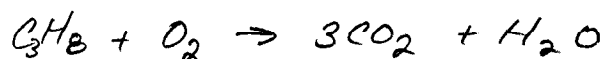


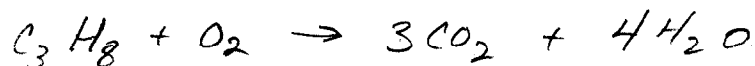
Consider $C_3H_8 + O_2 \rightarrow CO_2 + H_2O$ (propane combustion)

a) balance the equation

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



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



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



(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

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

(d) At STP ($25^\circ C, 1 \text{ atm}$) what volume of O_2 is required
if air is 21% O_2 by volume, what volume of air?

5000 ft³ air
0.006 · 60

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

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

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

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

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

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

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

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

$$C_x \approx 0.40 \frac{55g}{mol} = 22g/mol$$

$$H_y \approx 0.0667 \frac{55g}{mol} = 3.66g/mol$$

$$O_z \approx 0.5333 \frac{55g}{mol} = 29.33g/mol$$

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

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

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

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 \approx 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 = 60g/mol

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Problem 2.5

4

43% ETOH by volume. ($\text{CH}_3\text{CH}_2\text{OH}$). Density of ETOH is 0.79 kg/L . What is the alcohol concentration of whiskey in mol/L ? (molarity)

$$0.43 \text{ L } \text{CH}_3\text{CH}_2\text{OH} \frac{0.79 \text{ kg}}{\text{L}} = 0.3397 \text{ kg} = 339.7 \text{ g}$$

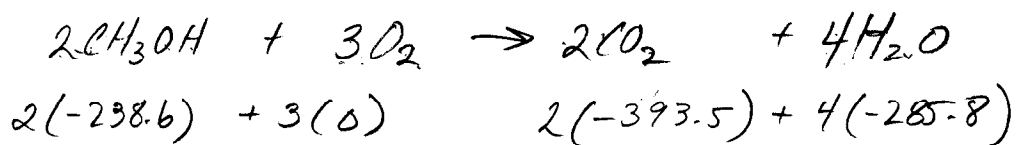
$$339.7 \text{ g ETOH} \frac{1 \text{ mol}}{46 \text{ g}} = 7.38 \text{ mol}$$

$\therefore [\text{CH}_3\text{CH}_2\text{OH}]$ 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 , $\rho = 6.1 \text{ lb/gal}$



$$\Delta H = -1453 \text{ kJ/mol}$$

Need gallons/mol

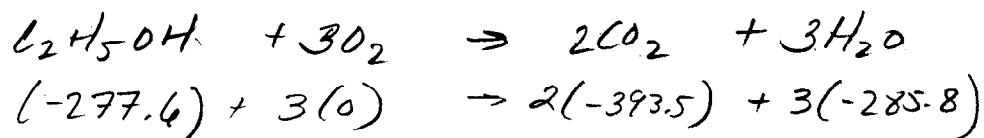
$$1 \text{ mol} = (12) + (16) + 4 = 32 \text{ grams} \cdot \frac{2.2046 \text{ lbs}}{10^3 \text{ grams}}$$

