



**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:

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

- 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  $\text{CCl}_4$  ( $\rho = 1.595 \text{ g/cm}^3$ ) in a pipe is  $100 \text{ cm}^3/\text{min}$ .

- 1.2.1 Calculate the mass flow rate in  $\text{kg/s}$ . (4)
- 1.2.2 Calculate the molar flowrate in  $\text{kgmole/s}$ . (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)

---

[21]

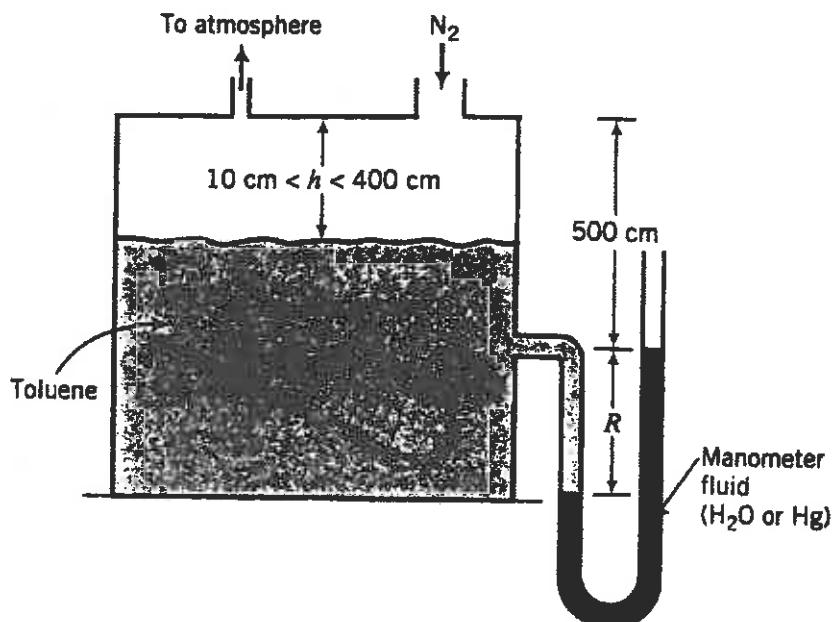
---

**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  $\text{kg/h}$ . (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 =  $887 \text{ kg/m}^3$ ; Density of water =  $1000 \text{ kg/m}^3$

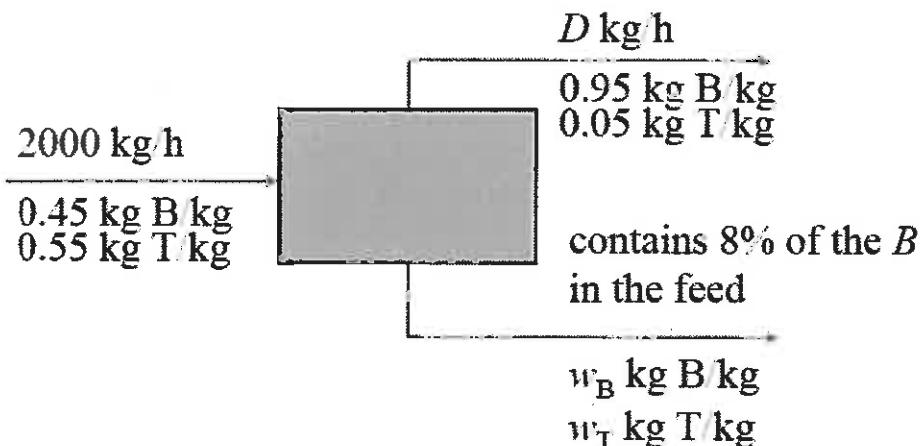


[26]

### 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.

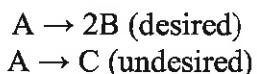
- 4.1 Draw a fully labeled process flow diagram of the process. (6)
- 4.2 Calculate the amount and composition of the liquid leaving the bottom of the column (15).
- 4.3 Calculate the ratio of the recycle stream (R) to the feed stream (F) i.e. R/F. (5)
- 4.4 What is the major reason of including the recycle stream in the process (2)

[28]

5/...

