Detailed solution of Quiz 2 2020-2021 Regular

Regular stream 2020/21

QUIZ 2, 2020-2021 ME 365 THERMODYNAMICS II

PROPERTIES OF GASES AND GAS MIXTURES

GAS STATE EQUATIONS

1. According to Avogadro's law, volume of a g mol of all gases at the pressure of____ and temperature of____ is same.
a) 760 mm Hg, 100 degree Celsius
b) 760 mm Hg, 0 degree Celsius
c) 750 mm Hg, 100 degree Celsius
d) 750 mm Hg, 0 degree Celsius

Fact

2. Which of the following statements is true?
a) number of kg moles of a gas = mass / molecular weight ✓
b) molar volume = total volume of the gas / number of kg moles ✓
c) both of the mentioned ✓
d) none of the mentioned ✗

$n = m/\tilde{M}$ ✓ (i)

Facts

$\tilde{V} = \frac{V}{n}$ ✓ (ii)

3. For which of the following gases, does the product (pv) when plotted against p gives depends only on temperature?
a) nitrogen ✓
b) hydrogen ✓
c) air and oxygen ✓
d) all of the mentioned

All ideal gases

IDEAL GAS – 1

4. Which of the following statement is true?
a) characteristic gas constant is given by dividing the universal gas constant by the molecular weight ✓
b) Avogadro's number (A) = 6.023 * 10^{26} molecules/kgmol ✓
c) Boltzmann constant (K) = 1.38 * 10^{-23} J/molecule K ✓
d) all of the mentioned

Facts

(i) $R = \frac{\tilde{R}_u}{\tilde{M}}$ ✓

(ii) $A = 6.023 \times 10^{26}$ moles/Kg mol ✓

(iii) $K = 1.38 \times 10^{-23}$ J/mole K

5. For real gases,
a) specific heats vary appreciably with temperature ✓
b) specific heats vary little with pressure ✓
c) both of the mentioned ✓
d) none of the mentioned ✗

6. Which of the following statement is true? (c is the specific heat at constant volume)
a) the equation du=c*dT holds good for an ideal gas for any process
b) for gases other than ideal ones, the equation holds true for a constant volume process only
c) for an ideal gas c is constant and hence Δu=c*ΔT
d) all of the mentioned

7. Characteristic gas constant is given by (here cp=specific heat at constant pressure and cv is the specific heat at constant volume)
a) R=cv – cp
b) R=cp + cv
c) R=cp – cv
d) none of the mentioned

Fact

IDEAL GAS – 2

8. Which of the following statement is true?
a) value of γ for monoatomic gases is 5/3
b) value of γ for diatomic gases is 7/5
c) for polyatomic gases, the value of γ is approximately taken as 4/3
d) all of the mentioned

9. Which of the following equation can be used to compute the entropy change between any two states of an ideal gas?
a) $s_2-s_1 = c_v*\ln(T_2/T_1) + R*\ln(v_2/v_1)$ ✓
b) $s_2-s_1 = cp*\ln(T_2/T_1) – R*\ln(p_2/p_1)$ ✓
c) $s_2-s_1 = cp*\ln(v_2/v_1) + c_v*\ln(p_2/p_1)$ ✓
d) all of the mentioned ✓

10. Which of the following is true for a polytropic process?
a) $p(v^n)$ is used to describe the process ✓
b) it is not adiabatic ✓
c) it can be reversible ✓
d) all of the mentioned ✓
11. Which of the following is true?
a) for n>γ, there will be positive heat transfer and gain in entropy ✓
b) for n<γ, there will be negative heat transfer and decrease in entropy ✓
c) both of the mentioned
d) none of the mentioned

For polytropic process

$$s_2-s_1 = C_v\left(\frac{n-\gamma}{n-1}\right)\ln\left(\frac{T_2}{T_1}\right)$$

IDEAL GAS – 3

12. Which of the following values of n are correct?
a) for isobaric process, n=0
b) for isothermal process, n=1
c) for isentropic process, n=γ
d) all of the mentioned

$\tilde{M}_{N_2} = 28$ Kg/Kmol $R_{N_2} = \frac{\tilde{R}_u}{\tilde{M}_{N_2}} = \frac{8.3144}{28}$

$R_{N_2} = 0.2969$ KJ/kg K

13. A rigid tank of 1 m^3 contains nitrogen gas at 600 kPa and 400 K. If 0.5 kg of gas flows out then what is the final pressure given the final temperature is 375 K?

a) 501.9 kPa
b) ~~503.9 kPa~~
c) 506.8 kPa ✓
d) none of the mentioned

$m = \frac{PV}{RT} = \frac{600 \times 1}{0.2969 \times 400} = 5.052$ Kg

$\therefore m_2 = m - 0.5 = 5.052 - 0.5 = 4.552$ Kg

$P_2 = (m_2 R T)/V = 4.552 \times 0.2969 \times 375/1 = 506.8$ kPa

14. A hollow metal sphere having an inside diameter of 150-mm is weighed first when evacuated and then after being filled to 875 kPa with an unknown gas. If the difference in mass is 0.0025 kg, and the temperature is 25 °C, find the gas.

a) helium ✓
b) argon
c) hydrogen
d) nitrogen

$V = \frac{\pi}{6} \times d^3 = \frac{\pi}{6} \times 0.15^3 = 0.001767\ m^3.$

Note $PV = n\tilde{R}_u T$ but $m = n\tilde{M}$.

