Consider $C_3H_8 + O_2 \rightarrow CO_2 + H_2O$ (propane combustion)

a) balance the equation

(i) balance C (add $3CO_2$ for total $3CO_2$ on right)

$$C_3H_8 + O_2 \rightarrow 3CO_2 + H_2O$$

(ii) balance H (add $3H_2O$ for total $4H_2O$ on right)

$$C_3H_8 + O_2 \rightarrow 3CO_2 + 4H_2O$$

(iii) balance O (10-O on right, so make $5O_2$ on left

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

(b) How many mol of oxygen to burn 1 mol of propane?

1 mol propane needs 5 mol of $O_2(g)$ or 10 mol of O

(c) How many grams of O to burn 100g propane

$$100g\,C_3H_8 \cdot \frac{1\text{ mol}}{44\text{ g}} \cdot \frac{5\text{ mol } O_2}{1\text{ mol } C_3H_8} \cdot \frac{32\text{ g } O_2}{1\text{ mol } O_2} = 363\text{ grams } O_2$$

(d) At STP (25°C, 1atm) what volume of O_2 is required

If air is 21% O_2 by volume, what volume of air?

2.1

$$V_{O_2}: \; 363g\,O_2 \; \frac{1\,mol}{32g} \cdot \frac{22.4L}{1\,mol} = 254.5L \; \frac{m^3}{1000L} = 0.25m^3$$

$V_{AIR}: \; 0.21(V_{AIR}) = V_{O_2}$ (partial pressures $\Rightarrow V \propto \frac{\text{mole}}{\text{fraction}}$)

$$V_{AIR} = \frac{254.5L}{0.21} = 1212\,L \; \frac{m^3}{1000L} = 1.21\,m^3 \text{ air}$$

(e) At STP what volume of CO_2 is produced when 100g of propane is burned?

$$100g\,C_3H_8 \; \frac{1\,mol}{44g} \cdot \frac{3\,mol\,CO_2}{1\,mol\,C_3H_8} \cdot \frac{22.4L}{1\,mol} = 152.7 \; L\,CO_2$$

$$= \frac{152.7L}{1000L} = 0.15\,m^3\,CO_2$$

Unknown substance is 40 w/o C, 6.67 w/o H, 53.33 w/o O. MW ≈ 55g/mol. What is the compound's formula and correct MW?

$$C_x H_y O_z \approx 55 g/mol$$

$$C_x \approx 0.40 \; 55 g/mol = 22 g/mol$$

$$H_y \approx 0.0667 \; 55 g/mol = 3.66 g/mol$$

$$O_z \approx 0.5333 \; 55 g/mol = 29.33 g/mol$$

MW-C = 12 $\quad x = \frac{22}{12} = 1.8333$

MW-H = 1 $\quad y = \frac{3.66}{1} = 3.66$

MW-O = 16 $\quad z = \frac{29.33}{16} = 1.833$

Empirical formula is $C_{1.833} H_{3.66} O_{1.833}$

Observe $\frac{3.66}{1.833} = 1.996$ (2 for all practical purposes)

∴ Atomic ratios are $C_x H_{2x} O_x$

Now choose x so that MW ≈ 55

MW in terms of x

$$12(x) + 2(x) + 16(x) = 30x$$

x is probably 2

∴ Formula is $C_2 H_4 O_2$, MW = 60 g/mol

CIVE 1331 PROBLEM 2.5

43% ETOH by volume. (CH_3CH_2OH). Density of ETOH is 0.79kg/L. What is the alcohol concentration of whiskey in mol/L? (molarity)

$$0.43\,L\ CH_3CH_2OH\ \frac{0.79\,kg}{L} = 0.3397\,kg = 339.7\,g$$

$$339.7\,g\ \cancel{ETOH}\ \frac{1\,mol}{46\,g} = 7.38\,mol$$

∴ $[CH_3CH_2OH]$ in whiskey is 7.38 mol/L

or 7.38 M

Find heating values (HHV) of following fuels in Btu/gal

a) Methanol CH_3OH, $\rho = 6.1$ lb/gal

$$2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$$
$$2(-238.6) + 3(0) \qquad 2(-393.5) + 4(-285.8)$$

$\Delta H = -1453$ kJ/mol

Need gallons/mol

$$1\text{ mol} = (12)+(16)+4) = 32\text{ grams} \cdot \frac{2.2046\text{ lbs}}{10^3\text{ grams}}$$

$$= 0.0705\text{ lbs} * \frac{1\text{ gal}}{6.7\text{ lbs}} = 0.01156\text{ gal}$$

$$1453 \cdot kJ \cdot \frac{0.9478\text{ Btu}}{1\text{ kJ}} = 1377.15\text{ Btu}$$

$$\therefore \Delta H = -\frac{1377.15\text{ Btu}}{0.01156\text{ gal}} = -130,790\text{ Btu/gal}$$

b) Ethanol

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$
$$(-277.6) + 3(0) \rightarrow 2(-393.5) + 3(-285.8)$$

$\Delta H = -1366.8$ kJ/mol

$2(12) + 6 + 16 = 46$ g/mol

$46 \text{ grams} \cdot \frac{2.2046}{10^3} = 0.1014 \text{ lbs} \cdot \frac{1}{6.6} = 0.0153 \text{ gal}$

$-1366.8 \cdot 0.9478 = -1295 \text{ Btu}/$

$\therefore \Delta H = \frac{-1295 \text{ Btu}}{0.0153 \text{ gal}} = -84309 \text{ Btu/gal}$

c) Propane

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$
$$(-103.8) \quad 5(0) \qquad 3(-393.5) + 4(-285.8)$$