**QUESTION 5**

5.1 Consider the following pair of reactions:



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):

**[20]**

---

**TOTAL MARKS [120]**

---

**CHEMICAL ENGINEERING TECHNOLOGY 2 – WAR2111**  
**ANNEXURE**

**FACTORS FOR UNIT CONVERSIONS**

Quantity	Equivalent Values
<b>Mass</b>	1 kg = 1000 g = 0.001 metric ton = 2.20462 lb <sub>m</sub> = 35.27392 oz 1 lb <sub>m</sub> = 16 oz = $5 \times 10^{-3}$ ton = 453.593 g = 0.453593 kg
<b>Length</b>	1 m = 100 cm = 1000 mm = $10^6$ microns ( $\mu\text{m}$ ) = $10^{10}$ angstroms ( $\text{\AA}$ ) = 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
<b>Volume</b>	1 m <sup>3</sup> = 1000 L = $10^6$ cm <sup>3</sup> = $10^3$ mL = 35.3145 ft <sup>3</sup> = 220.83 imperial gallons = 264.17 gal = 1656.68 qt 1 ft <sup>3</sup> = 1728 in. <sup>3</sup> = 7.4805 gal = 0.028317 m <sup>3</sup> = 28.317 L = 28.317 cm <sup>3</sup>
<b>Force</b>	1 N = 1 kg·m/s <sup>2</sup> = $10^5$ dynes = $10^5$ g·cm/s <sup>2</sup> = 0.22481 lb <sub>f</sub> 1 lb <sub>f</sub> = 32.174 lb <sub>m</sub> ·ft/s <sup>2</sup> = 4.4482 N = $4.4482 \times 10^5$ dynes
<b>Pressure</b>	1 atm = $1.01325 \times 10^5$ N/m <sup>2</sup> (Pa) = 101.325 kPa = 1.01325 bar = $1.01325 \times 10^5$ dynes/cm <sup>2</sup> = 760 mm Hg at 0°C (torr) = 10.333 m H <sub>2</sub> O at 4°C = 14.696 lb <sub>f</sub> /in. <sup>2</sup> (psi) = 33.9 ft H <sub>2</sub> O at 4°C = 29.921 in. Hg at 0°C
<b>Energy</b>	1 J = 1 N·m = $10^7$ ergs = $10^5$ dyne·cm = $2.778 \times 10^{-7}$ kW·h = 0.23901 cal = 0.7376 ft-lb <sub>f</sub> = 9.486 $\times 10^{-4}$ Btu
<b>Power</b>	1 W = 1 J/s = 0.23901 cal/s = 0.7376 ft-lb <sub>f</sub> /s = $9.486 \times 10^{-4}$ Btu/s = $1.341 \times 10^{-3}$ 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.kif-split.hr/periodni/en/>

