UNIVERSITY OF JOHANNESBURG

PROGRAM	:	NATIONAL DIPLOMA *CHEMICAL ENGINEERING*
SUBJECT	:	**CHEMICAL ENGINEERING TECHNOLOGY 2**
CODE	:	**WAR2111**
DATE	:	SSA DECEMBER EXAMINATION 01 DECEMBER 2014
DURATION	:	(SESSION 2) 11:30 – 14:30
WEIGHT	:	40: 60
TOTAL MARKS	:	120

EXAMINER	:	PROF F. NTULI
MODERATOR	:	DR H. RUTTO
NUMBER OF PAGES	:	5 PAGES AND 2 ANNEXURE

REQUIREMENTS	:	CALCULATORS ALLOWED (ONE PER STUDENT)

INSTRUCTIONS TO CANDIDATES:

1. NUMBER ALL QUESTIONS CORRECTLY.
2. ANSWER ALL THE FIVE QUESTIONS.
3. THE MARKS ALLOCATED TO EACH QUESTION ARE INDICATED AFTER THE QUESTION AND THE TOTAL MARKS AT THE END.

QUESTION 1

1.1 The specific enthalpy of iron is given by the expression:

$$\hat{H}(\text{J/g}) = 17.3T(^\circ\text{C})$$

1.1.1 What are the units of 17.3? (2)
1.1.2 Convert the equation to SI units. (6)

1.2 The volumetric flow rate of CCl_4 ($\rho = 1.595$ g/cm^3) in a pipe is 100 cm^3/min.
1.2.1 Calculate the mass flow rate in kg/s. (4)
1.2.2 Calculate the molar flowrate in kgmole/s. (3)
1.2.3 Calculate the specific volume of the solution in SI units. (2)

1.3 Work (W) is defined as “force (F) acting upon an object to cause a displacement (L). Determine the dimension of W. (4)

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QUESTION 2

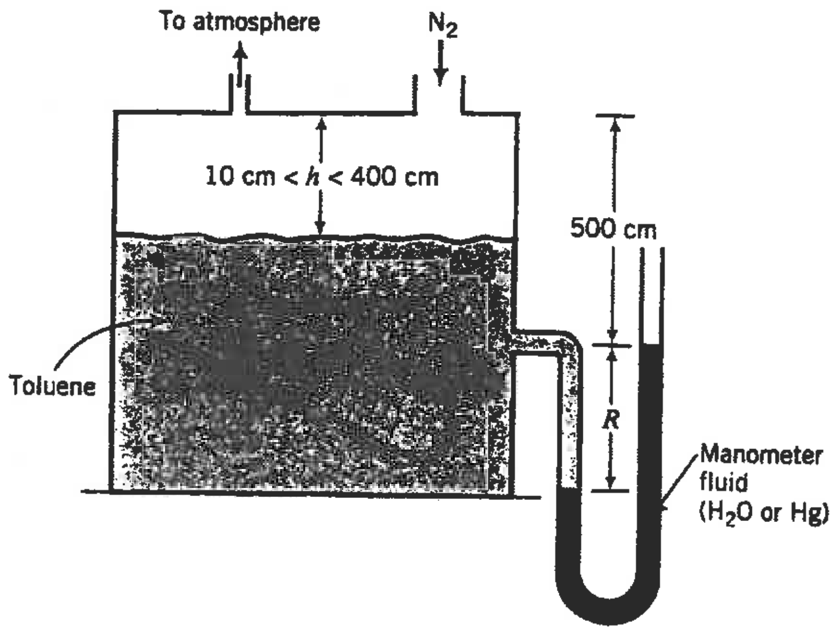
2.1 The feed to an ammonia synthesis reactor contains 25 mole % nitrogen and the balance hydrogen. Calculate the following:
2.1.1 The average molecular weight of the mixture. (5)
2.1.2 The rate of flow of nitrogen into the reactor in kg/h. (4)
2.1.3 The concentration of hydrogen in the feed stream in ppm. (3)

2.2 The level of toluene (a flammable hydrocarbon) in a storage tank may fluctuate between 10 and 400 cm measured from the top of the tank. Since it is impossible to see inside the tank, an open end manometer with water or mercury as the manometer fluid is to be used to determine the toluene level. One leg of the manometer is attached to the tank 500 cm from the top as shown in the figure below. A nitrogen blanket at atmospheric pressure is maintained over the tank contents.