$\therefore \tilde{M} = \frac{m R_u T}{PV}$ $= \frac{m}{\tilde{M}} \tilde{R}_u T$

$\tilde{M} = \frac{0.0025 \times 8.3144 \times 298.15}{875 \times 0.001767}$

$\tilde{M} = 4.008$ kg/kmol which is Helium

15. A piston cylinder contains air at 600 kPa, 290 K and a volume of 0.01m^3. A constant pressure process gives 54 kJ of work out. Find the final temperature of the air.

Ideal gas $PV = mRT$

$P_1 = P_2$

a) 2700 K $P_1V_1 = mRT_1$
b) 2800 K $P_2V_2 = mRT_2$
c) 2900 K
d) 3000 K

$|W| = P\Delta V \Rightarrow \Delta V = |W|/P = \frac{54\ kNm}{600\ kN/m^2} = 0.09\ m^3.$

$V_2 = V_1 + \Delta V = 0.01 + 0.09$

$V_2 = 0.1\ m^3.$

$\frac{P_2V_2}{P_1V_1} = \frac{T_2}{T_1} \Rightarrow T_2 = \frac{P_2V_2T_1}{P_1V_1} = \frac{V_2}{V_1} \times T_1 = \frac{0.1}{0.01} \times 290$

$T_2 = 2900$ K

GAS COMPRESSION

16. For γ>n>1 and for the same pressure ratio p_2/p_1, the maximum work is needed for
a) isothermal compression ✗
b) adiabatic compression ✓
c) polytropic compression ✗
d) all need same work ✗

17. For minimum work the intermediate pressure is the _____ of the suction and discharge pressures.
a) arithmetic mean
b) geometric mean
c) sum
d) difference

18. Heat rejected in the intercooler is given by (here cp is the specific heat at constant pressure)
a) $cp*(T_3-T_2)$
b) $cp*(T_3+T_2)$
c) $cp*(T_2-T_3)$
d) none of the mentioned

19. The isothermal efficiency of a compressor is given by
a) p_1*v_1/ total work of compression
b) $p_1*v_1*\ln(p_2/p_1)$ / total work of compression
c) total work of compression / $p_1*v_1*\ln(p_2/p_1)$
d) total work of compression / p_1*v_1

20. The volumetric efficiency is given by
a) $1-C+C(p_2/p_1)^{1/n}$ ✗
b) $1+C-C(p_2/p_1)^{1/n}$ ✓
c) $1+C+C(p_2/p_1)^{1/n}$ ✗
d) $1-C-C(p_2/p_1)^{1/n}$ ✗

Fact

PSYCHOMETRICS

PROPERTIES OF ATMOSPHERIC AIR

21. Complete dry air exists in nature.
a) true
b) false

22. In a mixture of dry air and water vapour,
a) mole fraction of dry air = pa/p
b) mole fraction of water vapour = pw/p
c) both of the mentioned
d) none of the mentioned

23. When the partial pressure of water (p_w) is very small,
a) saturation temperature of water vapour at pw is less than atmospheric temperature
b) water vapour in air exists in superheated state
c) air is said to be in unsaturated state
d) all of the mentioned

24. If water is injected into a container which has unsaturated air,
a) water will evaporate
b) moisture content of air will decrease
c) p_w will decrease
d) all of the mentioned

25. The degree of saturation is the ratio of
a) (saturated specific humidity / actual specific humidity)^2
b) 1/(saturated specific humidity * actual specific humidity)
c) saturated specific humidity / actual specific humidity
d) actual specific humidity / saturated specific humidity

26. The wet bulb temperature is the ____ temperature recorded by moistened bulb.
a) lowest
b) highest
c) atmospheric
d) none of the mentioned

27. At any dry bulb temperature, the ____ the difference of the wet bulb temperature reading below the dry bulb temperature, the____ is the amount of water vapour held in mixture.
a) smaller, smaller ✗
b) greater, greater ✗
c) greater, smaller ✓
d) smaller, greater ✗

PSYCHROMETRIC CHART AND PROCESSES

28. Which of the following statements is true relating to the Psychrometric chart?
a) the chart is plotted for pressure equal to 760mm Hg
b) the constant wet bulb temperature line represents adiabatic saturation process
c) the constant wet bulb temperature line coincides with constant enthalpy line
d) all of the mentioned

