BMED 2210: Conservation Principles in BME
Fall 2013,

Exam 2
March 3, 2014
1:05 – 1:55 pm

Instructor: Edward Botchwey

Instructions: This is a closed book exam. The use of wireless devices is not permitted. The use of programmable calculators is only permitted if all relevant content has been erased from the calculator memory.

Show ALL work to receive full credit. If appropriate draw the system (indicating the all necessary components). Write the accounting equations and write the conservation equations needed to solve the problem. Label all variables and equations, and present your solution clearly. Numerical answers without units will not receive full credit.

If unable to finish due to time write how you would solve the problem with the appropriate equations to receive partial credit for the process.

Name: Answer Key

GT ID: ______________________

The work presented here is solely my own. I did not receive any assistance nor did I assist other students during the exam. I pledge that I have abided by the above rules and the Georgia Tech Honor Code.

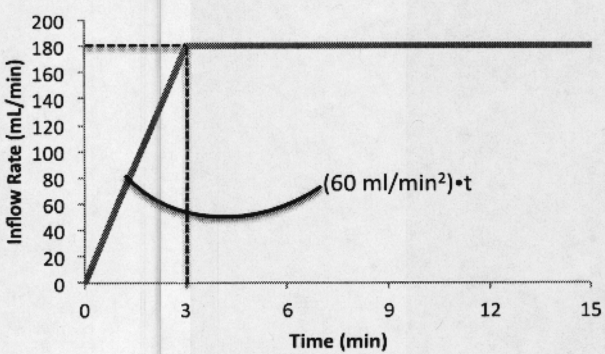
Signature: ______________________

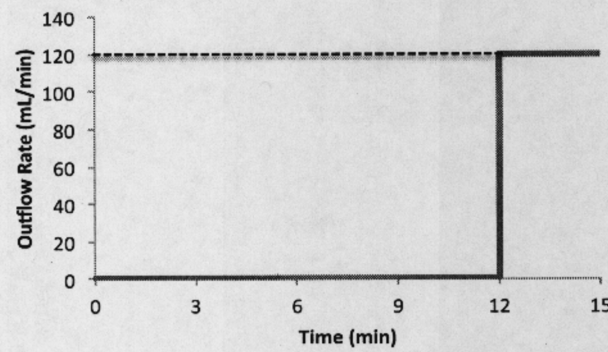
Problem 1: ____/ 17.5
Problem 2: ____/ 17.5
Problem 3: ____/ 25
Problem 4: ____/ 40
Extra Credit: ____/5

Total: ____/ 100 points

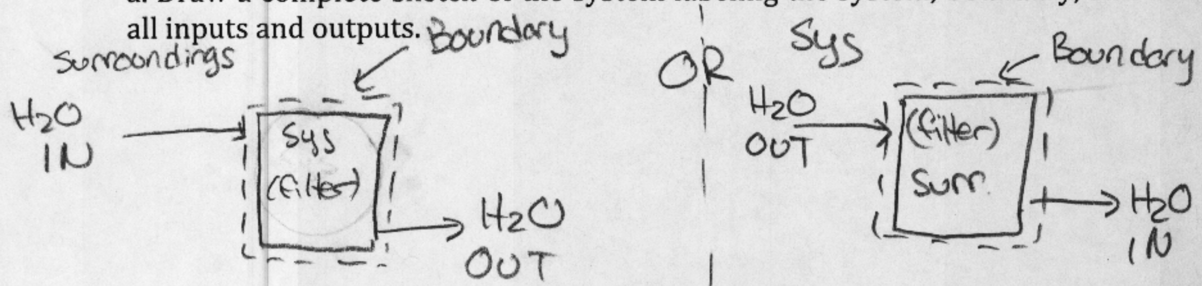
17.5pts

Problem 1: A graduate student begins pumping water into an open-air filtering unit at a variable flow rate as depicted below. However the student leaves, forgetting to turn off the pump causing the unit to fill with water. As a safety mechanism, the filter system begins to release water after 12 minutes. This release rate however is not fast enough to counteract the incoming flow of water. The filter system has a total capacity of 5L and was half full at the start of the process. Determine how long it take for the filter system to overflow?





