Name:

Enrolment No:

UPES

UNIVERSITY OF PETROLEUM AND ENERGY STUDIES

End Semester Examination, June 2021

Programme Name: M.TECH CFD **Semester :IInd**
Course Name : Combustion and Reaction Fronts **Time : 03 hrs**
Course Code : ASEG 7027 **Max. Marks : 100**

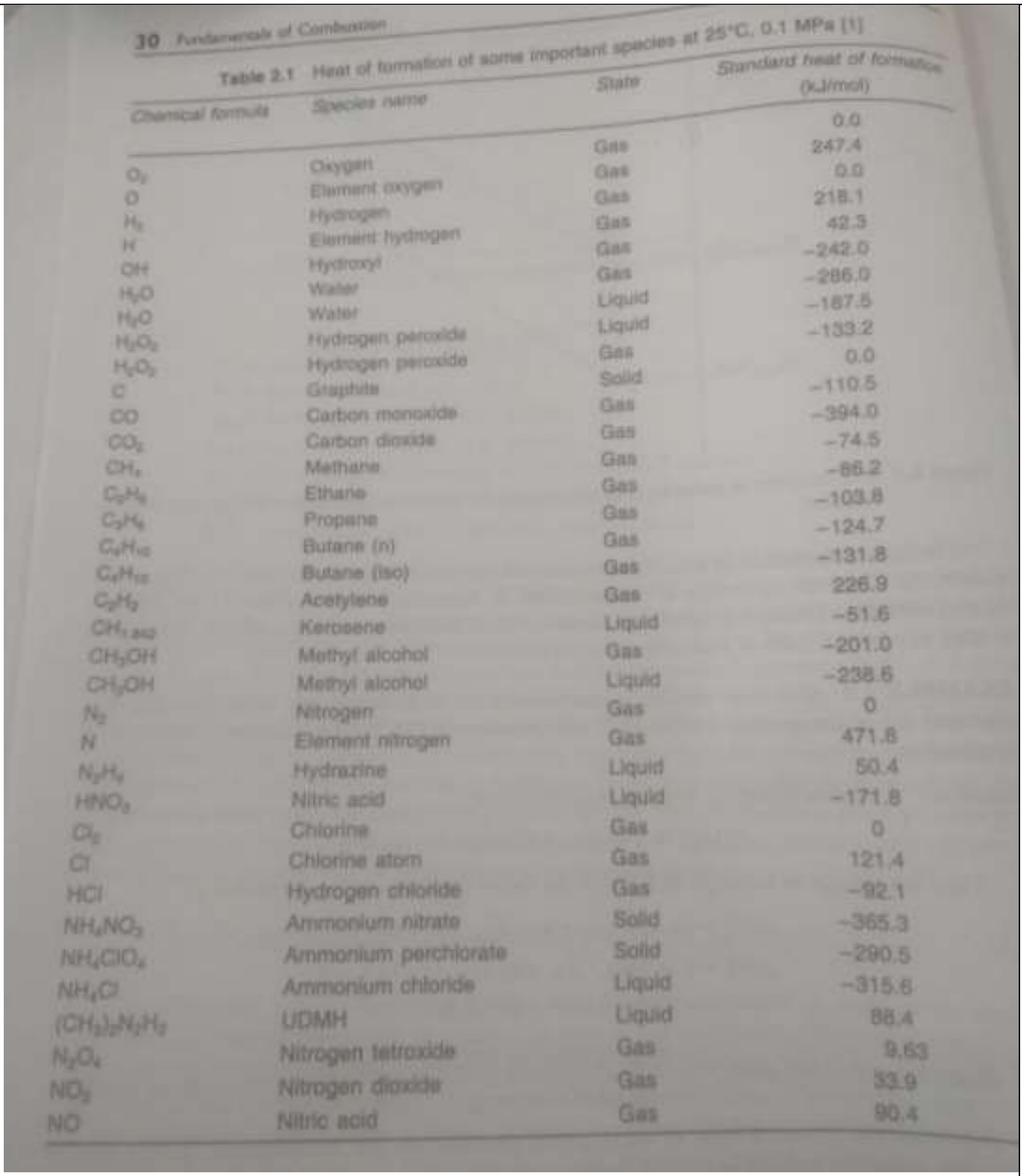
SECTION A

S. No.	Answer all the Questions (30 Marks)	**Marks**	**CO**
Q 1	Explain the difference between diffusion flames and Premixed flames, describe the practical examples? What is the influence of Turbulance on the flame structure?	**5**	**CO1**
Q 2	How does particulates form in combustion system. What are the methods used to reduce particulate emission from combustion system?	**5**	**CO2**
Q 3	Explain about bluff body flame stabilization, Why it is a challenge in Micro Combustion Systems. What will happen to the height in the turbulent ranges?	**5**	**CO3**
Q 4	Explain about Electronegativity, and its significance in selection of fuels and oxidizers with the examples. Define Hess's Law. Describe the use of Hess's Law for analysis of chemical reactions.	**5**	**CO1**
Q5.	Explain the significance of D^2 Law with its mathematical expressions? How it is used in Droplet combustion? Explain the validity for solid fuel combustion	**5**	**CO4**
Q6.	What do you mean by flashback and blow-off? How can this be related to the burning velocity?	**5**	**CO3**

SECTION B

