*Name* : .....

*Roll No.* : .....

*Invigilator's Signature* : .....

**CS/B.Tech (CT)/SEM-4/CT-404/2010**

# 2010
# PROCESS CALCULATIONS

*Time Allotted* : 3 Hours Full Marks : 70

*The figures in the margin indicate full marks.*

*Candidates are required to give their answers in their own words as far as practicable.*

Answer any *five* questions. 5 × 14 = 70

1. A pure hydrocarbon gas is burnt in a furnace giving a flue gas containing 10·8% $CO_2$ 3·8% $O_2$ and rest $N_2$ and inerts. Calculate

   a) The atomic ratio of H/C, and from this ratio, the formula of the fuel.

   b) If the combustion gases leave the furnace at normal pressure and 430° C, calculate the volumetric ratio of flue gas/fuel gas.

   c) If the furnace burns 90 kg of fuel/hr, calculate the volume of combustion gas in $m^3/min$. 14

2. a) A furnace using a high grade petroleum fuel oil containing 5·4% sulphur. The flue gas in analysed without prior removal of $SO_2$ which is therefore reported along with $CO_2$, showing 13·9% $(CO_2 + SO_2)$, 0·4% CO, 0·1% $H_2$, 2·4% $O_2$ and 83·2% $N_2$. What is the composition of the flue gas ?

   b) A hydrocarbon gas on combustion gives out a flue gas of composition, $CO_2$–11·6%, CO – 2·0%, $H_2$ – 1·6%, $O_2$ – 4·2% and rest $N_2$. Calculate the percentage of excess air used. 8 + 6

3. a) An evaporator is fed with 14,000 kg/hr of a solution containing 10% NaCl, 15% NaOH and rest water. During operation, water is evaporated and NaCl is precipitated as crystals. The thick liquor bearing the evaporator contains 45% NaOH, 2% NaCl and rest water.

Calculate : i) Kg/hr. water evaporated

ii) Kg/hr. salt precipitated

iii) Kg/hr. thick liquor.

b) Ethylene oxide is produced by oxidation of $C_2H_4$ 100 kg moles of $C_2H_4$ are fed to a reactor and the product formed contains 80 kg mole ethylene oxide and 10 kg mole $CO_2$. The reactions are as under :

$$C_2H_4 + \frac{1}{2}O_2 \rightarrow C_2H_4O \qquad (1)$$

$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O \qquad (2)$$

Calculate : a) Conversion of $C_2H_4$ in percentage

b) Yeild of oxide in percentage. 9 + 5

4. a) Calculate standard heat of formation of chloroform $\{CHCl_3(g)\}$ from its element using Hess's law. Given

$$C(s) + O_2(g) \rightarrow Co_2(g)$$

$$\Delta H_1 = -94051 \text{ cals} \qquad (1)$$

$$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$$

$$\Delta H_2 = -68317 \text{ cals} \qquad (2)$$

$$\frac{1}{2}H_2(g) + \frac{1}{2}Cl_2(g) + H_2O(l) \rightarrow HCl(aq)$$

$$\Delta H_3 = -40023 \text{ cals} \qquad (3)$$

$$CHCl_3(g) + \frac{1}{2}O_2(g) + H_2O(l) \rightarrow CO_2(g) + 3HCl(aq)$$

$$\Delta H_C = -121800 \text{ cals} \qquad (4)$$

b) Calculate the heat of formation of ethane gas from the following reactions :

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

$$\Delta H_1 = -94051 \text{ cals} \qquad (1)$$

$$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$$

$$\Delta H_2 = -68317 \text{ cals} \qquad (2)$$

$$C_2H_6(g) + 3{\cdot}5O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$

$$\Delta H_C = -372820 \text{ cals} \qquad (3) \qquad 8 + 6$$

5. The gases entering a sulphur converter contains 2·1% $SO_3$, 8·5% $SO_2$, 9·6% $O_2$ and 79·8% $N_2$. Only the reaction $SO_2 + \frac{1}{2}O_2 \rightarrow SO_3$ takes place. No materials are added or removed except the single process stream coming in and going out. The outlet gases contain 82·46% $N_2$. How much heat is evolved per 100 mole of entering gas, if the reaction takes place isothermally at 720 K ?

Data : Heat of formation of $SO_3$ at 290 K = – 98·18 kJ

Mean specific heat of $SO_3$ = 51·58 J/mole-K

Mean specific heat of $SO_2$ = 45·67 J/mole-K

Mean specific heat of $\frac{1}{2}O_2$ = 30·98 J/mole-K 14

6. A fritted glaze of following formula :

$$\left.\begin{matrix} 0{\cdot}05\ Na_2O \\ 0{\cdot}10\ K_2O \\ 0{\cdot}26\ CaO \\ 0{\cdot}39\ PbO \\ 0{\cdot}10\ MgO \\ 0{\cdot}10\ ZnO \end{matrix}\right\} 0{\cdot}28\ Al_2O_3 \quad 2{\cdot}6\ SiO_2 \quad 0{\cdot}30\ B_2O_3$$

Calculate the batch composition of the frit and the mill batch using feldspar, borax, red lead, clacined ZnO, precipited $MgCo_3$, whiting flint. 14

7. Determine the batch composition to yield a glass of the following composition :

$SiO_2$ – 67%, $Al_2O_3$ – 3%, CaO –12%, $Na_2O$ – 12% & $K_2O$ – 6%

using cullet with composition of $SiO_2$ – 70%, $Na_2O$ – 15%, CaO – 13%, $Al_2O_3$ – 2%. The raw materials used are glass sand, lime stone, feldspar, anhydrous soda ash, potassium carbonate, cullet used to the extent of 20%. 14

8. a) The per cent composition of a glaze is found by analysis PbO – 22·80%, $Na_2O$ – 6·96%, $K_2O$ – 11·54%, $Al_2O_3$ – 9·7%, $SiO_2$ – 41·0% & $B_2O_3$ – 8·00%. Report these results as a glaze formula & also calculate the formula wt.

b) From the following lead frit formula, calculate the leather composition using red lead, feldspar, china clay & flint.

$$\left.\begin{matrix} 0{\cdot}9\ PbO \\ 0{\cdot}1\ K_2O \end{matrix}\right\} 0{\cdot}3\ Al_2O_3;\ 2{\cdot}1\ SiO_2.$$ 7 + 7