a. Draw a complete sketch of the system labeling the system, boundary, surroundings, and all inputs and outputs. (2.5pts)



(0.5pts) for each part

b. Write and simplify the accounting equation for the system. Then write the appropriate mass conservation equation for the system and simplify. (For 1st Sys Drawn)

Accounting: $IN - OUT + \cancel{GEN} - \cancel{CON} = ACC \Rightarrow IN - OUT = ACC$ (2.5pts)

Mass Eq: $\int_{t_0}^{t_f} \dot{m}_{in}\,dt - \int_{t_0}^{t_f} \dot{m}_{out}\,dt = m_f - m_0$ (3pts)

ρ is constant for liquids $\Rightarrow \int_{t_0}^{t_f} \dot{V}_{in}\,dt - \int_{t_0}^{t_f} \dot{V}_{out}\,dt = V_f - V_0$ (2pts)

(5.5pts)

$$\Rightarrow \boxed{\int_0^{3min} 60\frac{mL}{min^2}t\,dt + \int_{3min}^{t_f} 180\frac{mL}{min} - \int_{12min}^{t_f} 120\frac{mL}{min} = 5000mL - 2500mL}$$

c. When the filter unit begins to overflow what aspect(s) of the system has now changed?

the water is leaving through an outflow stream now (2pts) causing the system to be at steady state

Extra Credit (1.5 Points): Solve for the time it takes for water to overflow in the system.

$$\frac{60\frac{mL}{min^2}}{2}t^2\Big|_0^3 + 180\frac{mL}{min}t\Big|_3^{t_f} - 120\frac{mL}{min}t\Big|_{12}^{t_f} = 2500mL$$ (0.5pts)

2

$$270\,mL + 180\frac{mL}{min}t_f - 540mL - 120\frac{mL}{min}t_f + 1440\,mL = 2500\,mL$$ (0.5pts)

$\boxed{t_f = 22\,min}$ (0.5pts)

17.5pts

Problem 2: One of the major components in a refrigerator system is a condenser. Refrigerant warmed by absorbing heat in the refrigerator is pumped as a gas into the condenser at 1.3 kmol/hr. In the condenser refrigerant is cooled from 12 °C to -46 °C where it undergoes a phase change from gas to liquid. The now liquid refrigerant is further cooled to -75 °C where it exits the condenser to cool the refrigerator once again. Assume steady state.

Properties of Refrigerant 404A: (Temperature Table in Appendix)

Specific Heat capacity (Liquid): 1.64 $\frac{kJ}{kg\ °C}$ Molecular Weight: 97.60 g/mol

Specific Heat capacity (gas): 1.03 $\frac{kJ}{kg\ °C}$

a. What does PV in the definition for enthalpy represent? (2pts) the energy it takes to "make room" for it in the sys or Pressure or flow + Volume work

b. (1pt) State function is a(n) (1pt) intensive property that depends on the current state of existence of the system.

c. Draw the path for the enthalpy changes associated with the condenser.

Refrigerant (gas) @ 12°C (1pt)

$\downarrow$ $\Delta H_{cool,g}$ (0.5pts)

Refrigerant (gas) @ -46°C (1pt) $\xrightarrow[(0.5pts)]{\Delta H_{con}}$ Refrigerant (liquid) @ -46°C (1pt)

$\uparrow$ $\Delta H_{cool,\ell}$ (0.5pts)

Refrigerant (liquid) @ -75°C (1pt)

d. Calculate the total change in enthalpy ($\dot{H}_T$).