	Answer all the Questions (50 Marks)		

Q 7	A small, low emission, stationary gas turbine engine operates ta full load 3950 kW at an equivalence ratio of 0.286 with an air flow rate of 15. 9 Kg/s. The equivalent composition of the fuel is $C_{1.16}H_{4.32}$. Determine the fuel mass flow rete and the operating air fuel ratio of the engine?	**10**	**CO2**
Q 8	Benzene gas (C_6H_6) at 25°C is burned during a steady-flow combustion process with 95 percent theoretical air that enters the combustion chamber at 25°C. All the hydrogen in the fuel burns to H_2O, but part of the carbon burns to CO. If the products leave at 1000 K, determine (*a*) the mole fraction of the CO in the products and (*b*) the heat transfer from the combustion chamber during this process	**10**	**CO4**
Q 9	A gaseous fuel having a volumetric analysis of 65% CH4, 25% C2H6, 5% CO, and 5% N2 is burned with 30% excess air. Determine a) mass AF ratio, (b). mass of CO2 produced (c). mass of water formed (d). mass of products formed?	**10**	**CO1**
Q 10	Determine the detonation pressure for a gaseous mixture of H_2 and O_2 for a particular mixture ratio, when this mixture at initial pressure of 0.2 MPa and 300 K is increased its density by three times due to formation of detonation wave. Assume the ideal gas law when specific heat ratio is 1.25. Assume that the product contains only gaseous H_2O molecules.	**10**	**CO 3**



