

**INDUSTRIAL PROCESS CALCULATIONS
(CHE2103)**

Time Allotted : 2½ hrs

Full Marks : 60

Figures out of the right margin indicate full marks.

*Candidates are required to answer Group A and
any 4 (four) from Group B to E, taking one from each group.*

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

Group – A

1. Answer any twelve:

12 × 1 = 12

Choose the correct alternative for the following

- (i) Air contains 21 mol% O₂ (mol.wt. = 32) and 79 mol% N₂ (mol.wt = 28). The average molecular weight of air is
(a) 28.84 (b) 30.00 (c) 25.24 (d) 27.50
- (ii) Which one is not a dimensionless group?
(a) $\frac{k}{\rho C_p}$ (b) $\frac{hD}{k}$ (c) $\frac{C_p \mu}{k}$ (d) None of the above.
- (iii) Integral mass balances are those which
(a) describes what happens between two instants of time
(b) describes what is happening in a system at an instant of time
(c) both (a) and (b)
(d) none of the above.
- (iv) A bypass stream in a chemical process is useful because it
(a) facilitates better control of the process
(b) improves the conversion
(c) increases the yield of product
(d) none of these.
- (v) Identify the limiting reactant for the reaction $A+2B+3C = 2D+E$, when 4 mole of A, 3 mole of B and 4.5 mole of C is supplied to the reactor.
(a) A (b) B (c) C (d) B & C both
- (vi) At Dew point relative humidity of air is
(a) 0 (b) 50% (c) 100% (d) in between 0 to 100%
- (vii) Addition of a non-volatile solute to a solvent produces
(a) freezing point depression (b) boiling point elevation
(c) vapour pressure lowering (d) no effect.

- (viii) A vapour whose partial pressure is less than its equilibrium vapour pressure is called
 (a) saturated vapour (b) unsaturated vapour
 (c) supersaturated vapour (d) none of these.
- (ix) Heat of reaction is function of
 (a) temperature only (b) pressure only
 (c) both temperature and pressure (d) neither temperature nor pressure.
- (x) Which of the following would require maximum amount of % excess air for complete combustion?
 (a) Coke oven gas (b) Furnace oil
 (c) Pulverized coal (d) Lump coal.

Fill in the blanks with the correct word

- (xi) A sample of LDO (density 0.85kg/L) from a refinery contains 0.68 mass% sulfur. The concentration of this impurity in ppm is _____.
- (xii) Dimension of viscosity is _____.
- (xiii) To control the build-up of inert component in the reactor recycle stream of the reactor is _____.
- (xiv) The partial pressure of a sparingly soluble gas in equilibrium with the solvent is proportional to the mole fraction of the dissolve solute gas in solution. This is known as ____ law.
- (xv) Calorific value of a fuel at constant pressure is _____ than the calorific value at constant volume for the same fuel.

Group - B

2. (a) A 0.50 molar aqueous molar solution of sulphuric acid flows into a process unit at a rate of 1.25 m³/min. The specific gravity of the solution is 1.03. Calculate:
 (i) The mass concentration of sulphuric acid in kg/m³
 (ii) The mass flow rate of sulphuric acid in kg/s
 (iii) The mass fraction of sulphuric acid. [[CO1](Apply/LOCQ)]
- (b) A 5.0 wt % aqueous sulphuric acid solution (density = 1.03 g / ml) flows through a 45 m long pipe with a 6.0 cm diameter at a rate of 87 liter /min. What is the molarity of sulphuric acid in the solution? [[CO1](Apply/LOCQ)]
- (c) A gas mixture contains 10 % H₂, 40 % CH₄, 30 % CO and 20 % CO₂ by moles. The gas mixture is at 30°C and 1.5 atm pressure and may be taken as an ideal gas. Find the mass composition of the gas, its average molecular weight and density. [[CO2](Analyse/LOCQ)]

$$(1 + 1 + 1) + 3 + (2 + 2 + 2) = 12$$
3. (a) It is required to make 1000 Kg of mixed acid containing 60% H₂SO₄, 32% HNO₃ and 8% water by blending (i) the spent acid containing 11.3 % HNO₃, 44.4 % H₂SO₄ and 44.3% H₂O (ii) 90% HNO₃ and (iii) 98% H₂SO₄. Calculate the quantities of each of these three acids required for blending. [[CO2](Analyse/IOCQ)]

- (b) A solution of sodium sulphate in water is saturated at a temperature of 40°C. Calculate the weight of crystals and the percentage yield obtained by cooling 100 Kg of this solution to a temperature of 5°C.
 Solubility data: At 40°C: 32.6 mass % Na₂SO₄
 At 5°C: 5.75 mass % Na₂SO₄

[[CO2](Apply/LOCQ)]

6 + 6 = 12

Group - C

4. (a) In the operation of a synthetic ammonia plant, a 1:3 N₂-H₂ mixture is fed to the convertor resulting in a 30% conversion of ammonia. The ammonia formed is separated by condensation and the unconverted gas is recycled to the reactor. The initial N₂-H₂ mixture contains 0.25 parts of argon to 100 part of N₂-H₂ mixture. The tolerance limit of argon entering the reactor is assumed to 8 part of N₂-H₂ mixture. Estimate the fraction of recycle that is continuously purged.