29. When humidity ratio of air ____ the air is said to be dehumidified.
a) increases
b) decreases
c) remains constant
d) none of the mentioned

30. Cooling and dehumidification of air is done in summer air conditioning.
a) true
b) false

31. When air passes through silica gel,
a) it absorbs water vapour molecules
b) latent heat of condensation is released
c) dry bulb temperature of air increases
d) all of the mentioned

32. In adiabatic evaporative cooling, heat transfer between the chamber and its surroundings is ____
a) zero
b) high
c) low
d) none of the mentioned

COMBUSTION OF FUELS

33. The process of burning fuels in the presence of oxygen is called ________
a) Induction
b) Ignition
c) Condensation
d) Combustion

34. The substance which helps in combustion of fuels is called ________
a) Igniter
b) Flammables
c) Supporter
d) Inflammables

35. $C + O_2 \rightarrow$ ____
a) CO
b) CO_2
c) CO_3
d) $2CO$

FUELS AND COMBUSTION

36. Which are the main constituents of fuel from given options?
a) Carbon and Nitrogen
b) Oxygen and Hydrogen
c) Carbon and Hydrogen
d) Helium and Oxygen

37. On what basis is the coal classified?
a) Period of formation
b) Depending on capacity to burn
c) Region/area where is it formed
d) Physical and chemical composition

CALORIFIC VALUES OF FUEL – 1

38. The amount of heat liberated by complete combustion of unit quantity of fuel is known as ________
a) Agitation
b) Combustion
c) Calorific value
d) Thermogenesis

39. Which gas has the highest calorific value among given option?
a) Oxygen
b) Helium
c) Hydrogen
d) Nitrogen

40. Which calorimeter is used to find calorific values of solid and liquid fuels?
a) Boy's calorimeter
b) Bomb calorimeter
c) Junker's calorimeter
d) Calvet-type calorimeter

41. What value of a substance, usually a fuel or food is the amount of heat released during the combustion?
a) Energy value
b) Flash point value
c) Fire point value
d) Auto ignition

42. What is the factor on which, difference between the two heating values of fuel depends on?
a) Physical properties
b) Reactants
c) Chemical composition
d) Products

CALORIFIC VALUES OF FUEL – 2

43. Which is the common method to relate higher calorific value to lower calorific value?
a) $HCV = LCV + H_v (n_{H2O, out} / n_{fuel, in})$
b) $LCV = HCV + H_v (n_{H2O, out} / n_{fuel, in})$
c) $HCV = LCV + H_v (n_{fuel, in} / n_{H2O, out})$
d) $LCV = HCV + H_v (n_{fuel, in} / n_{H2O, out})$

44. Which value is determined by bringing all products of combustion back to original pre-combustion temperature?
a) Higher calorific value
b) Low calorific value
c) Flash point value
d) Fire point value

45. Which formula is used to determine higher calorific value of fuel?
a) Rayleigh's formula
b) Lamme's equation
c) Dulongs's formula
d) Cauchy's formula

Fact.

46. Which fuel has higher calorific value among given fuels?
a) Natural gas
b) Gasoline
c) Diesel
d) Fuel oil

ADDITIONAL QUESTIONS ON REFRIGERATION

47. In a vapour compression refrigeration system, a throttle valve is used in place of expander because
   a) It considerably reduces the system weight
   b) It improves the COP, as the condenser is small
   c) The positive work involved in the isentropic expansion of liquid is very small
   d) It leads to significant cost reduction

48. Consider the following statements:
Moisture should be removed from refrigerants in order to avoid:
1. Compressor seal failure
2. Freezing at the expansion valve
3. Restriction to refrigerant
4. Corrosion steel parts
On these statements
a) 1, 2, 3 and 4 are correct
b) 1 and 2 are correct
c) 2, 3 and 4 are correct
d) 1, 3 and 4 are correct

49. The refrigerant used for absorption refrigerators working on the heat from solar collectors is a mixture of water and
a) Carbon dioxide
b) Sulphur dioxide
c) Lithium bromide
d) Freon-12.

50. The desirable combination of properties for a refrigerant includes:
(a) High specific heat and high specific volume of refrigerant vapour
(b) High heat transfer coefficient and low latent heat
(c) High thermal conductivity and low freezing point
(d) High latent heat of vaporisation and low specific volume of refrigerant vapour

51. Match items in List I (A –D) with those in List II (1-4) and List III (6-10) and then select the correct answer using the codes given below the Lists:

List I	List II	List III
A. Reversed Carnot engine	1. Condenser	6. Generator
B. Sub-cooling	2. Evaporator	7. Increase in refrigerating effect
C. Super heating	3. Vortex refrigerator	8. Highest COP
D. Constant enthalpy	4. Throttling	9. Adiabatic
	5. Heat pump	10. Dry compression

Codes:

	A	B	C	D
A.	3, 10	1, 7	2, 9	4, 6
B.	5, 8	1, 7	2, 10	4, 9
C.	4, 10	3, 8	3, 10	1, 6
D.	2, 7	5, 8	4, 6	1, 9

52. When the discharge pressure is too high in a refrigerators system, high pressure control is installed to

a) Stop the cooling fan
b) Stop the water circulating pump
c) Regulate the flow cooling water
d) Stop the compressor

53. Consider the following statements:
In the case the vapour compression machine, if the condensing temperature of the refrigerant is closer to the critical temperature, then there will be

1. Excessive power consumption
2. High compression
3. Large volume flow

Of these statements

a) 1, 2 and 3 are correct
b) 1 and 2 are correct
c) 2 and 3 are correct
d) 1 and 3 are correct

54. A single stage vapour compression refrigeration system cannot be used to produce ultra low temperature because

a) refrigerants for ultra-low temperature are not available
b) Lubricants for ultra-low temperature are not available
c) Volumetric efficiency will decrease considerably
d) Heat leakage into the system will be excessive

55. Vapour absorption refrigeration system works using

a) ability of a substance to get easily condensed
b) Ability of a vapour to get compressed or expanded
c) Affinity of a substance of another substance
d) Absorptivity of a substance

56. Which one of the following statements regarding ammonia absorption refrigeration system is correct?
The solubility of ammonia in water is
a) a function of the temperature and pressure of solution
b) A function of the pressure of the solution irrespective of the temperature
c) A function of temperature of the solution alone
d) Independent of the temperature and pressure of the solution

57. The flash chamber in single-stage simple vapour compression cycle
a) Increases the refrigerating effect
b) Decreases the refrigerating effect
c) Increases the work of compression
d) has no effect on refrigerating effect

58. Consider the following statements:
In a vapour compression system, a thermometer placed in the liquid line can indicate whether the
1. Refrigerant flow is too low
2. Water circulation is adequate
3. Condenser is fouled
4. Pump is functioning properly
Of these statements:
a) 1, 2 and 3 are correct
b) 1, 2 and 4 are correct
c) 1, 3 and 4 are correct
d) 2, 3 and 4 are correct

59. Match **List I (A-D)** with **List II (1-4)** and then select the correct answer using the codes given below the Lists:

Lists I	List II
A. Bell Coleman refrigerator	1. Compressor
B. Simple vapour-compression refrigerator	2.Generator
C. Absorption refrigerator	3.Flash Chamber
D. Jet refrigerator	4.Expansion cylinder

Codes:

a) A B C D
1 4 3 2

b) A B C D
4 1 3 2

c) A B C D
1 4 2 3

d) A B C D
4 1 2 3

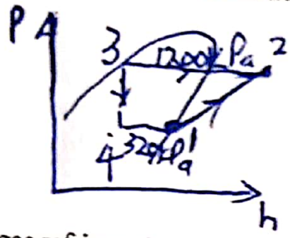
$W_{12} = h_2 - h_1 = 279.37 - 251.88 = 27.49\ kJ/kg$

CALCULATIONS ON HEAT PUMP, GAS REFRIGERATION, MXTURES, PSYCHROMETRY, AIR CONTIONING AND COMBUSTION OF FUELS

$q_H = h_2 - h_3$
$q_H = 279.37 - 117.77$
$q_H = 161.16$
$P_1 = 320\ kPa$
$s_1 = 0.9306$
$h_1 = 251.88\ kJ/kg$

60 Consider a heat pump that operates on the ideal vapour compression refrigeration cycle with R-134a as the working fluid between the pressure limits of 0.32 and 1.2 MPa. The coefficient of performance of this heat pump is approximately:

(*a*) 0.17
(*b*) 1.2
(c) 3.1
(*d*) 4.9
(*e*) 5.9



Interpolating
$P_2 = 1200\ kPa$, $s_1 = s_2 = 0.9306\ kJ/kgK$
$h_2 = 278.27 + \frac{(0.9306-0.9267)}{(0.9614-0.9267)}(289.64 - 278.27)$
$h_2 = 279.37\ kJ/kg$
$h_3 = h_{f@1200kPa} = 117.77\ kJ/kg = h_4$
$COP_{hp} = \frac{161.16}{27.49}$
$COP = 5.9$

Reverse Brayton Cycle

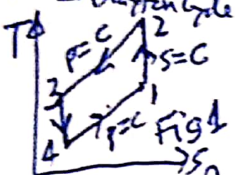


Fig 1

$T_{min} = T_4$ $P_1 = P_4$ $P_3 = P_2$
$\gamma_{air} = 1.4$

61 An ideal gas refrigeration cycle using air as the working fluid operates between the pressure limits of 80 and 280 kPa. Air is cooled to 35 °C before entering the turbine. The lowest temperature of this cycle is approximately:

$T_3 = 308K$

(*a*) -57.7 °C
(*b*) -26.1 °C
(*c*) 5.1 °C
(*d*) 11.2 °C
(e) 24.1 °C

$\frac{T_4}{T_3} = \left(\frac{P_4}{P_3}\right)^{\gamma-1/\gamma} \Rightarrow T_4 = T_3\left(\frac{80}{280}\right)^{0.4/1.4} = 308\left(\frac{80}{280}\right)^{0.4/1.4}$

$T_4 = 215.3K\ (-57.7°C)$

62 Consider an ideal gas refrigeration cycle using helium as the working fluid. Helium enters the compressor at 100 kPa and 17 °C and compressed to 400 kPa. Helium is then cooled to 20 °C before it enters the turbine. For a mass flow rate of 0.2 kg/s, the net power input required is approximately:

$C_{p_{He}} = 5.1926\ kJ/kgK$
$\gamma_{He} = 1.667$
$T_1 = 290K$
$T_3 = 293K$

$|\dot{W}_{net,in}| = 93.77\ kW$

(*a*) 28.3 kW
(*b*) 40.5 kW $\approx 93.8\ kW$ $|W_{net,in}| = \dot{m} C_p \left[(T_2 - T_1) - (T_3 - T_4)\right]$
(*c*) 64.7 kW
(*d*) 93.8 kW ✓ $T_2 = T_1\left(\frac{400}{100}\right)^{0.667/1.667} = 290\left(\frac{400}{100}\right)^{0.667/1.667} = 505K$
(*e*) 113 kW

$|\dot{W}_{net,in}| = 0.2 \times 5.1926\left[(505-290) - (293-168.3)\right]$

$T_4 = 293\left(\frac{100}{400}\right)^{0.667/1.667} = 168.3K$

63 An absorption air-conditioning system is to remove heat from the conditioned space at 20 °C at a rate of 150 kJ/s while operating in an environment at 35 °C. Heat is to be supplied from a geothermal source at 140 °C. The minimum rate of heat supply is approximately:

$T_E = 35°C\ (308K)$
$T_G = 140°C\ (413K)$
$T_L = 20°C\ (293K)$
$\dot{Q}_L = 150\ kJ/s$

(*a*) 86.2 kJ/s
(*b*) 21.2 kJ/s
(c) 30.2 kJ/s
(*d*) 61.2 kJ/s
(*e*) 150 kJ/s

$COP_{max,ABRS} = \left(1 - \frac{T_E}{T_G}\right)\left(\frac{T_L}{T_E - T_L}\right) = \left(1 - \frac{308}{413}\right)\left(\frac{293}{308-293}\right) = 4.966$

$\dot{Q}_{G,min} = \frac{\dot{Q}_L}{COP_{max}} = \frac{150\ kJ/s}{4.966} = 30.2\ kJ/s.$

$COP_{ARS} = \frac{\dot{Q}_L}{\dot{Q}_G}$

$\dot{Q}_{G,min} = \frac{\dot{Q}_L}{COP_{max}}$

64 An ideal-gas mixture consists of 3 kg of Ar and 6 kg of CO_2 gases. The mixture is now heated at constant volume from 250 K to 350 K. The amount of heat transfer is approximately:

(*a*) 374.1 kJ
(*b*) 435.6 kJ
(*c*) 487.9 kJ ✓
(*d*) 524.7 kJ
(*e*) 663.9 kJ

$m_{Ar} = 3Kg$; $Cv_{Ar} = 0.3122\ KJ/kgK$ (Lecture Material)

$m_{CO_2} = 6Kg$; $Cv_{CO_2} = 0.657\ KJ/kgK$ (Lecture Material)

$T_{in} = T_1 = 250K$ $T_{final} = T_2 = 350K$

$Q = (m_{Ar} Cv_{Ar} + m_{CO_2} Cv_{CO_2})(T_2 - T_1) = (3\times0.3122 + 6\times0.657)(350-250)$

$Q = 487.89 KJ \cong 487.9 kJ$

65 An ideal-gas mixture consists of 60 percent helium and 40 percent argon gases by mass. The mixture is now expanded isentropically in a turbine from 400 ^{0}C and 1.2 MPa to a pressure of 200 kPa. The mixture temperature at turbine exit is approximately:

✓ (*a*) 55.6 ^{0}C ✓
(*b*) 194.5 ^{0}C
(*c*) 129.9 ^{0}C
(*d*) 112.1 ^{0}C
(*e*) 400.1 ^{0}C

$\gamma_{He} = 1.667$; $\gamma_{Ar} = 1.667$; $\therefore \gamma_{mix} = 1.667$

$T_1 = 400^\circ C (673K)$; $T_2 = T_1\left(\frac{P_f}{P_i}\right)^{(\gamma-1)/\gamma} - 273$

$= 673\left(\frac{200}{1200}\right)^{0.667/1.667} - 273 = 55.59^\circ C \cong 55.6^\circ C$