GROUP	PERIOD	ATOMIC NUMBER (1985)	RECOMMENDATION (1985)	GROUP NUMBERS (1985)	NAME	CHEMICAL ABSTRACT SERVICE (1986)	RELATIVE ATOMIC MASS (1)	ATOMIC NUMBER (1985)	RECOMMENDATION (1985)	GROUP NUMBERS (1985)	NAME	CHEMICAL ABSTRACT SERVICE (1986)	RELATIVE ATOMIC MASS (1)	ATOMIC NUMBER (1985)	RECOMMENDATION (1985)	GROUP NUMBERS (1985)	NAME	CHEMICAL ABSTRACT SERVICE (1986)	RELATIVE ATOMIC MASS (1)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
1	1	1.0079	H	1	Hydrogen	1	1.0122	3	6.941	4	9.0122	2	1.0122	18	1.0115	18	1.0115	He	2 4.0026																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
2	1	2	Li	2	Boron	2	10.811	13	10.811	13	10.811	13	10.811	18	10.811	18	10.811	Helium	10 20.180																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																											
3	1	3	Na	3	Magnesium	3	11.96	20	20.078	21	24.956	22	27.867	23	30.942	24	31.996	25	34.938	26	35.845	27	38.933	28	38.693	29	35.46	30	35.39	31	36.723	32	37.922	34	38.96	35	39.98	36	39.98	37	40.00	38	40.00	39	40.00	40	40.00	41	40.00	42	40.00	43	40.00	44	40.00	45	40.00	46	40.00	47	40.00	48	40.00	49	40.00	50	40.00	51	40.00	52	40.00	53	40.00	54	40.00	55	40.00	56	40.00	57	40.00	58	40.00	59	40.00	60	40.00	61	40.00	62	40.00	63	40.00	64	40.00	65	40.00	66	40.00	67	40.00	68	40.00	69	40.00	70	40.00	71	40.00	72	40.00	73	40.00	74	40.00	75	40.00	76	40.00	77	40.00	78	40.00	79	40.00	80	40.00	81	40.00	82	40.00	83	40.00	84	40.00	85	40.00	86	40.00	87	40.00	88	40.00	89	40.00	90	40.00	91	40.00	92	40.00	93	40.00	94	40.00	95	40.00	96	40.00	97	40.00	98	40.00	99	40.00	100	40.00	101	40.00	102	40.00	103	40.00	104	40.00	105	40.00	106	40.00	107	40.00	108	40.00	109	40.00	110	40.00	111	40.00	112	40.00	113	40.00	114	40.00	115	40.00	116	40.00	117	40.00	118	40.00	119	40.00	120	40.00	121	40.00	122	40.00	123	40.00	124	40.00	125	40.00	126	40.00	127	40.00	128	40.00	129	40.00	130	40.00	131	40.00	132	40.00	133	40.00	134	40.00	135	40.00	136	40.00	137	40.00	138	40.00	139	40.00	140	40.00	141	40.00	142	40.00	143	40.00	144	40.00	145	40.00	146	40.00	147	40.00	148	40.00	149	40.00	150	40.00	151	40.00	152	40.00	153	40.00	154	40.00	155	40.00	156	40.00	157	40.00	158	40.00	159	40.00	160	40.00	161	40.00	162	40.00	163	40.00	164	40.00	165	40.00	166	40.00	167	40.00	168	40.00	169	40.00	170	40.00	171	40.00	172	40.00	173	40.00	174	40.00	175	40.00	176	40.00	177	40.00	178	40.00	179	40.00	180	40.00	181	40.00	182	40.00	183	40.00	184	40.00	185	40.00	186	40.00	187	40.00	188	40.00	189	40.00	190	40.00	191	40.00	192	40.00	193	40.00	194	40.00	195	40.00	196	40.00	197	40.00	198	40.00	199	40.00	200	40.00	201	40.00	202	40.00	203	40.00	204	40.00	205	40.00	206	40.00	207	40.00	208	40.00	209	40.00	210	40.00	211	40.00	212	40.00	213	40.00	214	40.00	215	40.00	216	40.00	217	40.00	218	40.00	219	40.00	220	40.00	221	40.00	222	40.00	223	40.00	224	40.00	225	40.00	226	40.00	227	40.00	228	40.00	229	40.00	230	40.00	231	40.00	232	40.00	233	40.00	234	40.00	235	40.00	236	40.00	237	40.00	238	40.00	239	40.00	240	40.00	241	40.00	242	40.00	243	40.00	244	40.00	245	40.00	246	40.00	247	40.00	248	40.00	249	40.00	250	40.00	251	40.00	252	40.00	253	40.00	254	40.00	255	40.00	256	40.00	257	40.00	258	40.00	259	40.00	260	40.00	