$\Delta \dot{H}_T = \Delta \dot{H}_{cool,g} + \Delta \dot{H}_{con} + \Delta \dot{H}_{cool,\ell}$ (3pts)

$\Delta \hat{H}_{cool,g}$: $C_p \Delta T$ (1pt) $= 1.03 \frac{kJ}{kg °C}(-46°C - 12°C)$ (0.5pts) $= -59.74 \frac{kJ}{kg}$ ($\cancel{0.5pts}$)

$\Delta \hat{H}_{con} = -\Delta H_{vap}$ @ 46°C $= -201.8 \frac{kJ}{kg}$ (1.5pts)

$\Delta \hat{H}_{cool,\ell} = C_p \Delta T$ (1pt) $= 1.64 \frac{kJ}{kg °C}(-75°C - -46°C)$ (0.5pts) $= -47.56 \frac{kJ}{kg}$ ($\cancel{0.5pts}$)

$\Delta \dot{H}_T = \dot{m}(\Delta H_{cool,g} + \Delta H_{con} + \Delta H_{cool,\ell})$

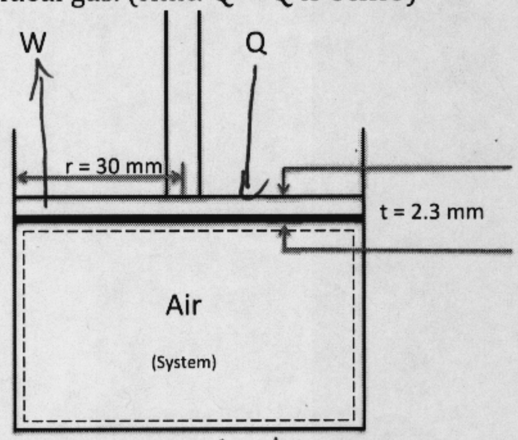
$= \left(\frac{1.3\ kmol}{hr}\right)\left(97.60 \frac{kg}{kmol}\right)\left(-59.74 + -201.8 \frac{kJ}{kg} + -47.56 \frac{kJ}{kg}\right) = \boxed{-39218.6 \frac{kJ}{hr}}$ (0.5pts)

Extra Credit (3.5 Points): If 28 kW of heat is being removed from the system, calculate the work being done by the condenser. The simplified accounting and energy conservation equations must be present to receive full credit.

25pts

Problem 3: A frictionless piston-cylinder assembly contains 5 kg of air at 22 °C and 500 ~~bar~~ KPa. Due to a temperature difference with the outside and inside air the assembly expands from 1.4 L to 27.8 L at a constant pressure. Knowing the change in internal energy of the assembly is 6.4 kJ and the transfer of heat takes 15 seconds, determine the temperature of the surrounding air. Assume the walls of the piston are a perfect insulator and heat transfer only occurs at the steel head of the piston. There are no changes in kinetic or potential energy. Steam cannot be treated as an ideal gas. (Hint: $Q = \dot{Q} \times \text{Time}$)

$C_{p,air}$: 1050 J/(kg °C)
$C_{p,steel}$: 486 J/(kg °C)
K_{air}: 0.0271 W/(m °C)
K_{steel}: 51.9 W/(m °C)



a. Is the system open, closed or isolated? (Circle one) (2pts)
b. Is heat entering or leaving the system? (Draw the direction in the figure above) (2pts)
c. Is work entering or leaving the system? (Draw the direction in the figure above) (2pts)
d. Write and simplify the accounting equation for the system. Then write the appropriate energy conservation equation for the system and simplify.

