

**16-CHEM-A3, HEAT and MASS TRANSFER**

**DECEMBER 2018**

**Three Hours Duration**

**NOTES:**

- 1) If doubt exists as to the interpretation of any question, you are urged to submit a clear statement of any assumptions made along with the answer paper.
- 2) Property data required to solve a given problem are provided in the problem statement or are available in the recommended texts. If you are unable to locate the required data, do not let this prevent you from solving the rest of the problem. Even in the absence of property data, you still have the opportunity to provide a solution methodology.
- 3) This is an **open-book exam**. One textbook of your choice with notations listed on the margins etc., but no loose notes are permitted into the exam. Candidates may use any **non-communicating** calculator.
- 4) All problems are worth **25 points**. At least **two problems** from **each part** must be attempted.
- 5) **Only the first two** questions as they appear in the answer book from each section will be marked.

**PART A – HEAT TRANSFER**

- 1) A steam pipe (100 cm long, 10 cm outside diameter) is covered with two layers of insulating material, each 2.5 cm thick. The thermal conductivity of one insulating material is three times that of the other. Compute the effectivity of the two layers when the better insulating material is on the inside compared to when it is on the outside. Assuming the same overall temperature difference in both cases.
  
  
  
  
  
  
  
  
  
  
- 2) Water at 30 °C enter a tube (25 mm internal diameter, 28 mm outside diameter) at a flow rate of 1200 liters per hour. Steam condenses on the outside surface of the tube at a temperature of 120 °C and the film heat transfer coefficient may be taken as 5800 Watts per m<sup>2</sup> per degree Kelvin. Find the length of the tube required to heat the water to 70 °C.

DATA: Thermal conductivity of the metal tube wall = 950 W/m<sup>2</sup>.K  
Thermal conductivity of water = 0.63 W/m<sup>2</sup>.K  
Average density of water = 0.98 g/cm<sup>3</sup>  
Average viscosity of water = 6 x 10<sup>-4</sup> Pa.s

3) Liquid oxygen at atmospheric pressure is stored in a spherical vessel (30 cm outside diameter). The system is insulated by enclosing the container inside another concentric sphere of 50 cm inside diameter and the space between them is evacuated. Both the sphere surfaces are made of aluminum (emissivity = 0.3). The temperature of the outer sphere is 40 °C.

(a) [10 points] Calculate the rate of heat flow due to radiation.

(b) [15 points] What will be the reduction in heat flow if polished aluminum with an emissivity of 0.05 is used for the container walls?

DATA: Boiling point of liquid oxygen at atmospheric pressure = - 183 °C



- 3) A liquid mixture feed containing 40% by mole of methanol and the rest water is differentially distilled at atmospheric pressure until 60% by mole of the liquid was distilled. The equilibrium data for methanol-water system at 1 atm pressure is given below:

<b>Mole Fraction of Methanol in Liquid Phase</b>	<b>Mole Fraction of Methanol in Vapor Phase</b>
0.05	0.27
0.10	0.42
0.20	0.57
0.30	0.66
0.40	0.73
0.50	0.78

Compute the compositions of the distillate and the residue.

# The Periodic Table of the Elements

		Atomic #																																																																																													
		Element name →																																																																																													
		Symbol →																																																																																													
		Avg. Mass ←																																																																																													
1	Hydrogen H 1.01	2	Helium He 4.00	3	Lithium Li 6.94	4	Beryllium Be 9.01	5	Boron B 10.81	6	Carbon C 12.01	7	Nitrogen N 14.01	8	Oxygen O 16.00	9	Fluorine F 19.00	10	Neon Ne 20.18																																																																												
11	Sodium Na 22.99	12	Magnesium Mg 24.31	13	Aluminum Al 26.98	14	Silicon Si 28.09	15	Phosphorus P 30.97	16	Sulfur S 32.07	17	Chlorine Cl 35.45	18	Argon Ar 39.95	19	Potassium K 39.10	20	Calcium Ca 40.08	37	Rubidium Rb 85.47	38	Sr 87.62	55	Cesium Cs 132.91	56	Barium Ba 137.33	87	Francium Fr (223)	88	Radium Ra (226)	103	Lr (262)	104	Rf (267)	105	Db (268)	106	Sg (271)	107	Bh (272)	108	Hs (270)	109	Mt (276)	110	Ds (281)	111	Rg (280)	112	Cn (285)	113	Uut (284)	114	Uuq (289)	115	Uup (288)	116	Uuh (293)	117	Uus (294?)	118	Uuo (294)																																
21	Scandium Sc 44.96	22	Titanium Ti 47.88	23	Vanadium V 50.94	24	Chromium Cr 52.00	25	Manganese Mn 54.94	26	Iron Fe 55.85	27	Cobalt Co 58.93	28	Nickel Ni 58.69	29	Copper Cu 63.55	30	Zinc Zn 65.39	31	Gallium Ga 69.72	32	Germanium Ge 72.61	33	Arsenic As 74.92	34	Selenium Se 78.96	35	Bromine Br 79.90	36	Krypton Kr 83.80	39	Yttrium Y 88.91	40	Zirconium Zr 91.22	41	Niobium Nb 92.91	42	Molybdenum Mo 95.94	43	Technetium Tc (98)	44	Ruthenium Ru 101.07	45	Rhodium Rh 102.91	46	Palladium Pd 106.42	47	Silver Ag 107.87	48	Cadmium Cd 112.41	49	Indium In 114.82	50	Tin Sn 118.71	51	Antimony Sb 121.76	52	Tellurium Te 127.60	53	Iodine I 126.90	54	Xenon Xe 131.29	71	Lutetium Lu 174.97	72	Hafnium Hf 178.49	73	Tantalum Ta 180.95	74	Tungsten W 183.84	75	Rhenium Re 186.21	76	Osmium Os 190.23	77	Iridium Ir 192.22	78	Platinum Pt 195.08	79	Gold Au 196.97	80	Mercury Hg 200.59	81	Thallium Tl 204.38	82	Lead Pb 207.20	83	Bismuth Bi 208.98	84	Polonium Po (209)	85	Astatine At (210)	86	Radon Rn (222)
57	Lanthanum La 138.91	58	Cerium Ce 140.12	59	Praseodymium Pr 140.91	60	Neodymium Nd 144.24	61	Promethium Pm (145)	62	Samarium Sm 150.36	63	Europium Eu 151.97	64	Gadolinium Gd 157.25	65	Terbium Tb 158.93	66	Dysprosium Dy 162.50	67	Hoium Ho 164.93	68	Erbium Er 167.26	69	Thulium Tm 168.93	70	Ytterbium Yb 173.04	89	Actinium Ac (227)	90	Thorium Th 232.04	91	Protactinium Pa 231.04	92	Uranium U 238.03	93	Neptunium Np (237)	94	Plutonium Pu (244)	95	Americium Am (243)	96	Curium Cm (247)	97	Berkelium Bk (247)	98	Californium Cf (251)	99	Einsteinium Es (252)	100	Fermium Fm (257)	101	Mendelevium Md (258)	102	Nobelium No (259)																																								

- Alkali metals
- Alkaline earth metals
- Transition metals
- Other metals
- Metalloids (semi-metal)
- Nonmetals
- Halogens
- Noble gases

\*lanthanides  
\*\*actinides

