JAIPUR ENGINEERING COLLEGE AND RESEARCH CENTRE

Year & Sem – B.Tech I year I Sem
Subject –Engg.Chemistry
Unit – II
Presented by – Ms.Rekha Vijay
Designation - Asst.Professor
Department - Chemistry

VISSION OF INSTITUTE

To become a renowned centre of outcome based learning, and work towards academic, professional, cultural and social enrichment of the lives of individuals and communities.

MISSION OF INSTITUTE

❖**Focus on evaluation of learning outcomes and motivate students to inculcate research aptitude by project based learning.**

❖**Identify, based on informed perception of Indian, regional and global needs, the areas of focus and provide platform to gain knowledge and solutions.**

❖**Offer opportunities for interaction between academia and industry.**

❖**Develop human potential to its fullest extent so that intellectually capable and imaginatively gifted leaders may emerge in a range of profession.**

Engineering Chemistry: Course Outcomes

Students will be able to:
CO1: Explain the impurities of water (mainly hardness) and boiler troubles.
CO2: Describe processing technologies of fuel with numerical aspects of combustion of fuel.
CO3: Describe the engineering material (cement, glass and lubricant) with respect to their manufacturing, composition, classification & properties.
CO4: Explain corrosion with its controlling measures, organic reaction mechanism and synthesis of drugs (Aspirin & Paracetamol) with their properties and uses.

JECRC
Department of Applied Sciences
Lecture Plan (Session- 2020-2021)

Course Name: Engineering Chemistry **Year/Semester: 1st Year/ Semester- I**

Course code: 1FY2-03 **No. of Lecture Req. /(Avl.): /(40/44)**

Semester starting: 21 Sept. 2020 **Semester Ending: 24 Dec. 2020**

Unit No./ Total Lect. Req.	Topics	Lect. No.	Date of Delivery	Book Referred	Pg. No.
Unit-I 10	Introduction to syllabus, Common natural impurities, hardness, Degree of hardness,	1			
	Units of hardness, Determination of hardness by complexometric (EDTA method).	2			
	Municipal water supply, Requisite of drinking water, purification of water, Sedimentation,	3			
	Filtration, disinfection, Breakpoint chlorination.	4			
	Boiler troubles: Scale and Sludge formation, Internal treatment Methods	5			
	Priming and Foaming, Boiler corrosion and caustic embrittlement	6			
	Water softening: Lime-Soda process	7			
	Water softening: Zeolite (Permutit) process, Demineralization process.	8			
	Numerical problems based on Hardness, EDTA,	9			
	Numerical problems based on Lime-Soda and Zeolite process.	10			

Unit-II 10	**2.Organic Fuels: Solids fuels: Coal, Classification of Coal, Proximate analyses of coal and its significance**	**11**			
	Ultimate analyses of coal and its significance,	12			
	Gross and Net Calorific value, Determination of Calorific value of coal by Bomb Calorimeter.	13			
	Metallurgical coke, Carbonization processes; Otto-Hoffmann byproduct oven method.	14			
	Liquid fuels : Advantages of liquid fuels, Mining, Refining and Composition of petroleum, Cracking	15			
	Synthetic petrol, Reforming, Knocking, Octane number, Anti-knocking agents, Cetane number	16			
	Gaseous fuels; Advantages, manufacturing, composition and Calorific value of coal gas and oil gas	17			
	Determination of calorific value of gaseous fuels by Junker's calorimeter, Numerical problems based on Junkers calorimeter	18			
	Numerical problems based on determination of calorific value bomb calorimeter, /Dulongs formula, proximate & ultimate Analysis.	19		Engg. Chemistry (New Age International)	
	Numerical problems based on combustion of fuel.	20		Engg. Chemistry (New Age International)	

Unit-III 3	**3.Corrosion and its control: Definition and significance of corrosion, Mechanism of chemical (dry) corrosion**	**21**			
	Mechanism of electrochemical (wet) corrosion, galvanic corrosion, concentration corrosion and pitting corrosion.	22			
	Protection from corrosion; protective coatings-galvanization and tinning, cathodic protection, sacrificial anode and modifications in design.	23			

Unit-IV 10	**4.Engineering Materials: Portland Cement; Definition, Manufacturing by Rotary kiln.**	**24**			
	Chemistry of setting and hardening of cement. Role of Gypsum.	25			
	Glass: Definition, Manufacturing by tank furnace, significance of Annealing	26			
	Types and properties of soft glass, hard glass	27			
	Borosilicate glass, glass wool, safety glass.	28			
	Lubricants: Classification	29			
	Lubricants: Mechanism	30			
	Properties; Viscosity and viscosity index	31			
	Flash and fire point, cloud and pour point.	32			
	Emulsification and steam emulsion number.	33			