Accounting: IN - OUT + $\cancel{GEN}$ - $\cancel{CON}$ = ACC ⇒ IN - OUT = ACC (2.5pts)

Energy Eq: $\cancel{E_{in} - E_{out}} + Q + W = \Delta E_T^{sys} = \cancel{\Delta E_P^{sys}} + \cancel{\Delta E_K^{sys}} + \Delta U^{sys}$

$\boxed{Q + W = \Delta U^{sys}}$ (7pts)

e. Calculate the work due to steam expanding in the assembly. (101.325 J = 1 L·atm)

$W = -\int_{V_1}^{V_2} P\,dV = -\int_{1.4L}^{27.8L} 500\text{bar}\,dV$ (3pts)

$= -500\,\text{KPa}(27.8L - 1.4L)\left(\frac{1\,atm}{101.325\,kPa}\right)\left(\frac{101.325\,J}{1L \cdot atm}\right) = -13200\,J$ (1pts)

f. Calculate the temperature of the surroundings.

$Q = \Delta U^{sys} - W$ (2pts) ⇒ $\frac{KA(T_{surr} - T_{sys}) \cdot time}{t} = \Delta U^{sys} - W$ (3pts)

$$\frac{51.9 \frac{J}{s \cdot m \cdot °C}\left[(\pi)(0.03m)^2\right](T_{surr} - 22°C)(15s)}{0.0023m} = 6400J - -13200J$$

⇒ $\boxed{T_{sur} = 42.48\,°C}$ (0.5pts)

40pts

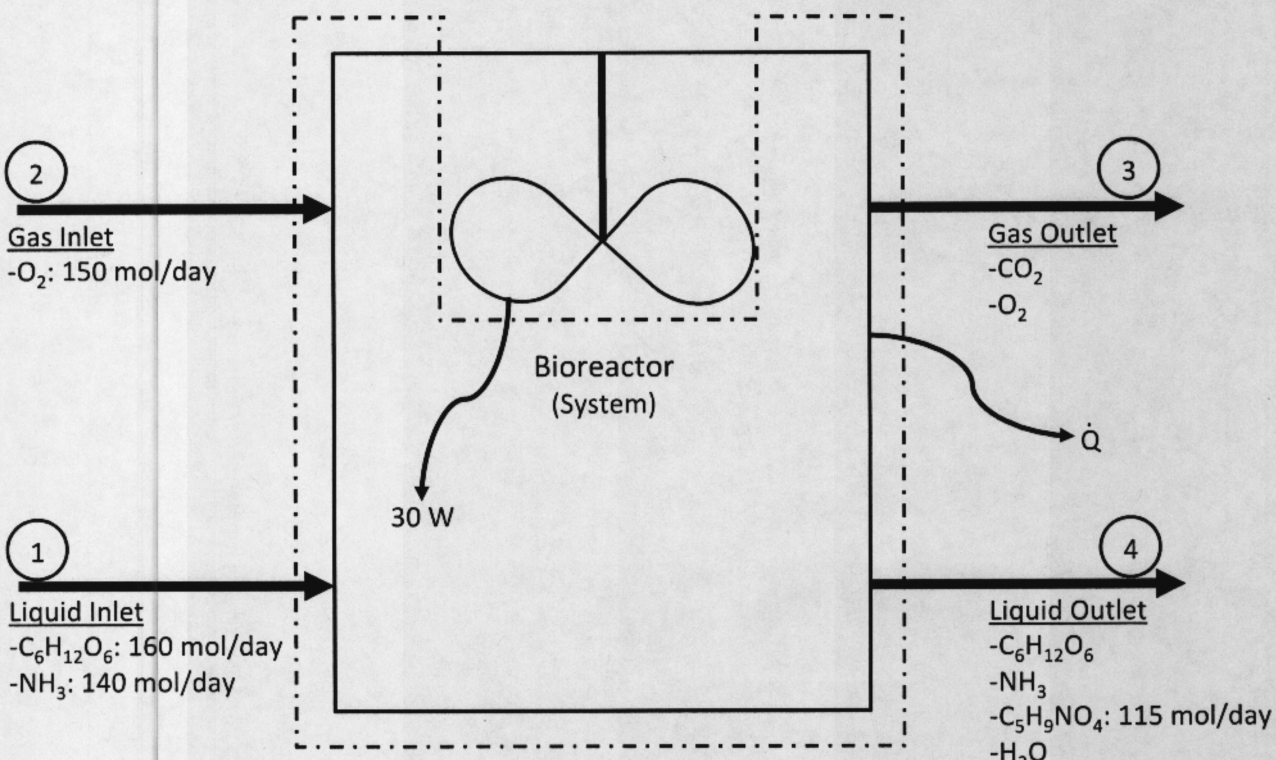
Problem 4: Glucose is converted into glutamic acid in the following reaction

