



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

WASTE TO ENERGY CONVERSION

TUTORIAL ON CHARACTERIZATION OF WASTES

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CHEMICAL ENGINEERING



Problem 1

To determine the water equivalent of a bomb calorimeter 1.1651 gram benzoic acid sample (HHV 6318 cal/g) was used. The experiment produced a net corrected temperature rise of 3.077°C . The acid titration required 11.9 ml of standard alkali and 8 cm of Parr 45C10 nickel-chromium fuse wire was consumed in the firing. Determine the water equivalent of the bomb calorimeter.

Solution:

Given data

$$H = 6318 \text{ cal/gram}$$

$$T = 3.077^{\circ}\text{C}$$

$$M = 1.1651 \text{ gram}$$

$$C_1 = 11.9 \text{ ml}$$

$$C_2 = 0$$

$$C_3 = 8 \text{ cm}$$



Therefore,

$$E_1 = (11.9 \text{ ml})(1 \text{ cal/ml}) = 11.9 \text{ cal};$$

$$E_2 = (13.7)(C_2)(m) \text{ calories} = 0 \text{ as } C_2 \text{ is } 0$$

$$E_3 = (2.3)(C_3) = (2.3 \text{ cal/cm}) (8 \text{ cm}) = 18.4 \text{ cal}$$

We know that

$$W = (H^*M + E_1 + E_2 + E_3)/T$$

$$W = \frac{(6318)(1.1651) + 11.9 + 18.4}{3.077} = 2402.1 \text{ cal per deg C}$$



Problem 2

1 gram of a MSW sample is heated at 105 °C for 24 h and the weight of the dried material is found as 0.9 g, which is further heated in a furnace at 950 °C for 7 min in absence of air by putting the lid of the crucible. The weight loss is found as 0.3 g. The remaining material is cooled with lid cover. When the temperature reaches to ambient temperature, its lid is opened and it is further heated in an oven at 750 °C for half an hour in presence of oxygen. After cooling the material, the residual mass of the material is found as 0.14 g. Determine the moisture content, volatile matter, ash and fixed carbon of the waste.

Solution

Initial mass = 1 g

Moisture content = $(1-0.9)*100 = 10 \%$

VM content = $(0.3)*100 = 30 \%$

Ash content = $(0.14)*100 = 14 \%$

Fixed carbon = $100-10-30-14 = 46 \%$



Problem 3

An industrial waste water is tested for measuring BOD_5 value. The waste water is diluted 100 times with dilution water before it is use in the test. The OD of one real and blank sample are determined, which is 10 ppm. Other two BOD bottles filled with real and blank sample are incubated for 5 days at 20°C . After 5 days the DO value of the real and blank samples are found as 3 ppm and 9.7 ppm respectively. Calculate the BOD_5 of the original waste water sample. If 5 ml of microbial seeds are used in the preparation of 300 ml dilution water, how the BOD value will differ.

Solution

We know that

$$BOD_5 \text{ (in mg/L)} = D^* \left[\underset{\text{Sample}}{[(DO)_{t=0} - (DO)_{t=5}]} - \underset{\text{Blank}}{[(DO)_{t=0} - (DO)_{t=5}]} \right] \quad \text{Where } D^* = \text{dilution factor}$$



In the present case

$$D = 100$$

$(DO)_{t=0} = 10$ ppm for both real sample and blank test bottles

$(DO)_{t=5}$ for real sample test bottle = 3 ppm

$(DO)_{t=5}$ for blank test bottle = 9.7 ppm

$$\begin{aligned}\text{Therefore, } BOD_5 (\text{in ppm}) &= 100[(10-3)-(10-9.7)] \\ &= 670 \text{ ppm}\end{aligned}$$



For seeded dilution

$$\text{BOD}_5 \text{ (in mg/L)} = D^* \left[\underset{\text{Sample}}{[(\text{DO})_{t=0} - (\text{DO})_{t=5}]} - \underset{\text{Blank}}{[(\text{DO})_{t=0} - (\text{DO})_{t=5}] * f} \right]$$

Where D^* = dilution factor

f = ratio of seed volume in dilution solution to seed volume in BOD test on seed, normally f is near to 1

Seed volume in 300 ml dilution water = 5 ml

For 100 time dilution 3 ml of real waste water sample is added with 297 ml of dilution water to prepare real/test sample