$C_{v_{H_2}} = 10.183\ KJ/kgK$

Insulated tank $Q = 0$

$m = n\tilde{M}$

$\tilde{M}_{H_2} = 2Kg/Kmol$

$\tilde{M}_{CO_2} = 44Kg/Kmol$

$C_{v_{CO_2}} = 0.657\ KJ/kgK$

66 One compartment of an insulated rigid tank contains 2 kmol of CO_2 at 20 ^{0}C and 150 kPa while the other compartment contains 5 kmol of H_2 gas at 35 ^{0}C and 300 kPa. Now the partition between the two gases is removed, and the two gases form a homogeneous ideal-gas mixture. The temperature of the mixture is approximately:

(*a*) 25.6 ^{0}C
(*b*) 29.6 ^{0}C ✓
(*c*) 22.6 ^{0}C
(*d*) 32.6 ^{0}C
(*e*) 34.6 ^{0}C

$m_{H_2} = 5\times2 = 10Kg$; $m_{CO_2} = 2\times44 = 88Kg$

$T_{i_{H_2}} = 35^\circ C (308K)$

$T_{i_{CO_2}} = 20^\circ C (293K)$

$Q = m_{H_2} C_{v_{H_2}}(T_2 - T_{i_{H_2}}) + m_{CO_2} C_{v_{CO_2}}(T_2 - T_{i_{CO_2}})$

$\Rightarrow 0 = 10\times10.183(T_2-35) + 88\times0.657(T_2-20)$ Solving $T_2 = 29.56^\circ C \cong 29.6^\circ C$

67 A piston–cylinder device contains an ideal-gas mixture of 3 kmol of He gas and 7 kmol of Ar gas at 50 ^{0}C and 400 kPa. Now the gas expands at constant pressure until its volume doubles. The amount of heat transfer to the gas mixture is approximately:

$T_i = 50^\circ C (323K)$

$T_f = 646K$

why: gas expand at constant pressure and volume doubles

$\tilde{M}_{He} = 4Kg/Kmol$

1 = Argon

2 = Helium

$m_2 = 3\times4 = 12Kg$

$m_1 = 7\times35.95$

$m_1 = 279.65Kg$

$\tilde{m}_{Ar} = 35.95Kg/Kmol$

(*a*) 6.2 MJ
(*b*) 4.2 MJ
(*c*) 27 MJ
(*d*) 10.1 MJ
(*e*) 67.1 MJ ✓

$Q = m_1 C_{p_1}(T_f - T_i) + m_2 C_{p_2}(T_f - T_i)$

$= 279.65\times0.5203(646-323) + 12\times5.1926(646-323)$

$Q = 67.123 MJ \cong 67.1 MJ$

$C_{p_{Ar}} = 0.5203\ KJ/kgK$

$C_{p_{He}} = 5.1926\ KJ/kgK$

From Table in lecture Material on page 83

For the turbine

$$T_f = T_{in}\left(\frac{P_f}{P_{in}}\right)^{(\gamma-1)/\gamma} = 1500\left(\frac{100}{1000}\right)^{0.667/1.667} \approx 597\,K$$

68 An ideal-gas mixture of helium and argon gases with identical mass fractions enters a turbine at 1500 K and 1 MPa at a rate of 0.12 kg/s, and expands isentropically to 100 kPa. The power output of the turbine is approximately: $\gamma_{mix} = 1.667$

1 = Argon
2 = Helium.
$C_{p_1} = 0.5203\ kJ/kg\,K$
$C_{p_2} = 5.1926\ kJ/kg\,K$

(a) 252.8 kW
(b) 309.6 kW ✓
(c) 340.8 kW
(d) 462.9 kW
(e) 550 kW

$C_{p_{mix}} = m_{f_1} C_{p_1} + m_{f_2} C_{p_2} = 0.5 \times 0.5203 + 0.5 \times 5.1926$

$C_{p_{mix}} = 2.8475\ kJ/kg\,K$

~~$C_{p_{mix}} = 0.5$~~

m_{f_i} = mass fraction of i

$|\dot{W}_t| = 309.55\,kW \approx 309.6\,kW$

$|\dot{W}_{t}| = \dot{m}\, C_{p_{mix}} (T_i - T_f) = 0.12 \times 2.8475(1500 - 597)$

69 A room is filled with saturated moist air at 25 °C and a total pressure of 100 kPa. If the mass of dry air in the room is 100 kg, the mass of water vapour is approximately:

(a) 0.52 kg
(b) 1.97 kg
(c) 2.96 kg
(d) 2.04 kg ✓
(e) 3.17 kg

$P_{total} = 100\,kPa$ $\quad T_1 = 25°C$, $P_{g_1} = 3.1698\,kPa$ Table A4, and since RH = 100% $P_{v_1} = P_{g_1}$

