

**INDUSTRIAL SAFETY AND HAZARDS ANALYSIS  
(CHEN 3142)**

**Time Allotted : 3 hrs**

**Full Marks : 70**

*Figures out of the right margin indicate full marks.*

*Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.*

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

**SYMBOLS ARE OF USUAL SIGNIFICANCE**

**Group – A**

**(Multiple Choice Type Questions)**

1. Choose the correct alternative for the following: **10 × 1 = 10**
- (i) Deflagration is an explosion in which the reaction front  
 (a) Is stationary (b) Moves with a supersonic speed  
 (c) Moves with a subsonic speed (d) None of the above.
- (ii) Autoignition temperature (AIT):is  
 (a) A fixed temperature above which adequate energy is available in the environment to provide an ignition source  
 (b) A fixed temperature below which adequate energy is available in the environment to provide an ignition source  
 (c) A fixed temperature below which adequate energy is available in the environment to provide an ignition source  
 (d) None of the above.
- (iii) Lower Flammability Limit of a mixture is given by  
 (a)  $LFL_{mix} = \frac{1}{\sum \frac{y_i}{LFL_i}}$  (b)  $LFL_{mix} = \sum \frac{y_i}{LFL_i}$   
 (c)  $LFL_{mix} = \sum \frac{LFL_i}{y_i}$  (d) None of the above.
- (iv) The term Hazop originates from  
 (a) ICI (b) DOW (c) Union Carbide (d) none of the above.
- (v) A process has a reported FAR of 0.4. If an employee works a standard 8 hr shift 300 days per year, the death per person per year will be  
 (a)  $4.8 \times 10^{-5}$  (b)  $9.6 \times 10^{-6}$  (c)  $1.2 \times 10^{-5}$  (d)  $2.4 \times 10^{-6}$ .
- (vi) The major disadvantage of ventilation is  
 (a) The high operating cost (b) The high initial investment  
 (c) The lack of trained operator (d) All of the above.
- (vii) Disaster management plans are  
 (a) Monolayered (b) Bilayered (c) Multilayered (d) None of the above.

(viii) Fault trees are:

- (a) A logical method for identifying ways in which hazards can lead to accidents
- (b) A deductive method for identifying ways in which hazards can lead to accidents
- (c) Combination of both logical and deductive methods for identifying ways in which hazards can lead to accidents
- (d) None of the above.

(ix) Mond index takes account of circumstances other than processing, such a storage, loading and unloading

- (a) True
- (b) False
- (c) Not always true
- (d) None of the above.

(x) A BLEVE occurs if a vessel that contains

- (a) A liquid at a temperature above its atmospheric pressure boiling point ruptures
- (b) A gas above atmospheric pressure ruptures
- (c) A liquid at a temperature below its atmospheric pressure boiling point ruptures
- (d) A gas below atmospheric pressure ruptures.

### Group- B

2. (a) Define:

- (i) Unknown risk
- (ii) Predictable risks
- (iii) Temporary risks.

[[CO1](Remember/LOCQ)]

(b) Describe in detail the salient features of runaway reaction encountered in chemical process industry.

[[CO2](Analyze/IOCQ)]

(c) Write short notes on BLEVE. What is fire triangle?

[[CO1](Analyze/IOCQ)]

**3 + 4 + 5 = 12**

3. (a) Discuss in details the major approaches to inherently safer process designs.

[[CO2](Remember/LOCQ)]

(b) Estimate the Limiting Oxygen Concentration (LOC) for butane (C<sub>4</sub>H<sub>10</sub>) given that the LFL of butane is 1.9% by volume.

[[CO3](Evaluate/HOCQ)]

(c) Distinguish between OSHA and FAR

[[CO1](Analyze/IOCQ)]

**4 + 4 + 4 = 12**

### Group - C

4. (a) What are the documentation requirements for a typical HAZOP study? Describe in detail the procedure followed in HAZOP study.

[[CO3](Analyze/IOCQ)]

(b) Define Material Factor. Discuss in detail the procedure followed in calculating the Mond fire, explosion, and toxicity index.