2.2.1 If water is used as a manometer fluid and R = 800 mm. Calculate the level of toluene in the tank. (12)

2.2.2 What is the purpose of the nitrogen blanket? (2)

Density of toluene = 887 kg/m^3; Density of water = 1000 kg/m^3



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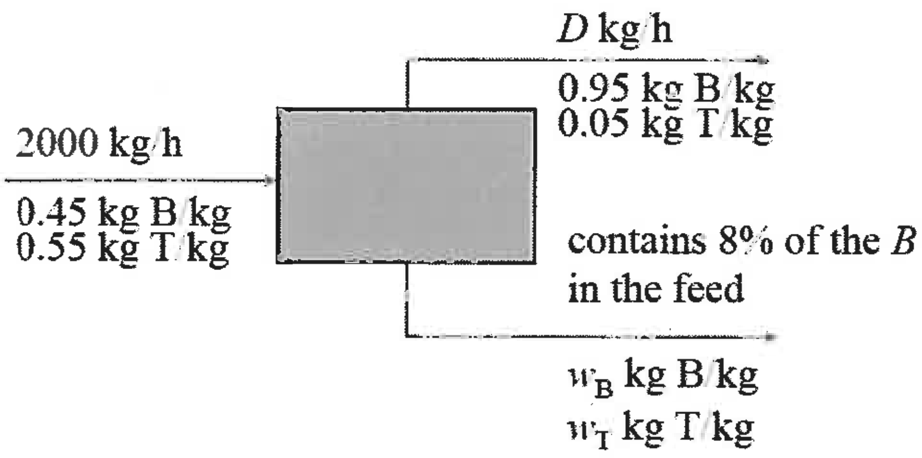
QUESTION 3

3.1 An evaporator is used to concentrate a dilute 5 wt% sodium hydroxide feed solution to 30 wt%. Draw a fully labelled flowchart and calculate the amount of water to be evaporated per 100 kg of feed solution. (10)

3.2 A distillation process for the separation of a mixture of toluene (T) and benzene (B) is shown below:



3.2.1 Calculate the degrees of freedom for the process and comment on the result. (5)

3.2.2 Calculate the value of all the unknown variables in the flow chart. (10)

[25]

QUESTION 4

1000 kmol of a liquid mixture containing 50 mol% benzene and the rest toluene is separated into two product streams by distillation. The vapour stream leaving at the top of the column, which contains 97 mol% benzene, is fed to a condenser to undergo complete condensation. The condensed liquid is split into two equal fractions: one is taken off as the final overhead product stream and the other (the reflux) is recycled to the top of the column. The final overhead product contains 89.2% of the benzene fed to the column.

4.1 Draw a fully labeled process flow diagram of the process. (6)

4.2 Calculate the amount and composition of the liquid leaving the bottom of the column (15).

4.3 Calculate the ratio of the recycle stream (R) to the feed stream (F) i.e. R/F. (5)

4.4 What is the major reason of including the recycle stream in the process (2)

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QUESTION 5

5.1 Consider the following pair of reactions:

$$A \rightarrow 2B \text{ (desired)}$$
$$A \rightarrow C \text{ (undesired)}$$

100 moles of A are fed to a batch reactor and the final product contains 10 mol of A, 160 mol of B and 10 mol of C. Calculate:

5.1.1 Percentage yield of B. (3)
5.1.2 The selectivity of B relative to C. (3)
5.1.3 The extents of the reactions. (4)

5.2 Starting with the energy balance for a closed system, derive an expression for the energy balance for an open system, explaining the meaning of each term in the equations (10):