30 Fundamentals of Combustion

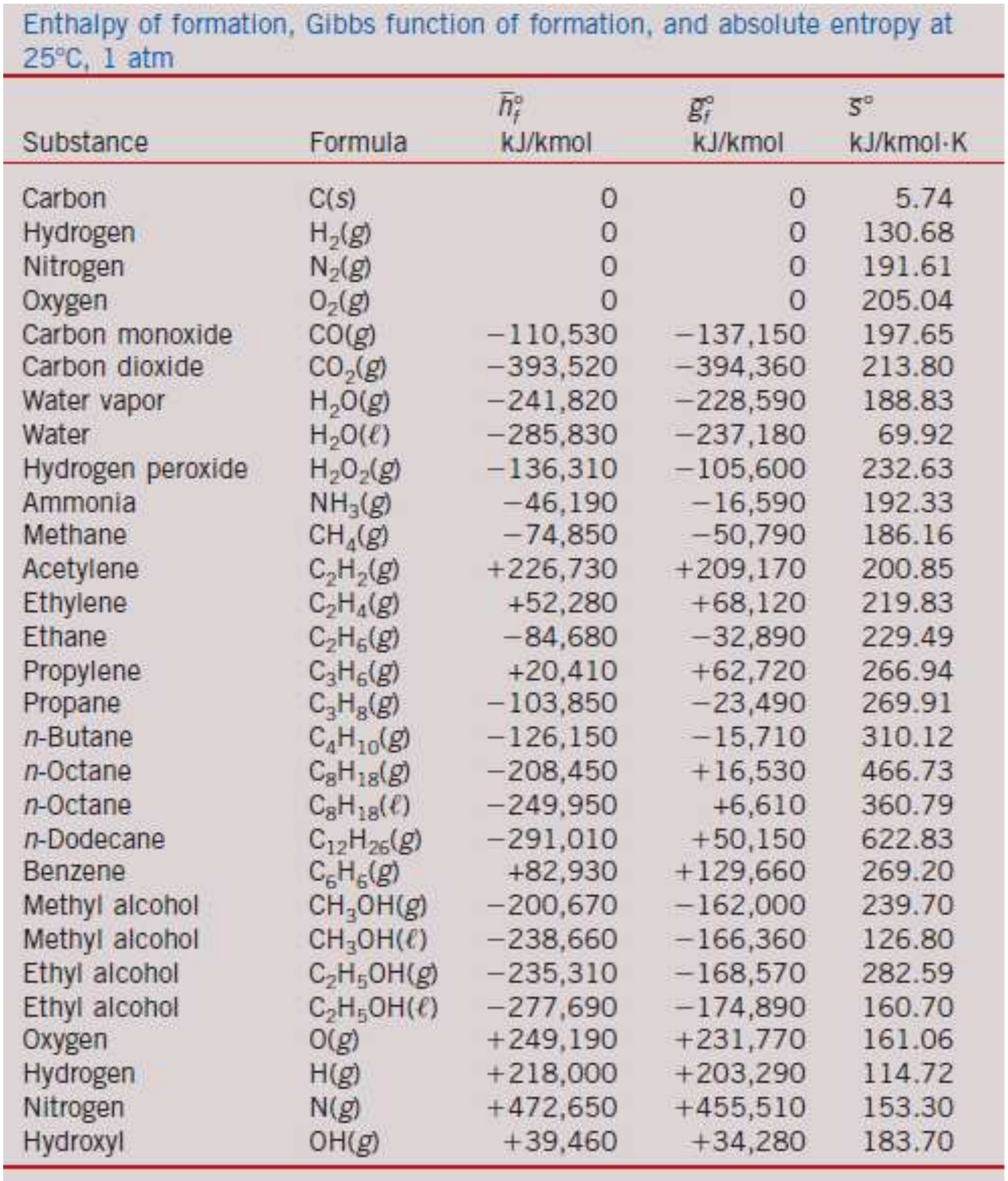
Table 2.1 Heat of formation of some important species at 25°C, 0.1 MPa [1]

Chemical formula	Species name	State	Standard heat of formation (kJ/mol)
O_2	Oxygen	Gas	0.0
O	Element oxygen	Gas	247.4
H_2	Hydrogen	Gas	0.0
H	Element hydrogen	Gas	218.1
OH	Hydroxyl	Gas	42.3
H_2O	Water	Gas	−242.0
H_2O	Water	Liquid	−286.0
H_2O_2	Hydrogen peroxide	Liquid	−187.5
H_2O_2	Hydrogen peroxide	Gas	−133.2
C	Graphite	Solid	0.0
CO	Carbon monoxide	Gas	−110.5
CO_2	Carbon dioxide	Gas	−394.0
CH_4	Methane	Gas	−74.5
C_2H_6	Ethane	Gas	−86.2
C_3H_8	Propane	Gas	−103.8
C_4H_{10}	Butane (n)	Gas	−124.7
C_4H_{10}	Butane (iso)	Gas	−131.8
C_2H_2	Acetylene	Gas	226.9
$CH_{1.842}$	Kerosene	Liquid	−51.6
CH_3OH	Methyl alcohol	Gas	−201.0
CH_3OH	Methyl alcohol	Liquid	−238.6
N_2	Nitrogen	Gas	0
N	Element nitrogen	Gas	471.8
N_2H_4	Hydrazine	Liquid	50.4
HNO_3	Nitric acid	Liquid	−171.8
Cl_2	Chlorine	Gas	0
Cl	Chlorine atom	Gas	121.4
HCl	Hydrogen chloride	Gas	−92.1
NH_4NO_3	Ammonium nitrate	Solid	−365.3
NH_4ClO_4	Ammonium perchlorate	Solid	−290.5
NH_4Cl	Ammonium chloride	Liquid	−315.6
$(CH_3)_2N_2H_2$	UDMH	Liquid	88.4
N_2O_4	Nitrogen tetroxide	Gas	9.63
NO_2	Nitrogen dioxide	Gas	33.9
NO	Nitric acid	Gas	90.4

