BASICS OF MATERIALS & ENERGY BALANCE
(CHEN 2103)

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.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) The heat of vaporization _____ with the increase in pressure
(a) increases (b) decreases
(c) becomes zero at critical pressure (d) both (b) and (c)

(ii) Solutions having same osmotic pressure are called
(a) ideal solution (b) isotonic solution
(c) saturated solution (d) supersaturated solution

(iii) An equimolar mixture of gas containing CO_2, H_2, O_2 and N_2 has the average molecular weight equal to
(a) 106 (b) 53 (c) 79.5 (d) 26.5

(iv) 1 cm / s^2 is equivalent to
(a) 9.95×10^9 km / yr^2 (b) 2.34×10^5 km / yr^2
(c) 5.5×10^8 km / yr^2 (d) 9.81 km / yr^2

(v) In a chemical process, the recycle stream is purged for
(a) increasing the yield (b) enriching the product
(c) limiting the inert (d) increasing the selectivity

(vi) The relation between higher heating value (HHV) and the lower heating value (LHV) of a fuel is given by
Where n = moles of water produced, ΔH_V = heat of vaporization of water at 25^0C
(a) HHV = LHV + ΔH_V (b) HHV = LHV - ΔH_V
(c) HHV = LHV + n ΔH_V (d) HHV = LHV - n ΔH_V

(vii) Antoine's equation measures the relation between the temperature and
(a) specific volume (b) saturated vapour pressure
(c) pressure (d) none of above

(viii) The term 'residual' in linear regression
(a) Measures goodness of fit of actual to fitted data
(b) Measures the error between actual data and predicted data at a point
(c) Measures the error between actual data and a straight line at any point
(d) none of above

(ix) Psychrometric charts correlate the specific humidity to
(a) saturated vapour pressure of moist air (b) dry bulb temperature only
(c) dry and wet bulb temperature (d) critical temperature of air

(x) The units of *a* in Van der Waal's equation of state
(a) [(pressure)(Volume)]^2 (b) [pressure]
(c) [Pressure/volume]^2 (d) None of the above

Group – B

2. (a) A partially submerged body is towed in water. The resistance R to its motion depends on density ρ, viscosity μ of water, length l of the body, velocity v of the body and the acceleration due to gravity g. Show that the resistance to the motion can be expressed in the form

$$\frac{R}{\rho l^2 v} = f\left[\left(\frac{\mu}{\rho v l}\right), \left(\frac{\lg}{v^2}\right)\right]$$

(b) In a textile mill, an evaporator system concentrates weak liquor containing 4% (by mass) caustic soda to produce a lye containing 25% solid (by mass). Calculate the rate of evaporation if the feed rate to evaporator is 750 kg/h.

8 + 4 = 12

3. The feed to a distillation column is 35 mole % n-pentane and 65 mole % n-hexane liquid mixture. The vapor stream leaving at the top of column, contains 98 mole% pentane and the balance hexane goes to a total condenser in which 95% vapor condenses. Half of the liquid condensate is returned at the top of column as reflux and the rest is withdrawn as overhead product (distillate) at 85 kmol/h. The distillate contains 95% of the pentane fed to the column. The liquid stream leaving the bottom of column goes to reboiler. Part of the stream is vaporized; the vapor is recycled to the bottom of the column as boilup and the residual liquid is withdrawn as bottoms product.

(i)Draw a diagram of the process will all relevant details in each flow stream.

(ii) Calculate the molar flow rate of the feed stream and the molar flow rate and composition of the bottoms product stream.

4 + 8 =12

Group – C

4. (a) What is meant by yield and selectivity of a chemical reaction?

(b) The fresh feed to an ammonia production process contains 24.75 mole % nitrogen, 74.25 mole % hydrogen, and the balance inerts (I). The feed is combined with a recycle stream containing the same species, and the combined stream is fed to a reactor in which a 25% single-pass conversion of nitrogen is achieved. The products pass through a condenser in which essentially all of the ammonia is removed, and the remaining gases are recycled. However, to prevent build up of the inerts in the system, a purge stream must be taken off. The recycle stream contains 12.5 mole% inerts. Calculate the overall conversion of nitrogen, the ratio (moles purge gas/mole of gas leaving the condenser), and the ratio (moles fresh feed/mole fed to the reactor).