$$C_6H_{12}O_6\,(l) + 1.11\ NH_3\,(l) + 1.01\ O_2\,(g) \rightarrow 1.11\ C_5H_9NO_4\,(l) + 0.45\ CO_2\,(g) + 2.67\ H_2O\,(l)$$

Mammalian cells use this reaction to convert glucose to glutamic acid. If such cells were placed in a bioreactor and the biochemical conditions were optimized, glutamic acid could be readily produced.

Assume a simple bioreactor containing mammalian cells ($CH_{1.79}N_{0.2}O_{0.5}$) produces 115 moles of glutamic acid ($C_5H_9NO_4$) per day. Glucose ($C_6H_{12}O_6$) and ammonia (NH_3) enter the bioreactor through a liquid inlet stream at a flow rate of 160 mol/day and 140 mol/day, respectively. Oxygen also, enters the system through a secondary inlet stream at 150 mol/day. In addition, heat is being removed to keep the system at a constant temperature and a stirrer inside the bioreactor is providing 30 watts of work. Knowing these conditions answer the following questions.

All products and excess reactants leave through either a liquid outlet or off-gas stream. The system is at steady state, and the reaction does NOT go to completion. Additionally, the system and all inputs and outputs are at standard conditions.



a. Is the system open, closed or isolated? (Circle one) (1pt)

b. Write and simplify the accounting equation for the system.

IN − OUT + GEN − CON = Acc (2.5pts)

0

20.5 pts

c. Mass Conservation

i. Write the overall mass conservation equation for this system.

$\dot{n}_{in,S} - \dot{n}_{out,S} + \sigma_S R = 0$ (5pts)

ii. What is the stoichiometric coefficient of mammalian cells ($CH_{1.79}N_{0.2}O_{0.5}$)? Why? (1.5pts)

(2pts) 0, (0.5pts) b/c mammalian cells are the catalyst for the rxn but do not take part in the actual chemical rxn.

iii. Determine the limiting reactant and reaction rate of the bioreactor.

LR $\left\{ \frac{\dot{n}_{in,S}}{-\sigma_S} \right\}$ (2pts)

$C_6H_{12}O_6$: $\frac{160 \frac{mol}{day}}{-(-1)} = 160 \frac{mol}{day}$ (0.5pts)

NH_3: $\frac{140 \frac{mol}{day}}{-(1.11)} = \boxed{126.12 \frac{mol}{day}} \Leftarrow LR$ (1pt)

O_2: $\frac{150 \frac{mol}{day}}{-(1.01)} = 148.5 \frac{mol}{day}$ (0.5pts)

$C_5H_9O_4$: (1pts)

$\dot{n}_{in} - \dot{n}_{out} + \sigma R = 0$, $\dot{n}_{in} = 0$

$R = \frac{\dot{n}_{out}}{\sigma} = \frac{115 \frac{mol}{day}}{1.11}$

(1pts) $\rightarrow \boxed{R = 103.60 \frac{mol}{day}}$

iv. Determine the outgoing molar flow rates of the products in the bioreactor.