Unit-V 7	**5. Organic reaction mechanism and introduction of drugs: Organic reaction mechanism: Substitution; SN1, SN2.**	**34**			
	Electrophilic aromatic substitution in benzene, free radical halogenations of alkanes,	35			
	Elimination: elimination in alkyl halides, dehydration of alcohols,	36			
	Addition: electrophilic and free radical addition in alkenes, nucleophilic addition in aldehyde and ketones	37			
	Rearrangement: Carbocation and free radical rearrangements	38			
	Drugs : Introduction, Synthesis, properties and uses of Aspirin	39			
	Drugs : Introduction, Synthesis, properties and uses of Paracetamol, Revision	40			

Lecture-19,20 (Unit-II FUEL)

Numerical problems based on :

- Determination of calorific value:
  - bomb calorimeter
  - Dulongs formula
- proximate& ultimate Analysis.
- Numerical problems based on combustion of fuel.

Theory of Combustion

(1) Combustion is a chemical reaction which occurs rapidly with evolution of heat and light. In this process the compound or an element reacts with oxygen, releasing energy. i.e. It is an exothermic reaction.

$C(s) + O_2(g) \rightarrow CO_2(g)$ + energy

The elementary principles applied in calculation of oxygen and air required for the con process are given as follows.

- . Air contains 21% oxygen by volume, and mass percent of oxygen is 23.
- Molecular mass of air is taken as 28.94 g/ mol
- Minimum oxygen required = Theoretical O, required - O, present is the fuel.
- Minimum O, required should be calculated on the basis of complete combustion.
- The mass of dry flue gases formed should be calculated by balancing the carbon in the fuel and carbon in the flue gases.

  The mass of any gas can be converted into its volume using gas equation :

  PV = nRT.

  where P - pressure of gas in atm.

  V - volume of gas in litres.

  n - No. of moles of gas.

  T - Temperature in kelvin.
- 22.4 litres of any gas at STP has a mass equal to its 1 mol.

  eg. 22.4 litres of CO2 at STP weighs 44 gm.
- Substances always combine in proportion. For e.g.

  C + O2→ CO2 Mass proportion

  12 32 44

  So 12 gms of carbon combine with 32 gm of O, to form 44 gm of CO2.

  2C0 + 02 → 2C02 Volume proportion

  2 1 2

  2 volume of CO reacts with 1 volume O, to form 2 volume of CO_2.
- The dry flue gas contains CO_2, SO_2, CO, N_2 and O_2
- CO2, and N2, requires no oxygen, since it does not undergo any combustion reaction. The chemical equations expressing the combustion of some of the constituents are as follows

$C + O_2 \rightarrow CO_2$

$H_2 + 1/2O_2 \rightarrow H_2O$

$CO + 0 \rightarrow CO_2$

$S + 0\ _2 \rightarrow SO_2$

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

$C_2H_6 + 7/2\ O_2 \rightarrow 2CO_2 + 3H_2O$

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

Example 16. The percentage composition of a coal sample is C = 80%, H = 4%, O = 3%, N = 3%, S = 2% and ash = 4.5%. Calculate the quantity of air required by weight, for the complete combustion of 1 kg of coal if 60% excess air is supplied.

[RTU Aug. 2010]

Solution:

Constituents	Wt. in 1 kg of coal	Combustion reaction	Wt. of O_2 (in kg.)
C	0.80	$C + O_2 \rightarrow CO_2$	$0.80 \times \frac{32}{12} = 2.13$
H	0.04	$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$	$0.04 \times \frac{16}{2} = 0.32$
O	0.03	–	–
N	0.03	–	–
S	0.02	$S + O_2 \rightarrow SO_2$	$0.02 \times \frac{32}{32} = 0.02$
			Total O_2 = 2.47 O_2 in fuel = – 0.03
			Net O_2 = 2.44 kg.

Total weight of air required for complete combustion of 1 kg of coal if 60% excess air is used

$$= 2.44 \times \frac{100}{23} \times \frac{160}{100}$$

$$= \mathbf{16.97\ kg.}$$

Example 15. A sample of coal was found to have the following percentage composition by weight C = 85%, H = 12%, O = 3% and ash = 7%. Calculate the weight of minimum air requirement for burning of 1 kg. of the fuel.