$m_{air} = 100\,kg$

$$\omega_1 = \frac{0.622\, P_{v_1}}{P_T - P_{v_1}} = \frac{0.622 \times 3.1698}{(100 - 3.1698)} = 0.0204\ \frac{kg\,H_2O}{kg\ dry\ air}$$

$m_v = \omega\, m_{air} = 0.0204 \times 1000 = 2.04\,kg$

70 A room contains 65 kg of dry air and 0.6 kg of water vapour at 25 °C and 90 kPa total pressure. The relative humidity of air in the room is approximately:

$m_v = 0.6\,kg$
$m_{air} = 65\,kg$
$P_T = 90\,kPa$

(a) 3.5 %
(b) 41.5 % ✓
(c) 55.2 %
(d) 60.9 %
(e) 73.0 %

$T_1 = 25°C$, $P_g = 3.1695$ But $\phi = RH = \frac{P_v}{P_g} = \frac{1.136}{3.1698} = 41.5\%$

Note $\omega = \frac{m_v}{m_{air}} = \frac{0.6}{65} = 0.00923$

and $\omega = \frac{0.622\, P_v}{P_T - P_v} \Rightarrow \omega = \frac{0.622\, P_v}{90 - P_v} \Rightarrow P_v = \frac{\omega P_T}{(0.622 + \omega)} = \frac{0.00923 \times 90}{(0.622 + 0.00923)}$

$P_v = 1.136\,kPa$

71 A 40-m³ room contains air at 30 °C and a total pressure of 90 kPa with a relative humidity of 75 percent. The mass of dry air in the room is approximately:

$V = 40\,m^3$
$P_T = 90\,kPa$
$R_{air} = 0.287\ kJ/kg\,K$

(a) 24.7 kg
(b) 29.9 kg
(c) 39.9 kg ✓
(d) 41.4 kg
(e) 52.3 kg

$T_1 = 30°C\ (303K)$ $\quad P_g = 4.2469\,kPa$ Table A4

$RH = 0.75 \Rightarrow P_{v_1} = 0.75 \times 4.2469 = 3.1852\,kPa$

$$\omega = \frac{0.622 \times P_{v_1}}{P_T - P_{v_1}} = \frac{0.622 \times 3.1852}{(90 - 3.1852)} = 0.0228\ \frac{kg\,H_2O}{kg\ dry\ air}$$

For air $P_a V = m R T_1$

$P_a = P_T - P_v = 90 - 3.1852 = 86.8148\,kPa$

$$m = \frac{P_a V}{R T_1} = \frac{86.8148 \times 40}{0.287 \times 303}$$

$m = 39.93\,kg \approx 39.9\,kg$

P_a = partial pressure of dry air

72 A room contains air at 30 °C and a total pressure of 96.0 kPa with a relative humidity of 75 percent. The partial pressure of dry air is approximately:

$P = 96\,kPa$
$RH = \phi = 0.75$
$P_a = ?$

(a) 82.0 kPa
(b) 85.8 kPa
(c) 92.8 kPa ✓
(d) 90.6 kPa
(e) 72.0 kPa

Note: $\omega = \frac{0.622 P_v}{P_a}$ $T_1 = 30°C$, $P_{g_1} = 4.2469\,kPa$. Table A4

$P_{v_1} = \phi_1 \times P_{g_1} = 0.75 \times 4.2469 = 3.1852\,kPa$

$P_{a_1} = P_1 - P_{v_1} = 96 - 3.1852 = 92.8148\,kPa \simeq 92.8\,kPa$

73 The air in a house is at 25 °C and 65 percent relative humidity. Now the air is cooled at constant pressure. The temperature at which the moisture in the air will start condensing is approximately:

(a) 7.4 °C
(b) 16.3 °C
(c) 18.0 °C ✓
(d) 11.3 °C
(e) 20.2 °C

$T_1 = 25°C \Rightarrow P_{g_1} = 3.1698\,kPa$ Table A4 $P_{sat@25°C} = P_{g_1}$

$\phi_1 = 0.65 \Rightarrow P_{v_1} = \phi_1 P_{g_1} = 0.65 \times 3.1698 = 2.0604\,kPa.$

$T_{dp} = T_{sat@2.0604\,kPa} = 15 + \frac{(2.0604 - 1.7057)}{(2.3392 - 1.7057)}(5) = 17.99°C \simeq 18°C$

Interpolating b/n 15°C and 20°C using values in Table A4

Note: T_{dp} is the temp at which water starts condensing

74 Propane (C_3H_8) is burned with 150 percent theoretical air. The air–fuel mass ratio for this combustion process is approximately: $\lambda = 1.5$

(a) 5.3
(b) 10.5
(c) 15.7
(d) 23.4 ✓
(e) 39.3

The stoichiometric combustion Equation is:

$C_3H_8 + 5[O_2 + 3.762N_2] \rightarrow 3CO_2 + 4H_2O + 18.81N_2$

Actual Combustion Eqn is: $C_3H_8 + 7.5(O_2 + 3.762N_2) \rightarrow 3CO_2 + 4H_2O + 2.5O_2 + 28.2N_2$