Therefore volume of seeds in real/test sample $(297*5)/300$ ml

Hence, $f = (5*300)/(5*297) = 1.01$

Thus,

$$\text{BOD} = 100[(10-3) - (10-9.7)*1.01] = 669.1 \text{ ppm}$$



Problem 4

2 g of a dried agricultural waste is leached with benzene and ethanol mixture (2:1 v/v) at $\sim 60^\circ\text{C}$ for 3 h. After leaching, the residue is dried in a hot air oven at 105°C to a constant weight of 1.8 g. This dried material is put in a flask containing 150 ml of (N/2) NaOH solution. The mixture is boiled for 3.5 h with recycled distilled water. After this the residue is washed with distilled water till all the sodium ions are removed and dried to a constant weight of 1.3 g. Determine the extractives and hemicelluloses content of this waste on dry basis. If moisture content of the waste is 15 %, determine these values with respect to original sample.



Basis: Dry sample

Initial weight (M_0) = 2 g

Weight after extractives = M_1 = 1.8 g

Weight after hemicellulose separation = M_2 = 1.3 g

Extractive content = $(M_0 - M_1) * 100 / M_0 = (2 - 1.8) * 100 / 2 = 10 \%$

Hemicellulose content = $(M_1 - M_2) * 100 / M_0 = (1.8 - 1.3) * 100 / 2 = 25 \%$

With respect to original waste material the extractives and hemicellulose contents are

Extractive content = $(85/100) * 10 \% = 8.5 \%$

Hemicellulose content = $(85/100) * 25 \% = 21.25 \%$

Problem 5

COD analysis of a waste water sample is carried out through chemical method using (N/10) K-dichromate solution as reducing agent. Excess dichromate is titrated against ferrous ammonium sulphate. 100 ml of waste water sample is used. The titter value of ferrous ammonium sulphate are 50 ml and 75 ml for original sample and blank sample respectively. Determine the COD of the sample. Assume there is no interfering element in the sample.

Solution

$$\begin{aligned}\text{COD} &= 8000(b-s)*n/\text{sample volume} \\ &= 8000(75-50)*0.1/100 \\ &= 200 \text{ mg/l}\end{aligned}$$

where b is the volume of FAS used in the blank sample,
 s is the volume of FAS in the original sample,
and n is the normality of FAS.



Problem 6

1.5 g of a solid waste is kept in the bomb of a calorimeter. The initial and final temperatures of water in bucket are 23 and 28 °C respectively. The bucket wash is titrated against N/10 Na_2CO_3 and the titer value is 2.5 ml. Sulphur content in the solid waste is 2 %. Parr 45C10 Ni-Cr wire is used to ignite the waste sample and 4 cm of the wire is fused. The water equivalent of the calorimeter is 2402 cal per °C. Hydrogen content of the waste is 8 %. Calculate the HHV and LHV of the solid waste.



Solution

Data given

$$H_g = (T \cdot W - E_1 - E_2 - E_3) / M$$

Therefore,

$$E_1 = (2.5 \text{ ml})(1 \text{ cal/ml}) = 2.5 \text{ cal};$$

$$E_2 = (13.7)(C_2)(m) \text{ calories} = 13.7 \cdot 2 \cdot 1.5 = 41.1 \text{ Cal}$$

$$E_3 = (2.3)(C_3) = (2.3 \text{ cal/cm})(4 \text{ cm}) = 9.2 \text{ cal}$$

$$H_g = (5 \cdot 2402 - 2.5 - 41.1 - 9.2) / 1.5 = 7971 \text{ Cal /gram}$$

$$\begin{aligned} H_n &= 0.555927 \cdot [1.8 H_g - 91.23 H] \text{ in KCal/Kg} = 0.555927 [1.8 \cdot 7971 - 91.23 \cdot 8] \\ &= 7570.59 \text{ KCal/Kg} \end{aligned}$$

$$M = 1.5 \text{ gram}$$

$$C_1 = 2.5 \text{ ml}$$

$$C_2 = 2 \%$$

$$C_3 = 4 \text{ cm}$$

$$T = 28 - 23 = 5 \text{ }^\circ\text{C}$$

$$W = 2402 \text{ cal per deg C}$$



Thanks...