2 + 10 = 12

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

$$CO_2 + 3H_2 \rightarrow CH_3OH + H_2O$$

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.

(b) A stack gas contains 60 mole% N_2, 15% CO_2, 10% O_2, and the balance H_2O. Calculate the mass composition of the gas on a dry basis.

8 + 4 = 12

Group – D

6. (a) Calculate the temperature and composition of a vapour in equilibrium with a liquid that contains 40 mole % benzene and 60 mole % toluene at 1 atm. The following data for the constants is given for using the Antoine's equation.

Compound	*A*	*B*	*C*
Benzene	6.9	1203.5	219.9
Toluene	6.95	1346.8	219.7

You may use an initial guess of 80 ^oC to start your solutions.

(b) What is the difference between the dew point and bubble point of a substance?

8 + 4 = 12

7. (a) The following data are given:

x	1	2	3	5	8
y	0.8	1.9	2.2	3	3.5

It is known that the equation $y = (m\sqrt{x} + b)^{1/2}$ best fits the data, where m and b are constants. Determine the constants m and b that best fit the data in the equation

(b) If instead, the equation $y = \frac{(m\sqrt{x} + b)^{1/2}}{x}$ would best fit the data, do you think you can determine the constants. If yes, what would you do to the data in the above table to determine the constants. If not, why?

8 + 4 = 12

Group – E

8. (a) The standard heat of reaction at 298 K for the following reaction is -42.433 kJ.

C_2H_4 (g) + H_2O (g) = C_2H_5OH (g).

Calculate the heat of reaction at 400 K. The constants in the heat capacity equation are given below (C_P is in J/mol-K)

	α	$\beta \times 10^3$	$\gamma \times 10^6$
C_2H_4	11.85	119.75	-36.53
H_2O	30.38	9.62	1.19
C_2H_5OH	29.27	166.39	-49.93

(b) The standard heats of the following combustions reactions have been determined experimentally.

$C_2H_6 + 7/2\ O_2 \rightarrow 2CO_2 + 3H_2O$ $\quad \Delta H_1 = -1559.8$ kJ / mol

$C + O_2 \rightarrow CO_2$ $\quad \Delta H_2 = -393.5$ kJ / mol

$H_2 + 1/2\ O_2 \rightarrow H_2O$ $\quad \Delta H_3 = -285.8$ kJ / mol

Use Hess's law to determine the heat of formation of ethane.

7 + 5 = 12

9. (a) Ammonium sulphate is to be crystallized from a solution containing 48% ammonium sulphate by cooling it in a crystallizer from 85°C to 35°C by means of cooling water which is available at a temperature of 20°C. During cooling the amount of water that evaporates is 5% of the mass of the feed solution. The feed rate is 1000 kg/h. The mass flow rate of cooling water is 850 kg/h. Determine the outlet temperature of water with the help of following data given: Solubility of ammonium sulphate 75, average specific heat of ammonium sulphate solution 2.97 kJ/kg K, heat of crystallization of ammonium sulphate 75.5 kJ/kg, latent heat of vaporization of water 2414 kJ/kg.

(b) A well stirred batch reactor wrapped in an electrical heating mantle is charged with a liquid reaction mixture. The reactant must be heated from an initial temperature of 25^0C to 250^0C before the reaction can take place at a measurable rate. Using the data given below determine the time required for this heating to take place.

Reactant: mass = 1.5 Kg, C_V = 0.90 Kcal / Kg. ^{0}C

Reactor: mass = 3.0 Kg, C_V = 0.12 Kcal / Kg. ^{0}C

Heating rate(Q) = 500 W

Negligible reaction and no phase change during heating. Negligible energy added to the system by the stirrer.

7 + 5 = 12

Department & Section	Submission Link
CHE	https://classroom.google.com/c/MTIyMDUwODUzMjgx/a/MjcxNDI1ODY1MTE3/details