\frac{1}{2}$ the equivalence point
the equivalence point = 20.00 mL $\frac{1}{2} = 10.00 \text{ mL}$
 pH at 10.00 mL = 3.44

$$\text{pH} = 3.44 = \text{pKa} \quad \text{pKa} = -\log K_a$$

$$\underline{K_a = 3.63 \times 10^{-4}}$$

ii. $25.00 \text{ mL} \xrightarrow{\text{(to neutralize acetylsalicylic acid)}} - 20.00 \text{ mL} = 5.00 \text{ mL NaOH}$

$$5.00 \text{ mL NaOH} \times \frac{1 \text{ L}}{1000 \text{ mL}} \times 0.100 \text{ M} = 5.00 \times 10^{-4} \text{ mol}$$

$$\frac{5.00 \times 10^{-4} \text{ mol}}{(25.00 \text{ mL} + 15.00 \text{ mL})} \times \frac{1000 \text{ mL}}{1 \text{ L}} = 0.0125 \text{ M NaOH} = 0.0125 \text{ M [OH}^-]$$

$$\text{pOH} = 1.90 \quad \text{pH} + \text{pOH} = 14$$

$$\underline{\underline{\text{pH} = 12.10}}$$

3. Answer the following questions about acetylsalicylic acid, the active ingredient in aspirin.

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$$3. (a) \quad 325 \text{ mg acid} \cdot \frac{1 \text{ g}}{1000 \text{ mg}} = 0.325 \text{ g}$$

$$\frac{\text{mass of acid}}{\text{total mass}} = \frac{0.325 \text{ g}}{2.00 \text{ g}} = 16.3\%$$

$$(b) \quad 1.2 \text{ g H}_2\text{O} \cdot \frac{1 \text{ mol}}{18 \text{ g}} \cdot \frac{2 \text{ mol H}}{1 \text{ mol H}_2\text{O}} = \frac{1.01 \text{ g H}}{1 \text{ mol H}} = 0.135 \text{ g H}$$

$$3.72 \text{ L CO}_2 \cdot \frac{1 \text{ mol}}{22.4 \text{ L}} \cdot \frac{1 \text{ mol C}}{1 \text{ mol CO}_2} \cdot \frac{12.01 \text{ g C}}{1 \text{ mol C}} = 2.000 \text{ g C}$$

$$3.000 - 0.135 - 2.000 = 0.865 \text{ g O}$$

(c) Equivalence point means there are equal number of moles...

$$\begin{aligned} \text{moles of NaOH} &= \text{moles of acetylsalicylic acid} \\ \text{moles of NaOH} &= 0.08843 \cdot 0.102 \text{ M} = 9.02 \cdot 10^{-3} \text{ mol} \end{aligned}$$

$$1.625 \text{ g acid} = 9.02 \cdot 10^{-3} \text{ mol}$$

$$\frac{1.625}{9.02 \cdot 10^{-3}} = \text{MM}$$

$$\text{molar mass} = 180.2 \text{ g/mol}$$

(d) (i) $pK_a = \text{pH}$ at equivalence point

$$pK_a = 8.13$$

$$K_a = 10^{-8.13} = 7.41 \cdot 10^{-9}$$

(ii) After equivalence point, there is just excess NaOH

$$25.00 \text{ ml NaOH} - 20.00 \text{ ml} = 5.00 \text{ ml}$$

$$5.00 \text{ ml} \cdot 0.1 \text{ M NaOH} = 5.0 \cdot 10^{-4} \text{ mol OH}^-$$

$$\frac{5.0 \cdot 10^{-4} \text{ mol OH}^-}{(25.00 \text{ ml} + 15.00 \text{ ml})} = 0.0125 \text{ M OH}^-$$

$$-\log(0.0125) = 1.90 = \text{pOH}$$

$$\text{pH} = 14.00 - 1.90 = 12.10$$

3C,

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25.00	?

$$a) \frac{325 \text{ mg}}{2 \text{ g}} \cdot \frac{1 \text{ g}}{1000 \text{ mg}} = \frac{325}{2000} = 0.1625 = 16.25\%$$



$$1.2 \text{ g H}_2\text{O} \cdot \frac{1 \text{ mol H}_2\text{O}}{18 \text{ g H}_2\text{O}} \cdot \frac{2 \text{ mol H}}{1 \text{ mol H}_2\text{O}} \cdot \frac{1 \text{ g H}}{1 \text{ mol H}} = 1.3 \text{ g H}$$

$$3.72 \text{ L CO}_2 \cdot \frac{1 \text{ mol CO}_2}{22.4 \text{ L CO}_2} \cdot \frac{1 \text{ mol C}}{1 \text{ mol CO}_2} \cdot \frac{12 \text{ g C}}{1 \text{ mol C}} = 2.0 \text{ g C}$$

ADDITIONAL PAGE FOR ANSWERING QUESTION 3.

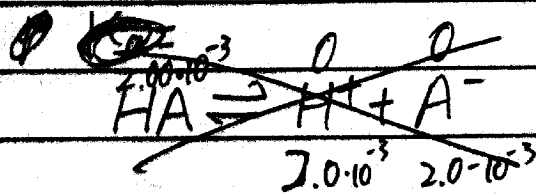
$$c) \frac{.102 \text{ mol}}{1 \text{ L}} \cdot .08843 \text{ L} \cdot \frac{1 \text{ mol H}^+}{1 \text{ mol NaOH}} = 9.02 \cdot 10^{-3} \text{ mol H}^+$$

$$9.02 \cdot 10^{-3} \text{ mol H}^+ \cdot \frac{1 \text{ mol HA}}{1 \text{ mol H}^+} = 9.02 \cdot 10^{-3} \text{ mol HA}$$

$$\frac{1.625 \text{ g HA}}{9.02 \cdot 10^{-3} \text{ mol HA}} = \boxed{180.2 \text{ g/mol}}$$

~~$$d) i) \frac{2.00 \cdot 10^{-3} \text{ mol}}{0.15 \text{ L}} = 1.33 \text{ mol/L}$$~~

~~$$[H^+] = \frac{1 \text{ mol}}{1 \text{ L}} \cdot .02 \text{ L} \cdot \frac{1 \text{ mol H}^+}{1 \text{ mol OH}^-} \cdot \frac{1}{.015 \text{ L}} = 1.33 \text{ mol/L} \cdot 1.33 \text{ mol/L} \cdot .015 \text{ L} = 2.0 \cdot 10^{-3}$$~~



$$3.44 = pK_a$$

$$10^{-3.44} = K_a$$

$$\boxed{K_a = 3.63 \cdot 10^{-4}}$$

20ml is the equivalence point



10ml is the half-point, where pH = pKa

$$ii) \text{pH} = \text{pKa} + \log\left(\frac{A^-}{HA}\right)$$