Solution:

Constituents	Wt. in 1 kg. of fuel	Combustion reaction	Wt. of O_2 required (in kg.)
C	0.85	$C + O_2 \rightarrow CO_2$	$0.85 \times \frac{32}{12} = 2.26$
H	0.12	$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$	$0.12 \times \frac{16}{2} = 0.96$
O	0.03	–	–
			Total $O_2 = 3.22$ O_2 in fuel $= -0.03$
			Net $O_2 = 3.19$ kg.

Weight of air required for combustion of 1 kg. of fuel

$$= 3.19 \times \frac{100}{23}$$

$$= \mathbf{13.86\ kg.}$$

Example 30: A smaple of coal was found to have the following percentage composition by weight C = 70%, H = 5%, O = 12%, N = 5%, ash = 8%. Calculate the weight of air required for combustion of 1 kg of fuel. also calculate the percentage composition of dry gaseous products

Solution :

Constituents	wt in 1 kg of fuel	combustion reaction	Wt of O_2 required (in kg.)	wt of dry products (in kg.)
C	0.70	$C + O_2 \rightarrow CO_2$	$0.70 \times \frac{32}{12} = 1.86$	$CO_2 = 0.7 \times \frac{44}{12} = 2.56$
H	0.05	$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$	$0.05 \times \frac{16}{2} = 0.4$	—
O	0.12	—	—	—
N	0.05	—	—	$N_2 = \frac{77}{100} \times 9.3 + 0.05 = 7.21$
			Total O_2 = 2.26	
			O_2 in fuel = 0.12	
			Net O_2 = 2.14 kg	

Weight of air required for combustion of 1 kg of fuel.

$$= 2.14 \times \frac{100}{23} = 9.3 \text{ kg}$$

Dry product analysis :

$CO_2 = 2.56$ kg

$N_2 = 7.21$ kg

Total wt of dry products $= CO_2 + N_2$

$= 9.77$ kg

$$\%CO_2 = \frac{2.56}{9.77} \times 100 = 26.2\%$$

$$\%N_2 = \frac{7.21}{9.77} \times 100 = 73.79\%$$

Example 20. A fuel is found to contain C = 80%, H = 5%, N_2 = 15%. Calculate the weight of air required for combustion of 1 kg of fuel. Also calculate the dry products by volume

Solution:

Constituents	Weight in 1 kg of fuel	Combustion reaction	Volume of O_2 required (m^3)	Volume of dry product (m^3)
CH_4	0.30	$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$	$0.30 \times 2 = 0.60$	$CO_2 = 0.30 \times 1 = 0.30$
CO	0.20	$CO + \frac{1}{2}O_2 \rightarrow CO_2$	$0.2 \times \frac{1}{2} = 0.1$	$CO_2 = 0.20 \times 1 = 0.20$
O_2	0.02	–	–	$O_2 = \frac{20}{100} \times 0.68 = 0.136$
N_2	0.48	–	–	$N_2 = \frac{79}{100} \times 3.87 + 0.48 = 3.53$
			Total O_2 = 0.70 O_2 in fuel = − 0.02 Net O_2 = 0.68 m^3	

Volume of air required for combustion of 1 m^3 of fuel = $0.68 \times \frac{100}{21} = 3.23\,m^3$

Total volume of air (20% excess) = $3.23 \times \frac{120}{100} = 3.87\,m^3$

Weight of air required for combustion of

$$1\ m^3 \text{ of fuel} = 3.87 \times \frac{28.94}{22.4} = \mathbf{4.99\ kg}$$

Dry product analysis:

Dry products	Volume of dry products (m^3)	Wt. of dry products (kg)	% of dry product
Total CO_2	0.5 m^3	$0.5 \times \frac{44}{22.4} = 0.98$	$\frac{0.98}{5.57} \times 100 = 17.5\%$
O_2	0.136	$0.136 \times \frac{32}{22.4} = 0.19$	$\frac{0.19}{5.57} \times 100 = 3.41\%$
N_2	3.53	$3.53 \times \frac{28}{22.4} = 4.4$	$\frac{4.4}{5.57} \times 100 = 78.9\%$
		Total wt = 5.57 kg	

Example 22. Calculate the amount of theoretical air required by weight and volume for complete combustion of 2 kg of coke. **[RTU, June 2008]**

Solution:

Constituent	Wt. of fuel	Combustion reaction	Wt. of O_2 required (in kg)
C	2 kg	$C + O_2 \rightarrow O_2$	$2 \times \frac{32}{12} = 5.33$ kg

Weight of air required for combustion of

$$2 \text{ kg of coke} = 5.3 \times \frac{100}{23} = 23.173 \text{ kg.}$$

Volume of air required for combustion of

$$2 \text{ kg of coke} = 23.173 \times \frac{22.4}{28.94} = 17.93 \text{ m}^3$$

Formula for calculation of HCV & LCV by Bomb calorimeter

$$HCV = \frac{(W + w)(t2 - t1)}{x}$$

$$LCV = HCV - (0.09\, H \times 587)\ Cal/g.$$

H = % of hydrogen present in the coal

Example 4. The determination of calorific value of a coal sample gave the following data, weight of coal sample = 0.9 gm.

