ENCH 501 F18 **Quiz #3** Name/ID: ____

October 9, 2018 Time Allowed: **40 minutes** Only Cheat Sheet permitted. aJ

Question 1 (8 points)

There is a spat going on between the provinces of Alberta and British Columbia on expanding the capacity of a pipeline system from the oil fields to shore. The addition of a new pipeline is to transport bitumen and heavy oil from Alberta to the sea terminal so that the "crude" can be loaded into tankers for the overseas market. Since bitumen and heavy oil are very viscous, the commodity is diluted with gas condensates to lower the viscosity. The B.C. government objects to such practices based on environmental stewardship. There is concern for spillage due to rupture of the pipe and contamination of lakes from products that would sink, as the hydrocarbon density is expected to be higher than for water. The objections are that bitumen fragments that sink is not easily recovered and do significant damage to aquatic life and the eco-system. The diluent, the condensates, contains substances such as aromatics and cyclic hydrocarbons that are carcinogenic. These would contaminate lakes, rivers and ground water. A compromise solution appears to be to do partial upgrading of the bitumen and heavy oil in Alberta to make the density lower than for water and reduce the viscosity of the liquids sufficiently for the product to be pumped in pipelines without addition of condensates. The following problem is on an upgrading process.

Substance A made up of a large hydrocarbon molecular species is thermally cracked in a batch reactor to form three molecules B, C and D. The molar mass of A is five times the molar mass of C, and the molar mass of C is three time that of D. Compound D is a gas that leaves the reactor as it is produced. The rate at which A is depleted in the reactor is proportional to the mass of A present in the reactor. The stoichiometric equation for the reaction is:

$A \rightarrow 2B + C + D$

When 45 kg of A was charged into the reactor at t = 0, no products were present. After 8 minutes from the start of heating, the mass of A had decreased by 5 kg.

a) (**6 pts**) Derive an expression for the mass of A (kg) present in the reactor as a function of time t (mins) from the start of the process.
b) (**2 pts**) Estimate the time for 98% of A to be converted.

Show all your steps.

Question 2 (2 points)

Unused engine oil at 30°C flows through two straight pipes joined by a 90° elbow. The inside diameter of the pipes and elbow is 5 cm. The viscosity of the oil and its density are respectively 0.369 Pa.s and 881 kg/m^3. If the volume rate of flow is 2.878 (10^{-3}) m^3/s, what types of motions are present within the elbow? Explain.

ENCH 501 Quiz #3 Solution

For the petroleum products, A, B, C and D are pseudo-compounds or hypothetical molecules that represent the complex hydrocarbon mixture. The stoichiometric equation (moles) is

$$A \rightarrow 2B + C + D$$

Let x be the total mass of D produced at time t. (The fact that it leaves the reactor does not matter as it is not involved in the rate of reaction.)

	A	B	C	D
molar masses	$5M_C$		M_C	
	$15M_D$	$\frac{11}{2}M_D$	$3M_D$	M_D
moles used or produced	$\frac{x}{M_D}$	$2\frac{x}{M_D}$	$\frac{x}{M_D}$	$\frac{x}{M_D}$
mass used or produced	$15x$	$11x$	$3x$	x
masses present	$45-15x$	$11x$	$3x$	x ← Total Mass is conserved

From conservation equation of species A

$$\underset{\downarrow\ 0}{\text{Input}} + \underset{-K_1 A}{\text{Generation}} = \underset{\downarrow\ 0}{\text{Output}} + \underset{\frac{dA}{dt}}{\text{Accumulation}}$$

Rate of generation ∝ mass A and it is a depletion, hence the −ve sign

Also K_1 is a rate constant – unknown.

$$\therefore \quad \frac{dA}{dt} = -k_1 A \quad \text{or} \quad \int_{A=A_0}^{A} \frac{dA}{A} = -k_1 \int_{t=0}^{t} dt$$

On integration

$$\ln A - \ln A_0 = \ln A/A_0 = -k_1 t$$

$$\text{or} \quad A = A_0 e^{-k_1 t}$$

Subst.

$$45 - 15x = 45 e^{-k_1 t}$$

$$x = 3\left(1 - e^{-k_1 t}\right)$$

Using the second condition, that 5 kgs of A was used in the first 8 mins,

$$5 \text{ kg} = 15x \quad \text{or} \quad x = \frac{1}{3}$$

$$\therefore \quad \frac{1}{3} = 3\left(1 - e^{-8k_1}\right)$$

$$k_1 = 0.014723 \text{ min}^{-1}$$

∴ The mass of A in reactor is given by

$$A = 45 e^{-0.014723t} \text{ (kg) with t in mins.}$$

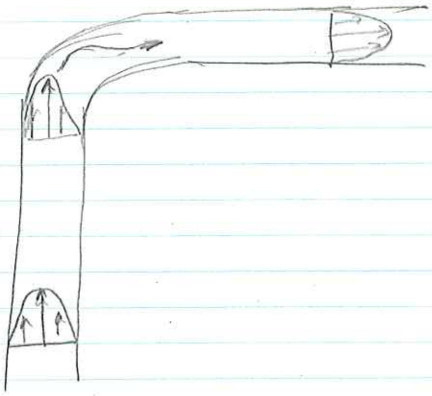
ⓑ 98% Conversion means 0.02(45) kg is left

$$\therefore \quad 0.02 = e^{-0.014723t}$$

$$\Rightarrow \quad t = 265.71 \text{ mins}$$

The conversion of A is independant of the mass of A originally charged into vessel.

Q. 2



Using data provided,

$D = 5\,cm$ or $0.05\,m$

$\rho = 881\ kg/m^3$

$\mu = 0.369\ Pa\cdot s$

$Q = 2.878(10^{-3})\ m^3/s$

we obtain that

$$\bar{u} = \frac{4Q}{\pi D^2} = 1.466\ m/s$$

and $Re = \dfrac{D\bar{u}\rho}{\mu} = 175$ ∴ flow is laminar.

In the straight pipe, the max. vel. is at ℄ and it equals $2\bar{U}$ or 2.932 m/s. Angular deformation is present always.
At the elbow, the inertia of the flow at $r=0$ upstream will cause the liquid at higher velocities to move towards the outer wall of the bend. Slower fluid will be displaced towards the inner wall of the bend.

Thus there would be
- translation
- angular deformation
- rotation