BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, Pilani Campus
Semester-I, 2017-2018

Plant Process Safety (CHE F413)
Comprehensive Exam [Closed Book]

Max Marks: 40 **Date:** 08-12-2017 (FN) **Duration:** 3 Hours

- **State clearly if any assumptions are being made.**
- **Label answers clearly; Begin each question on a new sheet.**
- **All parts of the same question must be answered sequentially.**

Q.1 Draw a flammability diagram for propylene. The reported Lower Flammability Limit and Upper Flammability Limit for propylene are 2% and 11 vol %, respectively. Using the diagram and equations: What must the oxygen concentration be reduced to before pumping in propylene? What propylene concentration must the vapour be reduced to before pumping air into the vessel before taking it out of service? Identify the flammability zone in the diagram, given upper flammability limit in pure oxygen is 53%. [8 M]

Q.2 Use the vacuum purge technique to purge oxygen out of a 500-liter tank containing air. Reduce the oxygen concentration to 1% using nitrogen containing 9000 ppm oxygen as the inert. The temperature is 27 ^{o}C. Assume the vacuum purge goes from atmospheric pressure to 22 mm Hg absolute. Determine number of purge cycles required, and the total moles of nitrogen used. [2 M]

Q.3 Given a source term and a ventilation rate, derive the equation to determine the average concentration (in ppm) of any volatile species at any time in an enclosure. [4 M]

Q.4 A 30 m long horizontal pipeline transporting benzene develops a leak at 13 m from the high pressure end. The diameter of the leak is estimated to be 2.54 mm. At the time the upstream pressure in the pipeline is 3.4 atm gauge, the downstream pressure is 2.7 atm gauge. Derive the source model equation for this case and estimate the mass flow rate of benzene through the leak. Assume pressure to be a linear function of pipe length and discharge coefficient as 0.61. Specific gravity of benzene is 0.8794. [5 M]

Q.5 An offshore separator is used to separate oil well fluids into gas and liquid components. If the gas outlet is blocked, pressure builds up in the separator vessel and it ruptures or explodes. The separator is equipped with a Process Shutdown (PSD) valve to stop the flow in case of blocked gas outlet. A Pressure Safety Valve (PSV) is installed at the top of the separator to release the gas to flare in case of PSD valve failure. The system is also equipped with a Rupture Disc (RD) to flow the gas out in case of PSV failure. PSD fails once in 100 times when it is put in demand, PSV works 9 out of 10 times, and RD fails once in 100 demands. Develop an Event Tree for this system using "Gas outlet blocked" as the initiating event. If the gas outlet is blocked 4 times per year, estimate the number of years for the rupture or explosion of the separator; frequency of gas flowing out of rupture disc.
[4 M]

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Q.6 Gunpowder is a mixture of Potassium Nitrate, Charcoal, and Sulfur. The reaction that occurs during combustion of gunpowder is: $2KNO_3 + 3C + S \rightarrow K_2S + 3CO_2 + N_2$. The heats of formation (kJ/mol) of KNO_3, CO_2, and K_2S are −494.6, −393.6, and −380.7, respectively. Determine the over pressure at a distance of 10 m when 2.2 kg of gunpowder is exploded outdoor with 100% efficiency. Estimate number of deaths from lung haemorrhage, given the probit parameters k_1 and k_2 are −77.1 and 6.91, respectively.

DATA: The energy of explosion of TNT is 1120 cal/g. Molecular weight of Potassium is 39 and Sulfur is 32. The following empirical equation for scaled over pressure for the scaled distance is available.

$$P_s = \frac{1616\left[1+\left(\frac{z_e}{4.5}\right)^2\right]}{\sqrt{1+\left(\frac{z_e}{0.048}\right)^2}\sqrt{1+\left(\frac{z_e}{0.32}\right)^2}\sqrt{1+\left(\frac{z_e}{1.35}\right)^2}}$$

[4 M]

Q.7 An exothermic reaction takes place in a reactor (Figure Q.7), a cooling system is needed to remove the excess heat of reaction. In the event of the loss of cooling function, the temperature of the reactor would increase, leading to additional energy release. This would cause a runaway reaction with pressures exceeding the bursting pressure of the vessel. The temperature within the reactor is measured and is used to control the cooling water flow rate by a valve. Using the node cooling coil, perform the HAZOP study on the system. [5 M]

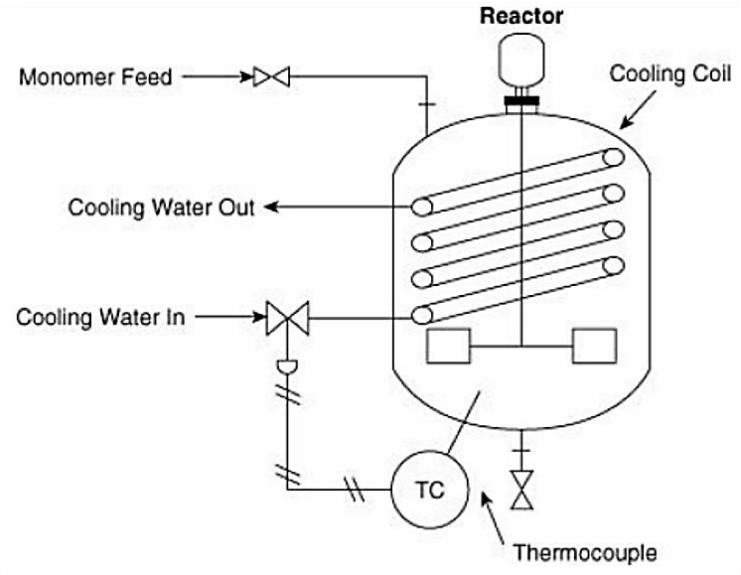

Figure Q.7

Q.8 A chemical company operates a batch reactor in which a polymerization reaction takes place. The polymer produced can have various properties depending on the process variables. If the properties do not satisfy the consumers, the whole batch of products may become useless and hence a loss to the company. Improper reaction atmosphere, improper reactant feed or poor mixing may spoil the desired properties of the products. Impurities in the reactor, wrong pressure set by the operator or improper temperature control by the operator can affect the reaction atmosphere. Improper reactant feed is due to impure reactants or improper flow rate maintained by the operator. Poor mixing results from wrong mixing speed set by the operator or building up of polymer on the baffles. Improper cleaning by the operator and accumulated build-up from several reactions may lead to building up of polymer on the baffles.

a. Draw the Fault Tree with "Useless Batch of Products" as the Top Event.
b. If all operator errors can be assigned a constant value of 0.0006 faults per year, probability of impure N_2 gas in the reactor is 0.0015, probability of impure reactant is 0.0018 and probability of accumulated build-up from several reactions is 0.0025, find the average rate for the occurrence of the top event.
c. Determine the minimal cut sets.

[3+3+2=8 M]

END OF THE QUESTION PAPER