Water equivalent of calorimeter = 440 gm.

Weight of water = 2560 gm.

Rise in temperature = 2.42°C

Cooling correction = 0.052°C

Fuse wire correction = 10.0 calories

Calculate HCV and LCV, if the coal contains 6%H and assume latent heat of steam is equal to 600 cals/gm.

Solution:

$$\text{HCV} = \frac{(W+w)(t_2 - t_1 + \text{cooling correction}) - (\text{Fuse wire correction})}{\text{Weight of coal sample}}$$

$$\text{HCV} = \frac{(2560+440)(2.42+0.052)-10}{0.9}$$

$$\textbf{HCV} = \textbf{8228.9 cal/gm.}$$

$$\text{LCV} = \text{HCV} - 0.09 \times 6 \times 600$$

$$= 8228.9 - 0.09 \times 6 \times 600$$

$$= \textbf{7904.9 cal/gm.}$$

Example 1. A sample of coal contains 93% C, 5% H, and 6% ash. When this coal was tested for its calorific value in the bomb calorimeter, the following results were obtained:

Weight of the coal burnt = 0.95 gm.

Weight of water taken = 2000 gm.

Water equivalent of bomb and calorimeter = 700 gm.

Increase in temperature = 2.48°C

Acid correction = 60.0 cal

Cooling correction = 0.02°C

Fuse wire correction = 10 cal

Calculate the HCV and LCV of coal. Given latent heat of condensation of steam = 587 cal/gm.

Solution:

$$HCV = \frac{[(W + w)(t_2 - t_1 + \text{cooling correction})] - [\text{Acid} + \text{Fuse wire correction}]}{\text{Mass of fuel}(x)}$$

$$= \frac{(2000 + 700)(2.48 + 0.02) - (60 + 10)}{0.95}$$

$= \mathbf{7031.6 \ cal/gm.}$

$LCV = HCV - 0.09H \times 587$ cal/gm.

$= 7031.6 - 0.09 \times 5 \times 587$

$= \mathbf{6767.45 \ cal/gm.}$

Dulong's formula for calculating the calorific value is given as:

Gross calorific Value (HCV)

$$= \frac{1}{100}[8080C + 34{,}500(H - \frac{O}{8}) + 2{,}240S]kcal/kg$$

Net Calorific value (LCV)

$$= [HCV - \frac{9H}{100} \times 587]kcal/kg$$

$$= [HCV - 0.09H \times 587]kcal/kg$$

Example 7. Calculate the higher and lower calorific value of a coal sample having the following composition:

C = 80%, H = 7%, S = 3.5%, N = 2.1%, O = 3% and ash = 4.4%

C = 8080, H = 34500, S = 2240

Solution: According to Dulong's formulas:

$$HCV = \frac{1}{100}\left[8080\%C + 34500\left(\%H - \frac{\%O}{8}\right) + 2240\%S\right] cal/gm.$$

$$= \frac{1}{100}\left[8080 \times 80 + 34500\left(7 - \frac{3}{8}\right) + 2240 \times 3.5\right] cal/gm.$$

HCV = 8828.025 cal/gm.

LCV = HCV – 0.09%H × 587 cal/gm.

LCV = 8828.025 – 0.09 × 7 × 587

LCV = 8458.215 cal/gm.

Example 11. A sample of coal contains 60% carbon, 33% oxygen, 6.0% hydrogen, 0.5% sulphur, 0.2% Nitrogen and 0.3% ash. Calculate HCV and LCV of coal.

Solution:

$$HCV = \frac{1}{100}\left[8080\%C + 34500\left(\%H - \frac{\%O}{8}\right) + 2240\%S\right] cal/gm.$$

$$= \frac{1}{100}\left[8080 \times 60 + 34500\left(6 - \frac{33}{8}\right) + 2240 \times 0.5\right]$$

$$\mathbf{HCV = 5506.1 \ cal/gm}$$

$$LCV = HCV - 0.09\%H \times 587 \ cal/gm$$

$$LCV = 5506.1 - 0.09 \times 6 \times 587$$

$$\mathbf{= 5189.1 \ cal/gm}$$

Example 8. The ultimate analysis of coal gives : carbon = 84%, sulphur = 1.5%, nitrogen = 0.6%, hydrogen = 5.5% and oxygen = 8.4%. Calculate the gross and net calorific values using Dulong's formula.