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

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

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

b) Ethanol



$$\Delta H = -1366.8 \text{ kJ/mol}$$

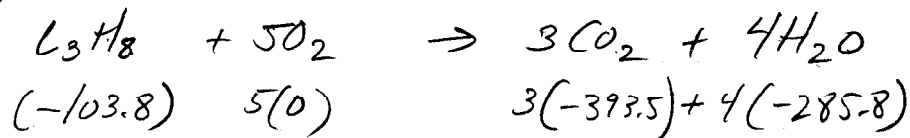
$$2(12) + 6 + 16 = 46 \text{ g/mol}$$

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

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

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

c) Propane



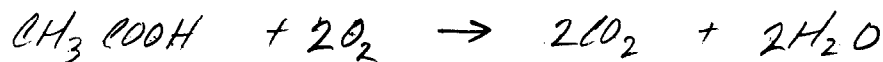
$$\Delta H = -2219.9 \text{ kJ/mol}$$

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

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

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

Find THOD of

200 mg/L of acetic acid; CH_3COOH 

balance C 2 ✓

$$\text{CH}_3\text{COOH} = 12 + 3 + 12 + 32 + 1 = 60 \text{ g/mol}$$

balance H 4 ✓

$$2\text{O}_2 = 64 \text{ g/mol}$$

balance O 6 ✓

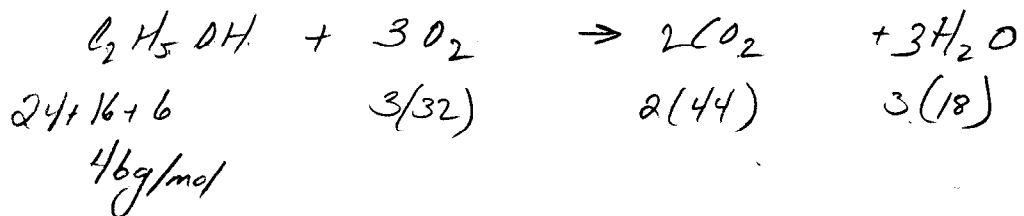
$$2\text{CO}_2 = 2(44) = 88 \text{ g/mol}$$

convert to masses

$$2\text{H}_2\text{O} = 2(18) = 36 \text{ g/mol}$$

60g CH_3COOH requires 64g O_2 for complete
oxidization

$$200 \text{ mg/L } \text{CH}_3\text{COOH} \cdot \frac{64 \text{ g } \text{O}_2}{60 \text{ g } \text{CH}_3\text{COOH}} = \underline{\underline{213 \text{ mg/L } \text{O}_2 \text{ required}}}$$

30 mg/L ethanol $\text{C}_2\text{H}_5\text{OH}$ 

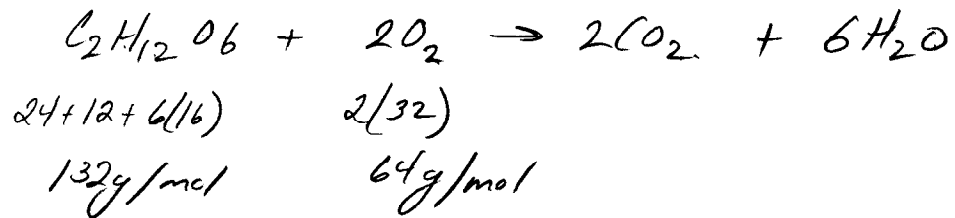
$$30 \text{ mg/L } \text{EtOH} \cdot \frac{96 \text{ g } \text{O}_2}{46 \text{ g } \text{EtOH}} = \underline{\underline{62.6 \text{ g/L } \text{O}_2 \text{ required}}}$$

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Problem 2.18

8

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



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

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



$[\text{HOCL}]$ is pH dependent. Find the fraction of $[\text{HOCL}]/([\text{HOCL}] + [\text{OCL}^-])$ as a function of pH.

$$\frac{[\text{H}^+][\text{OCL}^-]}{[\text{HOCL}]} = 2.9 \cdot 10^{-8}$$

$$\frac{[\text{OCL}^-]}{[\text{HOCL}]} = \frac{2.9 \cdot 10^{-8}}{10^{-\text{pH}}}$$

$$\frac{[\text{HOCL}]}{[\text{HOCL}] + [\text{OCL}^-]} = \frac{1}{1 + \frac{[\text{OCL}^-]}{[\text{HOCL}]}} = \frac{1}{1 + \frac{2.9 \cdot 10^{-8}}{10^{-\text{pH}}}}$$

pH	H^+	$\frac{[\text{OCL}^-]}{[\text{HOCL}]} = \frac{2.9 \cdot 10^{-8}}{10^{-\text{pH}}}$	$\frac{[\text{HOCL}]}{[\text{HOCL}] + [\text{OCL}^-]}$	%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.



Find fraction of H_2S in water at pH 6 and pH 8.

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

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

$$pH = -\log [H^+]$$

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

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

pH	$[H^+]$	$\frac{[H^+]}{0.86 \cdot 10^{-7}} = \frac{H_2S}{HS^-}$	$1 + \frac{HS^-}{H_2S}$	% H_2S
9	$1 \cdot 10^{-9}$	0.001627	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%