For Products: $\dot{n}_{in,S} - \dot{n}_{out,S} + \sigma_S R = 0 \Rightarrow \dot{n}_{out} = \sigma_S R$ (2pts), $\dot{n}_{in,S} = 0$

CO_2: $\dot{n}_{out} = 0.45 (103.60 \frac{mol}{day}) = \boxed{46.62 \frac{mol}{day}}$ (0.5pts)

H_2O: $\dot{n}_{out} = 2.67 (103.60 \frac{mol}{day}) = \boxed{276.61 \frac{mol}{day}}$ (0.5pts)

$C_5H_9NO_4$: $\dot{n}_{out} = \boxed{115 \frac{mol}{day}}$ Given (0.5pts)

v. Determine the fractional conversion of the glucose ($C_6H_{12}O_6$).

$C_6H_{12}O_6$: $\dot{n}_{in} - \dot{n}_{out} + \sigma R = 0$

$\dot{n}_{out} = \dot{n}_{in} + \sigma R$ (1pt)

$= 160 \frac{mol}{day} + (-1)(103.60 \frac{mol}{day})$

$= 56.4 \frac{mol}{day}$ (0.5pts)

$f_S = \frac{\dot{n}_{in} - \dot{n}_{out}}{\dot{n}_{in}} = \frac{160 \frac{mol}{day} - 56.4 \frac{mol}{day}}{160 \frac{mol}{day}} = \boxed{f_S = 0.65}$

(2pts) (0.5pts)

16 pts

d. Energy Conservation

i. Write the appropriate energy conservation equation for the system and simplify.

$$\sum_{in} \dot{m}(\hat{E}_p + \hat{E}_k + \hat{H}) - \sum_{out} \dot{m}(\hat{E}_p + \hat{E}_k + \hat{H}) + \sum \dot{Q} + \sum \dot{W}_{nonflow} = \frac{dE_T^{sys}}{dt}$$

$$\boxed{-\Delta \dot{H} + \dot{Q} + \dot{W} = 0}$$ (6pts)

ii. Why does heat and work have a positive sign in the first law of thermodynamics?

(1pts) In the general system work + Heat are always assumed to be positive when entering a system.

iii What are standard conditions? 25°C + 1atm (1pt)

iv. Using the table provided below, calculate the standard heat of reaction ($\widehat{\Delta H}_r^\circ$) for the system.

	$\widehat{\Delta H}_f^\circ$(kJ/mol)	$\widehat{\Delta H}_c^\circ$(kJ/mol)	MW (g/mol)
$C_6H_{12}O_6$:	-1274	-2808	180
NH_3:	-80.29	-382.6	17
O_2:	0	0	32
C_5H_9NO:	-1003.3	-2241.1	147
CO_2:	-393.51	0	44
H_2O:	-285.83	0	18

Combustion: $\Delta \hat{H}_r^\circ = \sum_r (|\sigma_r| \hat{H}_{c,r}^\circ) - \sum_p (|\sigma_p| \hat{H}_{c,p}^\circ)$ (2.5pts)

$= [(1)(-2808) + (1.11)(-382.6) - (1.11)(-2241.1)]$ kJ/mol

$$\boxed{\Delta \hat{H}_r^\circ = -745.07 \frac{kJ}{mol}}$$ (1pt)

v. Is this reaction endothermic or exothermic? (Circle one) (1pt)

vi. Find the amount of heat (kJ/day) being removed to keep the bioreactor at a constant temperature.

(1pt) $\dot{Q} = \Delta \dot{H} - \dot{W}$ $\Delta \dot{H} = \Delta \dot{H}_{rxn} = \Delta \hat{H}_r^\circ = \frac{f \dot{n}_{in} \hat{H}_r^\circ}{\sigma}$ (2pts)

$= \frac{f \dot{n}_{in} \hat{H}_r^\circ}{|\sigma|} - W$

$= \frac{(0.65)(160 \frac{mol}{day})(-745.07 \frac{kJ}{mol})}{|-1|} - 30 \frac{J}{s} \left(\frac{1 kJ}{1000 J}\right)\left(\frac{3600 s}{1 hr}\right)\left(\frac{24 hr}{1 day}\right)$

$$\boxed{\dot{Q} = -80079.3 \frac{kJ}{day}}$$ (0.5pts)

(This page was left intentionally blank.)