$\Delta H = -2219.9$ kJ/mol

$3(12) + 8 = 44 \text{ g/mol} \cdot \frac{2.2046}{10^3} = 0.097 \text{ lbs/mol} \cdot \frac{1 \text{ gal}}{4.1 \text{ lbs}} = 0.0236 \text{ gal}$

$-2219.9 \text{ kJ} \cdot 0.9478 = -2104 \text{ Btu}$

$\therefore \Delta H = \frac{-2104 \text{ Btu}}{0.0236 \text{ gal}} = -88930 \text{ Btu/gal}$

CIVE 1331 Problem 2-18

Find THOD of

200 mg/L of acetic acid; CH_3COOH

$$CH_3COOH + 2O_2 \rightarrow 2CO_2 + 2H_2O$$

balance C 2 ✓ $CH_3COOH = 12+3+12+32+1 = 60\,g/mol$

balance H 4 ✓ $2O_2 = 64\,g/mol$

balance O 6 ✓ $2CO_2 = 2(44) = 88\,g/mol$

Convert to masses $2H_2O = 2(18) = 36\,g/mol$

60 g CH_3COOH required 64 g O_2 for complete oxidization

$$200\,mg/L\text{-}CH_3COOH \cdot \frac{64\,g\ O_2}{60\,g\ CH_3COOH} = \underline{\underline{213\,mg/L}}\ O_2 \text{ required}$$

30 mg/L ethanol C_2H_5OH

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

$24+16+6$ $3(32)$ $2(44)$ $3(18)$

46 g/mol

$$30\,mg/L\ ETOH \cdot \frac{96\,g\ O_2}{46\,g\ ETOH} = \underline{\underline{62.6\,g/L}}\ O_2 \text{ required}$$

50mg/L sucrose $C_2H_{12}O_6$

$$C_2H_{12}O_6 + 2O_2 \rightarrow 2CO_2 + 6H_2O$$

$24+12+6(16)$ $2(32)$

132g/mol 64g/mol

$$50\,mg/L\ \text{sugar} \cdot \frac{64g\ O_2}{132g\ \text{sugar}} = 24.2\ mg/L\ \text{Oxygen.}$$

CIVE 1331 PROBLEM 2.19

Water is disinfected with chlorine gas which forms hypochlorous acid (the actual disinfectant)

$$HOCl \rightleftharpoons H^+ + OCl^- \qquad K_{eq} = 2.9 \cdot 10^{-8}$$

[HOCl] is pH dependent. Find the fraction of $[HOCl]/([HOCl]+[OCl^-])$ as a function of pH.

$$\frac{[H^+][OCl^-]}{[HOCl]} = 2.9 \cdot 10^{-8}$$

$$\frac{[OCl^-]}{[HOCl]} = \frac{2.9 \cdot 10^{-8}}{10^{-pH}}$$

$$\frac{[HOCl]}{[HOCl]+[OCl^-]} = \frac{1}{1+\frac{[OCl^-]}{[HOCl]}} = \frac{1}{1+\frac{2.9 \cdot 10^{-8}}{10^{-pH}}}$$

pH	H^+	$\frac{[OCl^-]}{[HOCl]} = \frac{2.9 \cdot 10^{-8}}{10^{-pH}}$	$\frac{[HOCl]}{[HOCl]+[OCl^-]}$	%HOCl
10	$1 \cdot 10^{-10}$	290	0.003	.3%
9	$1 \cdot 10^{-9}$	29	0.033	3.3%
8	$1 \cdot 10^{-8}$	2.9	0.256	25.6%
7	$1 \cdot 10^{-7}$	0.29	0.775	77.5%
6	$1 \cdot 10^{-6}$	0.029	0.971	97.1%
5	$1 \cdot 10^{-5}$	0.0029	0.997	99.7%

H_2S can be stripped from water like ammonia.

$$H_2S \rightleftharpoons H^+ + HS^- \qquad K_{eq} = 0.86 \cdot 10^{-7}$$

Find fraction of H_2S in water at pH6 and pH8.

$$\frac{[H^+][HS^-]}{[H_2S]} = 0.86 \cdot 10^{-7}$$

$$\frac{[H_2S]}{[HS^-]} = \frac{[H^+]}{0.86 \cdot 10^{-7}} \qquad pH = -\log[H^+]$$

$$\cancel{-\log[H_2S] - -\log[HS^-] = -\log[H^+] - -\log[0.86 \cdot 10^{-7}]}$$

$$\frac{[H_2S]}{[H_2S]+[HS^-]} = \frac{1}{1+\frac{HS^-}{H_2S}}$$

pH	$[H^+]$	$[H^+]/0.86 \cdot 10^{-7} = \frac{H_2S}{HS^-}$	$\frac{1}{1+\frac{HS^-}{H_2S}}$	$\% H_2S$
9	$1 \cdot 10^{-9}$	0.0011627	0.011	1.1%
8	$1 \cdot 10^{-8}$	0.11627	0.104	10.4%
7	$1 \cdot 10^{-7}$	1.16279	0.537	53.7%
6	$1 \cdot 10^{-6}$	11.6279	0.920	92.0%
5	$1 \cdot 10^{-5}$	116.279	0.991	99.1%
4	$1 \cdot 10^{-4}$	1162.79	0.999	99.9%
3	$1 \cdot 10^{-3}$	11627.9	0.999	99.99%