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TOTAL MARKS [120]

FACTORS FOR UNIT CONVERSIONS

Quantity	Equivalent Values
Mass	1 kg = 1000 g = 0.001 metric ton = 2.20462 lb_m = 35.27392 oz 1 lb_m = 16 oz = 5 × 10^{-4} ton = 453.593 g = 0.453593 kg
Length	1 m = 100 cm = 1000 mm = 10^6 microns (μm) = 10^{10} angstroms (Å) = 39.37 in. = 3.2808 ft = 1.0936 yd = 0.0006214 mile 1 ft = 12 in. = 1/3 yd = 0.3048 m = 30.48 cm
Volume	1 m^3 = 1000 L = 10^6 cm^3 = 10^6 mL = 35.3145 ft^3 = 220.83 imperial gallons = 264.17 gal = 1056.68 qt 1 ft^3 = 1728 $in.^3$ = 7.4805 gal = 0.028317 m^3 = 28.317 L = 28,317 cm^3
Force	1 N = 1 kg·m/s^2 = 10^5 dynes = 10^5 g·cm/s^2 = 0.22481 lb_f 1 lb_f = 32.174 lb_m·ft/s^2 = 4.4482 N = 4.4482 × 10^5 dynes
Pressure	1 atm = 1.01325 × 10^5 N/m^2 (Pa) = 101.325 kPa = 1.01325 bar = 1.01325 × 10^6 dynes/cm^2 = 760 mm Hg at 0°C (torr) = 10.333 m H_2O at 4°C = 14.696 lb_f/$in.^2$ (psi) = 33.9 ft H_2O at 4°C = 29.921 in. Hg at 0°C
Energy	1 J = 1 N·m = 10^7 ergs = 10^7 dyne·cm = 2.778 × 10^{-7} kW·h = 0.23901 cal = 0.7376 ft·lb_f = 9.486 × 10^{-4} Btu
Power	1 W = 1 J/s = 0.23901 cal/s = 0.7376 ft·lb_f/s = 9.486 × 10^{-4} Btu/s = 1.341 × 10^{-3} hp