EC 2:

Accounting: $IN - OUT + \underbrace{\cancel{GEN}}_{0} - \underbrace{\cancel{CON}}_{0} = \cancel{ACC} \Rightarrow IN = OUT$ (1.5 pts)

Energy: $-\Delta H + Q + W = 0$ (1.5pts)

$$W = \Delta H - Q$$

$$= -39218.6 \frac{kJ}{hr} - -28 \frac{kJ}{s} \cdot \frac{3600 s}{1 hr}$$

$$\boxed{W = 61581.4 \frac{kJ}{hr}}$$ (10.5pts)

(This page was left intentionally blank.)

(This page was left intentionally blank.)

Appendix

Factors for Unit Conversion

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

Example: The factor to convert grams to lb_m is $\left(\dfrac{2.20462\ \text{lb}_m}{1000\ \text{g}}\right)$.

Transition Elements — The Nonmetals

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	Noble Gases
1 H 1.00794																	2 He 4.00260
3 Li 6.941	4 Be 9.01218											5 B 10.81	6 C 12.011	7 N 14.0067	8 O 15.9994	9 F 18.9984	10 Ne 20.1797
11 Na 22.98977	12 Mg 24.305											13 Al 26.98154	14 Si 28.0855	15 P 30.9738	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.9559	22 Ti 47.88	23 V 50.9415	24 Cr 51.996	25 Mn 54.9380	26 Fe 55.847	27 Co 58.9332	28 Ni 58.69	29 Cu 63.546	30 Zn 65.39	31 Ga 69.72	32 Ge 72.59	33 As 74.9216	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.9059	40 Zr 91.224	41 Nb 92.9064	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.9055	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.41	49 In 114.82	50 Sn 118.710	51 Sb 121.75	52 Te 127.60	53 I 126.9045	54 Xe 131.29
55 Cs 132.9054	56 Ba 137.33	57* La 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.85	75 Re 186.207	76 Os 190.2	77 Ir 192.22	78 Pt 195.08	79 Au 196.9665	80 Hg 200.59	81 Tl 204.383	82 Pb 207.2	83 Bi 208.9804	84 Po (209)	85 At (210)	86 Rn (~222)
87 Fr (223)	88 Ra 226.0254	89† Ac 227.0278	104 Unq (261)	105 Unp (262)	106 Unh (263)												

