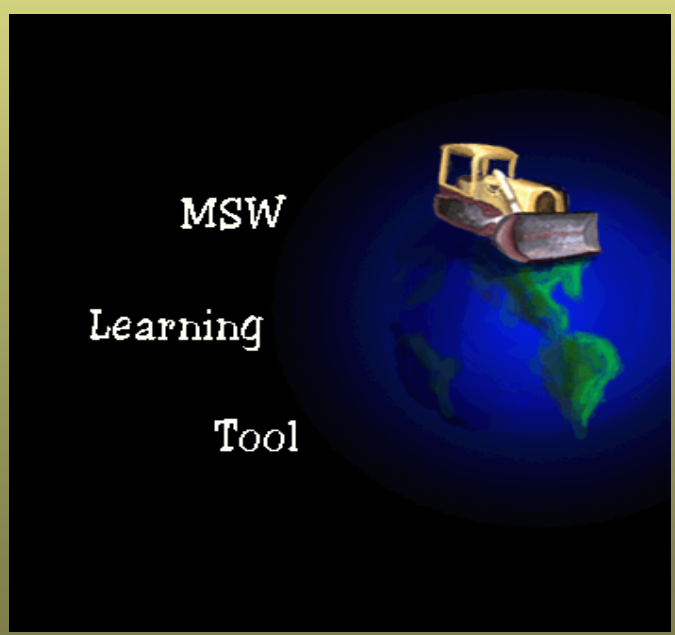
Determining the Chemical Composition of Solid Waste



Problem Statement

Determine the chemical composition of the organic fraction of the waste described in Table 1, with and without sulfur and with and without water.

Table 1. Composition of Solid Waste

Component	Wet Weight, lb	Percent MC
Food Wastes	9	70
Paper	34	6
Cardboard	6	5
Plastics	7	1
Textiles	2	10
Rubber	0.5	0
Leather	0.5	20
Yard wastes	18.5	65
Wood	2	20
Inorganic	20.5	3

Step 1: Calculate the Weight of Each Element

- Using data in Table 2, calculate the weight of C, H, O, N, S, and ash in each component
- Table 2 is based on dry waste only, first the dry weight of each component must be calculated
- Results are presented in Table 3

Table 2. Chemical Composition of Waste Components

Typical data on the ultimate analysis of the combustile components in residential MSW[a]

Component	Percent by weight (dry basis)					
	Carbon	Hydrogen	Oxygen	Nitrogen	Sulfur	Ash
Organic						
Food wastes	48.0	6.4	37.6	2.6	0.4	5.0
Paper	43.5	6.0	44.0	0.3	0.2	6.0
Cardboard	44.0	5.9	44.6	0.3	0.2	5.0
Plastics	60.0	7.2	22.8	—	—	10.0
Textiles	55.0	6.6	31.2	4.6	0.15	2.5
Rubber	78.0	10.0	—	2.0	—	10.0
Leather	60.0	8.0	11.6	10.0	0.4	10.0
Yard wastes	47.8	6.0	38.0	3.4	0.3	4.5
Wood	49.5	6.0	42.7	0.2	0.1	1.5
Inorganic						
Glass[b]	0.5	0.1	0.4	<0.1	—	98.9
Metals[b]	4.5	0.6	4.3	<0.1	—	90.5
Dirt, ash, etc.	26.3	3.0	2.0	0.5	0.2	68.0

[a] Adapted in part from Ref. 6.

[b] Organic content is from coatings, labels, and other attached materials.