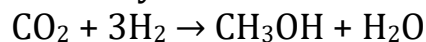
[[CO2](Evaluate/HOCQ)]

- (b) Propane is burned with excess air to ensure complete combustion. If 55 kg of CO₂ and 15 kg of CO are obtained when pure propane is completely burned with 500 kg air, determine the composition of flue gas on dry basis.

[[CO1](Analyse/IOCQ)]

8 + 4 = 12

5. (a) Methanol may be produced by the reaction of carbon dioxide and hydrogen.



The fresh feed to the process contains hydrogen and carbon dioxide in stoichiometric proportion, and 0.5 mole% inerts (I). The reactor effluent passes to a condenser, which removes essentially the entire methanol and water formed, none of the reactants or inerts. The latter substances are recycled to the reactor. To avoid build-up of the inerts in the system, a purge stream is withdrawn from the recycle. The feed to the reactor contains 2% inerts, and the single-pass conversion is 60%. Calculate the molar flow rates of the fresh feed, the total feed to the reactor, and the purge stream for methanol production rate of 1000 mol/h.

[[CO2](Evaluate/HOCQ)]

- (b) The molar composition of a sample of air is 78% Nitrogen, 21% Oxygen, 0.9% Argon, 0.06% Carbon dioxide and 0.04% water vapour. Calculate the mass composition of the air sample. (Given atomic weight of Argon is 40)

[[CO1](Apply/IOCQ)]

9 + 3 = 12

Group - D

6. (a) Define the following related to vapour gas system: absolute humidity, saturation humidity, humid heat.

[[CO4](Remember/LOCQ)]

- (b) 2.5 m³ of air initially at 50°C and 101.3 kPa with a molar humidity of 0.03 is compressed isothermally to 506.5 kPa and finally cooled to 21°C. Calculate the weight of water condensed and final volume of air. The vapour pressure of water at 50°C and 21°C are 12.34 kPa and 2.49 kPa respectively.

[[CO4](Evaluate/HOCQ)]

6 + 6 = 12

7. (a) How do you calculate the vapour pressure of binary solution using Raoult's law? [[CO3](Understand/LOCQ)]
 (b) What is Henry's law? How it is different from Raoult's law? [[CO3](Remember/LOCQ)]
 (c) If the pressure inside a pressure cooker is 200 kPa, what is the boiling point of water inside it? Given the latent heat of vaporization of water is 2257 kJ/kg. [[CO3](Apply/IOCQ)]
4 + 4 + 4 = 12

Group - E

8. (a) What is adiabatic flame temperature of fuel? Why theoretical flame temperature is greater than actual flame temperature of a furnace using the same fuel? [[CO6](Remember/LOCQ)]
 (b) Water is pumped with a 25 kW pump (pump efficiency 60%) from a reservoir to an overhead tank situated 15 m above the ground at the rate of 1 l/s. A heater is to be installed during its transfer from the reservoir to over head tank so as to keep the overhead tank temperature 10°C above the ground reservoir temperature. Assuming that there is a constant heat loss of 2 kW in the surrounding what capacity heater is required for the purpose. [[CO5](Evaluate/HOCQ)]
4 + 8 = 12
9. (a) Calculate the heat required to bring 150 mol/hr of a stream containing 60 % C₂H₆ and 40 % C₃H₈ by volume from 0°C to 400°C.
 Data: For C₂H₆, C_P = 0.04937 + 13.92 x 10⁻⁵ T – 5.816 x 10⁻⁸ T² + 7.280 x 10⁻¹² T³
 For C₃H₈, C_P = 0.06803 + 22.59 x 10⁻⁵ T – 13.11 x 10⁻⁸ T² + 31.71 x 10⁻¹² T³
 Where, C_P is in kJ / mol. °C and T = temperature in °C. [[CO5](Analyse/IOCQ)]
 (b) Water at 95°C is pumped from a storage tank at the rate of 25 m³/h. A pump with 2 hp motor is used for the purpose. The water passes through a heat exchanger, where it gives up heat at the rate of 700 kW and is delivered to a second storage tank at an elevation of 20 m above the first tank. What is the temperature of the water delivered to the second storage tank? Specific heat of water is 4.2 kJ/kg K. [[CO6](Evaluate/HOCQ)]
6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	37.5	24	38.5