Properties of Refrigerant 404A (SI Units): Temperature Table

TEMP.	PRESSURE kPa		VOLUME m³/kg		DENSITY kg/m³		ENTHALPY kJ/kg			ENTROPY kJ/(kg)(K)		TEMP.
°C	LIQUID p_f	VAPOR p_g	LIQUID v_f	VAPOR v_g	LIQUID $1/v_f$	VAPOR $1/v_g$	LIQUID h_f	$\hat{H}_v$	VAPOR h_g	LIQUID s_f	VAPOR s_g	°C
–75	20.5	19.3	0.0007	0.8645	1385.0	1.157	103.5	217.5	321.0	0.5911	1.6922	–75
–74	21.9	20.7	0.0007	0.8128	1382.4	1.230	104.6	217.0	321.6	0.5969	1.6898	–74
–73	23.3	22.1	0.0007	0.7648	1379.8	1.308	105.8	216.5	322.3	0.6027	1.6876	–73
–72	24.8	23.5	0.0007	0.7201	1377.2	1.389	106.9	216.0	322.9	0.6084	1.6854	–72
–71	26.5	25.1	0.0007	0.6785	1374.5	1.474	108.1	215.5	323.6	0.6142	1.6832	–71
–70	28.2	26.7	0.0007	0.6398	1371.9	1.563	109.3	215.0	324.2	0.6199	1.6811	–70
–69	29.9	28.4	0.0007	0.6036	1369.1	1.657	110.4	214.5	324.9	0.6256	1.6790	–69
–68	31.8	30.2	0.0007	0.5700	1366.4	1.755	111.6	214.0	325.5	0.6313	1.6770	–68
–67	33.8	32.1	0.0007	0.5385	1363.6	1.857	112.8	213.4	326.2	0.6370	1.6751	–67
–66	35.8	34.1	0.0007	0.5091	1360.9	1.964	113.9	212.9	326.8	0.6427	1.6732	–66
–65	38.0	36.2	0.0007	0.4816	1358.1	2.076	115.1	212.4	327.5	0.6483	1.6713	–65
–64	40.3	38.4	0.0007	0.4559	1355.2	2.193	116.3	211.9	328.2	0.6540	1.6695	–64
–63	42.7	40.7	0.0007	0.4319	1352.4	2.316	117.5	211.3	328.8	0.6596	1.6678	–63
–62	45.2	43.1	0.0007	0.4093	1349.6	2.443	118.7	210.8	329.5	0.6652	1.6661	–62
–61	47.8	45.7	0.0007	0.3881	1346.7	2.577	119.8	210.3	330.1	0.6708	1.6644	–61
–60	50.5	48.3	0.0007	0.3683	1343.8	2.715	121.0	209.7	330.8	0.6764	1.6628	–60
–59	53.3	51.1	0.0007	0.3497	1340.9	2.860	122.2	209.2	331.4	0.6820	1.6612	–59
–58	56.3	54.0	0.0007	0.3321	1337.9	3.011	123.4	208.6	332.1	0.6876	1.6596	–58
–57	59.4	57.0	0.0007	0.3157	1335.0	3.168	124.6	208.1	332.7	0.6931	1.6581	–57
–56	62.7	60.2	0.0008	0.3002	1332.1	3.331	125.8	207.5	333.4	0.6987	1.6567	–56
–55	66.1	63.4	0.0008	0.2856	1329.1	3.501	127.1	207.0	334.0	0.7042	1.6552	–55
–54	69.6	66.9	0.0008	0.2719	1326.1	3.678	128.3	206.4	334.7	0.7098	1.6539	–54
–53	73.3	70.5	0.0008	0.2590	1323.1	3.861	129.5	205.9	335.3	0.7153	1.6525	–53
–52	77.1	74.2	0.0008	0.2468	1320.1	4.052	130.7	205.3	336.0	0.7208	1.6512	–52
–51	81.1	78.1	0.0008	0.2353	1317.1	4.250	131.9	204.7	336.7	0.7263	1.6499	–51
–50	85.2	82.1	0.0008	0.2244	1314.1	4.456	133.1	204.2	337.3	0.7318	1.6487	–50
–49	89.5	86.4	0.0008	0.2142	1311.0	4.670	134.4	203.6	338.0	0.7373	1.6475	–49
–48	94.0	90.7	0.0008	0.2045	1308.0	4.891	135.6	203.0	338.6	0.7427	1.6463	–48
–47	98.7	95.3	0.0008	0.1953	1304.9	5.121	136.8	202.4	339.3	0.7482	1.6451	–47
–46	103.5	100.0	0.0008	0.1866	1301.8	5.359	138.1	201.8	339.9	0.7537	1.6440	–46
–45	108.6	104.9	0.0008	0.1784	1298.8	5.605	139.3	201.2	340.6	0.7591	1.6430	–45
–44	113.8	110.1	0.0008	0.1706	1295.7	5.861	140.6	200.6	341.2	0.7645	1.6419	–44
–43	119.2	115.4	0.0008	0.1633	1292.6	6.125	141.8	200.0	341.9	0.7700	1.6409	–43
–42	124.8	120.9	0.0008	0.1563	1289.5	6.399	143.1	199.4	342.5	0.7754	1.6399	–42
–41	130.6	126.6	0.0008	0.1496	1286.4	6.682	144.3	198.8	343.2	0.7808	1.6389	–41