$A/F = \frac{M_{air}}{M_{fuel}} = \frac{1029.6}{44}$ $A/F = 23.4$

$M_{air} = 7.5 \times 32 + 28.2 \times 28 = 1029.6\,kg$

$M_f = 3 \times 12 + 1 \times 8 = 44\,kg$

75 One kmol of methane (CH_4) is burned with an unknown amount of air during a combustion process. If the combustion is complete and there are 1 kmol of free O_2 in the products, the air–fuel mass ratio is approximately:

(a) 34.65
(b) 25.75 ✓
(c) 17.25
(d) 14.35
(e) 11.95

Stoichiometric Combustion is: $CH_4 + 2[O_2 + 3.762N_2] \rightarrow CO_2 + 2H_2O + 7.524N_2$

Actual Combustion Eqn: $CH_4 + 3[O_2 + 3.762N_2] \rightarrow CO_2 + 2H_2O + O_2 + 11.286N_2$

Stoichiometric 2 O_2 molecules. Actual there is extra 1 kmol of O_2 So O_2 kmols become 3

$M_{fuel} = 1 \times 12 + 1 \times 4 = 16\,kg$

$M_{air} = 3 \times 32 + 11.286 \times 28 = 412.008\,kg.$

$A/F = \frac{M_{air}}{M_{fuel}} = \frac{412.008}{16} = 25.75$

$$\tilde{R}_{CO_2} = \frac{\tilde{R}_u}{\tilde{M}_{CO_2}} = \frac{8.3144}{44} = 0.1889 \text{ kJ/kgK}$$

$C_{p_{CO_2}} = 0.846$ kJ/kgK PE483 Lecture material

76 An equimolar mixture of carbon dioxide and water vapour at 1 atm and 60 ^{0}C enter a dehumidifying section where the entire water vapour is condensed and removed from the mixture, and the carbon dioxide leaves at 1 atm and 60 ^{0}C. The entropy change of carbon dioxide in the dehumidifying section is approximately:

y_i = mole fraction of a constituent

$P_{1CO_2} = 0.5$ atm

$P_{2CO_2} = 1$ atm.

(*a*) -2.8 kJ/kg·K
(*b*) -0.131 kJ/kg·K ✓
(*c*) 0
(*d*) 0.131 kJ/kg·K
(*e*) 2.8 kJ/kg·K

$y_{i_{CO_2}} = 0.5$ $y_{i_{H_2O}} = 0.5$ equimolar mixture.

$T_1 = 60°C (333K)$

$T_2 = T_1$

$\Delta S_{CO_2} = C_{p_{CO_2}} \ln\left(\frac{T_2}{T_1}\right) - R_{CO_2} \ln\left(\frac{P_{2CO_2}}{P_{1CO_2}}\right)$

$\Delta S_{CO_2} = -0.1889 \ln\left(\frac{1}{0.5}\right) = -0.131$ kJ/kgK

77 Methane (CH_4) (HH V=55.56 MJ/kg, LHV=50.05 MJ/kg) is burned completely with 80 percent excess air during a steady-flow combustion process. If both the reactants and the products are maintained at 25 ^{0}C and 1 atm and the water in the products exists in the liquid form, the heat transfer from the combustion chamber per unit mass of methane, correct to the nearest integer, is:

$T_{reactants} = 25°C = T_{ref}$.

(*a*) 62.5 MJ/kg
(*b*) 132 MJ/kg
(*c*) 70 MJ/kg
(*d*) 56 MJ/kg
(*e*) 50 MJ/kg

$|Q_{out}| = HHV_{of\ CH_4}$. $\simeq 56$ MJ/kg.

$T_{products} = 25°C = T_{ref}$.

78 The higher heating value of a hydrocarbon fuel C_nH_m with $m= 8$ is given to be 1560 MJ/kmol of fuel. Then its lower heating value is approximately:

(*a*) 1384 MJ/kmol
(*b*) 1208 MJ/kmol
(*c*) 1402 MJ/kmol
(*d*) 1514 MJ/kmol
(*e*) 1551 MJ/kmol

$m/2 = 4$

mass of H_2O formed per kmol fuel $= 4$ kmol $\times 18$ kg/kmol

Notes: $h_{fg \text{ of water } @ 25^0C} = 2.443$ MJ/kg

$\widetilde{LHV} = HHV - \frac{m_{H_2O}}{n_{fuel}} \times h_{fg}$

$= 1560 \frac{MJ}{kmol\ fuel} - \frac{72 kg}{kmol\ fuel} \times 2.443 MJ/kg$

$= 1560 \frac{MJ}{kmol\ fuel} - 176 \frac{MJ}{kmol\ fuel}$

$= 1384 \frac{MJ}{kmol\ fuel}$.

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