$T(\text{K}) = T(°\text{C}) + 273.15$

$T(°\text{R}) = T(°\text{F}) + 459.67$

$T(°\text{R}) = 1.8T(\text{K})$

$T(°\text{F}) = 1.8T(°\text{C}) + 32$

PERIODIC TABLE OF THE ELEMENTS

http://www.ktf-split.hr/periodni/en/

GROUP NUMBERS IUPAC RECOMMENDATION (1985) — 13

GROUP NUMBERS CHEMICAL ABSTRACT SERVICE (1986) — IIIA

ATOMIC NUMBER — 5

RELATIVE ATOMIC MASS (1) — 10.811

SYMBOL — B

ELEMENT NAME — BORON

PERIOD	GROUP 1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIIIB	9 VIIIB	10 VIIIB	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	1 1.0079 H HYDROGEN																	2 4.0026 He HELIUM
2	3 6.941 Li LITHIUM	4 9.0122 Be BERYLLIUM											5 10.811 B BORON	6 12.011 C CARBON	7 14.007 N NITROGEN	8 15.999 O OXYGEN	9 18.998 F FLUORINE	10 20.180 Ne NEON
3	11 22.990 Na SODIUM	12 24.305 Mg MAGNESIUM											13 26.982 Al ALUMINIUM	14 28.086 Si SILICON	15 30.974 P PHOSPHORUS	16 32.065 S SULPHUR	17 35.453 Cl CHLORINE	18 39.948 Ar ARGON
4	19 39.098 K POTASSIUM	20 40.078 Ca CALCIUM	21 44.956 Sc SCANDIUM	22 47.867 Ti TITANIUM	23 50.942 V VANADIUM	24 51.996 Cr CHROMIUM	25 54.938 Mn MANGANESE	26 55.845 Fe IRON	27 58.933 Co COBALT	28 58.693 Ni NICKEL	29 63.546 Cu COPPER	30 65.39 Zn ZINC	31 69.723 Ga GALLIUM	32 72.64 Ge GERMANIUM	33 74.922 As ARSENIC	34 78.96 Se SELENIUM	35 79.904 Br BROMINE	36 83.80 Kr KRYPTON
5	37 85.468 Rb RUBIDIUM	38 87.62 Sr STRONTIUM	39 88.906 Y YTTRIUM	40 91.224 Zr ZIRCONIUM	41 92.906 Nb NIOBIUM	42 95.94 Mo MOLYBDENUM	43 (98) Tc TECHNETIUM	44 101.07 Ru RUTHENIUM	45 102.91 Rh RHODIUM	46 106.42 Pd PALLADIUM	47 107.87 Ag SILVER	48 112.41 Cd CADMIUM	49 114.82 In INDIUM	50 118.71 Sn TIN	51 121.76 Sb ANTIMONY	52 127.60 Te TELLURIUM	53 126.90 I IODINE	54 131.29 Xe XENON
6	55 132.91 Cs CAESIUM	56 137.33 Ba BARIUM	57-71 La-Lu Lanthanide	72 178.49 Hf HAFNIUM	73 180.95 Ta TANTALUM	74 183.84 W TUNGSTEN	75 186.21 Re RHENIUM	76 190.23 Os OSMIUM	77 192.22 Ir IRIDIUM	78 195.08 Pt PLATINUM	79 196.97 Au GOLD	80 200.59 Hg MERCURY	81 204.38 Tl THALLIUM	82 207.2 Pb LEAD	83 208.98 Bi BISMUTH	84 (209) Po POLONIUM	85 (210) At ASTATINE	86 (222) Rn RADON
7	87 (223) Fr FRANCIUM	88 (226) Ra RADIUM	89-103 Ac-Lr Actinide	104 (261) Rf RUTHERFORDIUM	105 (262) Db DUBNIUM	106 (266) Sg SEABORGIUM	107 (264) Bh BOHRIUM	108 (277) Hs HASSIUM	109 (268) Mt MEITNERIUM	110 (281) Uun UNUNNILIUM	111 (272) Uuu UNUNUNIUM	112 (285) Uub UNUNBIUM		114 (289) Uuq UNUNQUADIUM				

LANTHANIDE

6	57 138.91 La LANTHANUM	58 140.12 Ce CERIUM	59 140.91 Pr PRASEODYMIUM	60 144.24 Nd NEODYMIUM	61 (145) Pm PROMETHIUM	62 150.36 Sm SAMARIUM	63 151.96 Eu EUROPIUM	64 157.25 Gd GADOLINIUM	65 158.93 Tb TERBIUM	66 162.50 Dy DYSPROSIUM	67 164.93 Ho HOLMIUM	68 167.26 Er ERBIUM	69 168.93 Tm THULIUM	70 173.04 Yb YTTERBIUM	71 174.97 Lu LUTETIUM

ACTINIDE

7	89 (227) Ac ACTINIUM	90 232.04 Th THORIUM	91 231.04 Pa PROTACTINIUM	92 238.03 U URANIUM	93 (237) Np NEPTUNIUM	94 (244) Pu PLUTONIUM	95 (243) Am AMERICIUM	96 (247) Cm CURIUM	97 (247) Bk BERKELIUM	98 (251) Cf CALIFORNIUM	99 (252) Es EINSTEINIUM	100 (257) Fm FERMIUM	101 (258) Md MENDELEVIUM	102 (259) No NOBELIUM	103 (262) Lr LAWRENCIUM

(1) Pure Appl. Chem., 73, No. 4, 667-683 (2001)

Relative atomic mass is shown with five significant figures. For elements have no stable nuclides, the value enclosed in brackets indicates the mass number of the longest-lived isotope of the element.

However three such elements (Th, Pa, and U) do have a characteristic terrestrial isotopic composition, and for these an atomic weight is tabulated.

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