[[CO3](Analyze/IOCQ)]

**6 + 6 = 12**

5. (a) What are general process hazards and special process hazards?

[[CO3](Understand/LOCQ)]

(b) With the help of a neat flow chart discuss in detail the procedure for carrying out Dow Fire and Explosion Index analysis.

[[CO3](Understand/LOCQ)]

**6 + 6 = 12**

**Group – D**

6. A reactor effecting an exothermic reaction is at risk of thermal runaway in the event of coolant failure. Its protective trip system is intended to open a dump valve which empties the reactor if low coolant flow or high reaction temperature is detected. Draw a fault tree which summarizes the failure logic analysis given below and calculate the approximate frequency of the runaway reaction from the following data:

Failure	Failure rate (hr <sup>-1</sup> )
Pump failure	0.2
Line blocked	0.01
Supply tank empty	0.1
Dump valve fails shut	0.001/demand
Low flow trip failure	0.01/demand
High temperature trip failure	0.01/demand

Failure Logic Analysis: Runaway reaction occurs if cooling water failure occurs whilst the protective system is inoperative. Cooling water failure can occur because of pump failure, line blockage or an exhausted water supply. The protective system may be inoperative when either the shutdown system fails because the dump valve fails shut, or because the detection system fails.

[(CO4)(Evaluate/HOCQ)]

12

7. A distillation unit is used for handling flammable material operating at an elevated pressure. The column bottoms system includes a liquid cooling train and the liquid is discharged to a tank which is not designed to withstand full column pressure. Under normal operation a liquid seal is maintained in the column base and the bottom product is let down through a control valve linked to liquid level in the column. In the event of failure of control system and its associated back up, it is possible for high pressure gas to break through in the low pressure system. By using the probability data given below, construct an Event Tree for the consequence of break through and estimate the probability of fatal injury. The plant is run continuously and operated by a single process worker on a shift basis. Each shift worker will work 250 eight hour shifts per year. Calculate also the maximum frequency of liquid break through and estimate the probability to satisfy operating company safety criteria.

Data:

System	Probability
Cooling system fractures	0.02
Vapour cloud ignites	1.00
Operator present in the vapour cloud area	0.80
Operator escapes before ignition	0.25
Operator burned but survives	0.50

The operating company has a target FAR of 0.4 for a single incident.

[(CO4)(Analyze/IOCQ)]

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**Group - E**

8. (a) State the principles of industrial ventilation. Discuss in details the working principle of local ventilation. [(CO3)(Remember/LOCQ)]
- (b) Discuss in details the safety precautions to be taken during working in laboratory. [(CO3)(Understand/LOCQ)]
- (c) What do you understand by disaster management? Name the different types of disaster and explain them. [(CO3)(Remember/LOCQ)]
- 4 + 4 + 4 = 12**

9. (a) Prove that the working exposure to toxic vapour is given by:

$$C_{ppm} = \frac{Q_m R_g T}{k Q_v P M} \times 10^6$$

Where the notations bear their usual meanings. [(CO2)(Evaluate/HOCQ)]

- (b) An open toluene container in an enclosure is weighed as a function of time, and it is determined that the average evaporation rate is  $10^{-4}$  kg/min. The ventilation rate is  $2.83 \text{ m}^3/\text{min}$ . The temperature is  $27.6^\circ\text{C}$  and the pressure is 1 atm. Estimate the concentration of toluene vapor in the enclosure. [(CO2)(Evaluate/HOCQ)]
- (c) Discuss in details the cause and effect of any one major accident in chemical industry. [(CO2)(Analyse/IOCQ)]
- 4 + 4 + 4 = 12**

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	32.3	42.7	25.0

**Course Outcome (CO):**

1. Ability to use important technical fundamentals of chemical process safety and to impart basic knowledge that allows the students to evaluate occupational safety and health hazards in the workplace.
2. Ability to analyze the effects of workplace exposures, injuries and illnesses, fatalities.
3. Ability to use safety programs to prevent or mitigate damage or losses and to develop preventative measure to avoid accident.
4. Ability to use logic based quantitative risk analysis.

\*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question