261	40.00	262	40.00	263	40.00	264	40.00	265	40.00	266	40.00	267	40.00	268	40.00	269	40.00	270	40.00	271	40.00	272	40.00	273	40.00	274	40.00	275	40.00	276	40.00	277	40.00	278	40.00	279	40.00	280	40.00	281	40.00	282	40.00	283	40.00	284	40.00	285	40.00	286	40.00	287	40.00	288	40.00	289	40.00	290	40.00	291	40.00	292	40.00	293	40.00	294	40.00	295	40.00	296	40.00	297	40.00	298	40.00	299	40.00	300	40.00	301	40.00	302	40.00	303	40.00	304	40.00	305	40.00	306	40.00	307	40.00	308	40.00	309	40.00	310	40.00	311	40.00	312	40.00	313	40.00	314	40.00	315	40.00	316	40.00	317	40.00	318	40.00	319	40.00	320	40.00	321	40.00	322	40.00	323	40.00	324	40.00	325	40.00	326	40.00	327	40.00	328	40.00	329	40.00	330	40.00	331	40.00	332	40.00	333	40.00	334	40.00	335	40.00	336	40.00	337	40.00	338	40.00	339	40.00	340	40.00	341	40.00	342	40.00	343	40.00	344	40.00	345	40.00	346	40.00	347	40.00	348	40.00	349	40.00	350	40.00	351	40.00	352	40.00	353	40.00	354	40.00	355	40.00	356	40.00	357	40.00	358	40.00	359	40.00	360	40.00	361	40.00	362	40.00	363	40.00	364	40.00	365	40.00	366	40.00	367	40.00	368	40.00	369	40.00	370	40.00	371	40.00	372	40.00	373	40.00	374	40.00	375	40.00	376	40.00	377	40.00	378	40.00	379	40.00	380	40.00	381	40.00	382	40.00	383	40.00	384	40.00	385	40.00	386	40.00	387	40.00	388	40.00	389	40.00	390	40.00	391	40.00	392	40.00	393	40.00	394	40.00	395	40.00	396	40.00	397	40.00	398	40.00	399	40.00	400	40.00	401	40.00	402	40.00	403	40.00	404	40.00	405	40.00	406	40.00	407	40.00	408	40.00	409	40.00	410	40.00	411	40.00	412	40.00	413	40.00	414	40.00	415	40.00	416	40.00	417	40.00	418	40.00	419	40.00	420	40.00	421	40.00	422	40.00	423	40.00	424	40.00	425	40.00	426	40.00	427	40.00	428	40.00	429	40.00	430	40.00	431	40.00	432	40.00	433	40.00	434	40.00	435	40.00	436	40.00	437	40.00	438	40.00	439	40.00	440	40.00	441	40.00	442	40.00	443	40.00	444	40.00	445	40.00	446	40.00	447	40.00	448	40.00	449	40.00	450	40.00	451	40.00	452	40.00	453	40.00	454	40.00	455	40.00	456	40.00	457	40.00	458	40.00	459	40.00	460	40.00	461	40.00	462	40.00	463	40.00	464	40.00	465	40.00	466	40.00	467	40.00	468	40.00	469	40.00	470	40.00	471	40.00	472	40.00	473	40.00	474	40.00	475	40.00	476	40.00	477	40.00	478	40.00	479	40.00	480	40.00	481	40.00	482	40.00	483	40.00	484	40.00	485	40.00	486	40.00	487	40.00	488	40.00	489	40.00	490	40.00	491	40.00	492	40.00	493	40.00	494	40.00	495	40.00	496	40.00	497	40.00	498	40.00	499	40.00	500	40.00	501	40.00	502	40.00	503	40.00	504	40.00	505	40.00	506	40.00	507	40.00	508	40.00	509	40.00	510	40.00	511	40.00	512	40.00	513	40.00	514	40.00	515	40.00	516	40.00	517	40.00	518	40.00	519	40.00	520	40.00	521	40.00	522	40.00	523	40.00	524	40.00	525	40.00	526	40.00	527	40.00	528	40.00	529	40.00	530	40.00	531	40.00	532	40.00	533	40.00	534	40.00	535	40.00	536	40.00	537	40.00	538	40.00	539	40.00	540	40.00	541	40.00	542	40.00	543	40.00	544	40.00	545	40.00	546	40.00	547	40.00	548	40.00	549	40.00	550	40.00	551	40.00	552	40.00	553	40.00	554	40.00	555	40.00	556	40.00	557	40.00	558	40.00	559	40.00	560	40.00	561	40.00	562	40.00	563	40.00	564	40.00	565	40.00	566	40.00	567	40.00	568	40.00	569	40.00	570	40.00	571	40.00	572	40.00	573	40.00	574	40.00	575	40.00	576