Step 1: Sample Calculation

- Food Waste

MC = 70%

9 - 9(0.7) = 2.7 lb dry weight

Carbon: 2.7 (0.48) = 1.3 lb

Hydrogen: 2.7 (0.064) = 0.17 lb

Table 3. General Composition of Solid Waste

Component	Wet Weight	Dry Weight	Composition					
	lb.	lb.	C	H	O	N	S	Ash
Food Waste	9.0	2.7	1.30	0.17	1.02	0.07	0.01	0.14
Paper	34.0	32.0	13.90	1.92	14.06	0.10	0.06	1.92
Cardboard	6.0	5.7	2.51	0.34	2.54	0.02	0.01	0.29
Plastic	7.0	6.9	4.16	0.50	1.58	0.00	0.00	0.69
Textiles	2.0	1.8	0.99	0.12	0.56	0.08	0.00	0.05
Rubber	0.5	0.5	0.39	0.05	0.00	0.01	0.00	0.05
Leather	0.5	0.4	0.24	0.03	0.05	0.04	0.00	0.04
Yard Wastes	18.5	6.5	3.10	0.39	2.46	0.22	0.02	0.29
Wood	2.0	1.6	0.79	0.10	0.68	0.00	0.00	0.02
TOTAL	79.5	58.1	27.37	3.61	22.95	0.54	0.11	3.48

Step 2. Calculate the weight of H and O in water

- From Table 2 we see that **dry waste** has a weight of 58.1 pounds, and that as-**discarded-waste** has a weight of 79.5 pounds.
- We then subtract the weight of the dry waste from the weight of the saturated waste to give us the weight of the water in the waste.

79.5 lbs - 58.1 lbs = 21.4 lbs H_2O

Step 2: Continued

We now want to determine how much hydrogen and oxygen in pounds there are in the waste sample. We do this by using the equation:

$$\left[\frac{Total\_Moisture\_in\_lb}{molecular\_wt\_of\_water}\right] xmolecularwt\_of\_H$$

Step 2: Continued

$$\left[\frac{21.4lb}{18lb}\right] * 2 = 2.38lb\_H$$

Similarly for Oxygen:

$$\left[\frac{21.4lb}{18lb}\right] * 16 = 19.02lb\_O$$

Step 2: Continued

The amount of Hydrogen and Oxygen should be added to the H and O in the waste when we are calculating chemical composition with water. See Table 4.

Table 4. Percentage Distribution of the Elements with and without Water

Element	lb, w/o Water*	lb, w/ Water
Carbon	27.37	27.37
Hydrogen	3.61	5.99
Oxygen	22.95	42.00
Nitrogen	0.54	0.54
Sulfur	0.11	0.11
Ash	3.48	3.48

*Row 11, Table 3

Step 4: Determine Molar Composition of the Elements, Neglecting Ash

- We do this by dividing each component by its respective molecular weight
- Results in Table 5

Table 5. Molar Composition

Element	Atomic wt	Moles	Moles
		W/O Water	W/ Water
Carbon	12.01	2.279	2.279
Hydrogen	1.01	3.575	5.933
Oxygen	16.00	1.434	2.625
Nitrogen	14.01	0.038	0.038
Sulfur	32.07	0.003	0.003

Step 5. Determine Chemical Formula

- Determine the approximate chemical formula with and without sulfur and with and without water
- To determine the formula without sulfur, use the lowest represented element, nitrogen as the base; divide each value by the number of moles of nitrogen.
- Similarly, when determining the formula with sulfur use sulfur as a base and divide each by the number of moles of sulfur.
- See Table 6

Table 6.Normalized Mole Ratios

	Mole Ratio - (Nitrogen = 1)		Mole Ratio - (Sulfur=1)	
Element	**W/O Water**	**W/ Water**	**W/O Water**	**W/ Water**
Carbon	59.2	59.2	655.8	655.8
Hydrogen	92.9	154.1	1028.8	1707.4
Oxygen	37.3	68.2	412.8	755.5
Nitrogen	1.0	1.0	11.1	11.1
Sulfur	0.1	0.1	1.0	1.0

Summary of Results

- The chemical formulas without sulfur are:
  - Without water: $C_{59}H_{93}O_{37}N$
  - With water: $C_{59}H_{154}O_{68}N$
- The chemical formulas with sulfur are:
  - Without water: $C_{656}H_{1029}O_{413}N_{11}S$
  - With water: $C_{656}H_{1707}O_{756}N_{11}S$
- Note: all values in whole numbers

On Your Own Problem

- Calculate the chemical composition of a typical yard waste with and without water (based on N and S)
- Hint: Assume 100 lb of waste, 40 % Moisture Content

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Last updated July 2004 by Dr. Reinhart