Solution : According to Dulong's formula

$$HCV = \frac{1}{100}\left[8080C + 34500\left(\%H - \frac{\%O}{8}\right) + 2240S\right]$$

$$= \frac{1}{100}\left[8080 \times 84 + 34500\left(5.5 - \frac{84}{8}\right) + 2240 \times 1.5\right]$$

$$= 8356.05 \text{ Kcal/kg.}$$

$$\text{Low calorific value (LCV)} = \left(HCV - \frac{9H}{100} \times 587\right) \text{ Kcal/kg}$$

$$= \left(8356.05 - \frac{9 \times 5.5}{100} \times 587\right) \text{ Kcal/kg.}$$

$$= 8065.49 \text{ Kcal/kg.}$$

Proximate Analysis

Example 9: **A coal sample was analysed as follows: A 3.0 gm coal sample was weighed into silica crucible. After heating for 1 hour at 100°C, the residue weighed 2.7 gm. The crucible was then covered with a lid and strongly heated for seven minutes at 950 ± 20°C. The residue weighed 1.8 gm. The crucible was then heated without cover untill a constant weight is obtained. The residue was found to weigh 0.5 gm. Calculate the percentage of moisture, volatile matter, ash contents and carbon in a coal sample and to which type of analysis does the above belongs.**

Solution The above one is proximate analysis

$$\% \text{ moisture} = \frac{\text{Loss in weight}}{\text{Weight of coal taken}} \times 100$$

$$= \frac{3.0 - 2.7}{3} \times 100$$

$$= 10\%$$

$$\% \text{ of volatile matter} = \frac{\text{Loss in weight due to removal of volatile matter}}{\text{Weight of coal sample taken}} \times 100$$

$$\% \text{ of volatile matter} = \frac{2.7 - 1.8}{3.0} \times 100$$

$$= 30\%$$

$$\% \text{ Ash} = \frac{\text{Weight of ash left}}{\text{Weight of coal taken}} \times 100$$

$$= \frac{0.5}{3} \times 100$$

$$= 16.6\%$$

$$\% \text{ fixed carbon} = 100 - [\% \text{ moisture} + \% \text{ volatile matter} + \% \text{ ash}]$$

$$= 100 - [10 + 30 + 16.6]$$

$$= 100 - 56.6 = 43.4\ \%$$

Ultimate Analysis

Example 7: A 2.5 gm smaple of coal was heated in a Kjeldhal's flask with conc. H_2SO_4 in presence of K_2SO_4 and is then treated with excess of KOH. The liberated NH_3 is absorbed in 40 ml of 0.2 N H_2SO_4. After the absorptions, the excess acid required 7 ml of 0.2 N NaOH for exact neutralization. Determine the percentage of nitrogen in given sample of coal.

Solution

$$\% \text{ Nitrogen} = \frac{1.4 \times N_1 \times x}{W}$$

where,

$$N_1 = 0.2 \text{ N}$$

$$x = (40 - 7) \text{ ml}$$

$$W = 2.5 \text{ gm}$$

$$= \frac{1.4 \times 0.2 \times (40 - 7)}{2.5}$$

$$= 3.696\%$$

UNSOLVED PROBLEMS

Q1. A sample of coal was found to have the following % composition by weight C = 70%, O = 14%,H = 6% , H = 6% , N = 5% and rest = ash . Calculate the gross and net calorific value of coal sample using Dulong's formula.

- Q2. A sample of coal was found to contain the following: C = 80%, H = 5%, O = 1%, N = 2% remaining being ash . Calculate the amount of minimum air required for complete combustion of 1 Kg of coal sample.
- Q3. A sample of coal was found to contain the following: C = 85%, H = 7%, O = 3%, N = 5% remaining being ash. Calculate the amount of minimum air required for complete combustion of 10 Kg of coal sample.
- Q4. A sample of coal was found to contain the following: C = 85%, H = 7%, O = 3%, N = 5% remaining being ash. Calculate the amount of minimum air required for complete combustion of 1 Kg of coal sample also calculate the percentage composition of dry products of combustion.
- Q5. A sample gaseous fuel was found to contain the following: C = 85%, H = 7%, O = 3%, N = 5% remaining being ash. Calculate the amount of minimum air required for complete combustion of 1 m^3 of fuel sample also calculatethe percentage composition of dry products of combustion by volume.
- Q.6 Calculate the amount of oxygen and air required for complete combustion of 2 Kg of Coke.

JECRC Foundation

JAIPUR ENGINEERING COLLEGE AND RESEARCH CENTRE

Thank you!