Q 11	Derive the Species Trasport equation with the help of differential fluid element indicating the transport of species through the surface.	**10**	**CO 2**
SECTION-C			
	Answer all the Questions (20 Marks)		
Q 12	(a). Describe the procedure for determination of Equilibrium composition with the possible species H2, O2, O, H, OH, H2O. Explain the steps for formulation of	**20**	**CO5**

equilibrium constant Kp? Three Moles of Hydrogen are reacted with one mole of oxygen at ambient temperature and pressure with the following reaction

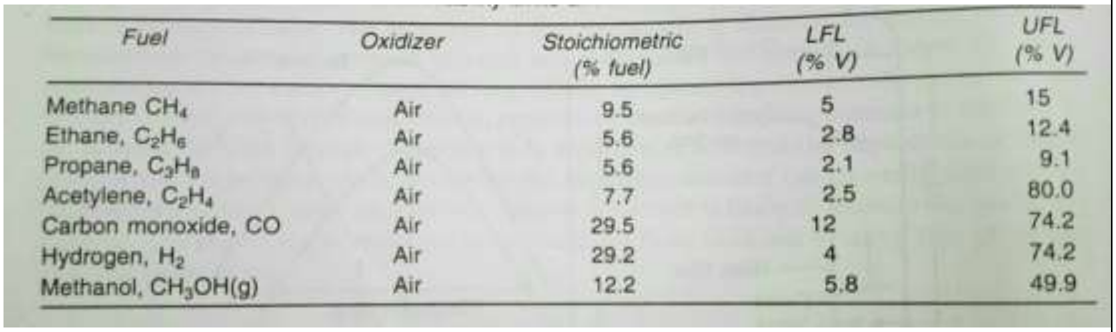
3H2+O2 ---------→ H2+O2+H2O+H+O+OH



Enthalpy of formation, Gibbs function of formation, and absolute entropy at 25°C, 1 atm

Substance	Formula	$\bar{h}_f^\circ$ kJ/kmol	$\bar{g}_f^\circ$ kJ/kmol	$\bar{s}^\circ$ kJ/kmol·K
Carbon	$C(s)$	0	0	5.74
Hydrogen	$H_2(g)$	0	0	130.68
Nitrogen	$N_2(g)$	0	0	191.61
Oxygen	$O_2(g)$	0	0	205.04
Carbon monoxide	$CO(g)$	−110,530	−137,150	197.65
Carbon dioxide	$CO_2(g)$	−393,520	−394,360	213.80
Water vapor	$H_2O(g)$	−241,820	−228,590	188.83
Water	$H_2O(\ell)$	−285,830	−237,180	69.92
Hydrogen peroxide	$H_2O_2(g)$	−136,310	−105,600	232.63
Ammonia	$NH_3(g)$	−46,190	−16,590	192.33
Methane	$CH_4(g)$	−74,850	−50,790	186.16
Acetylene	$C_2H_2(g)$	+226,730	+209,170	200.85
Ethylene	$C_2H_4(g)$	+52,280	+68,120	219.83
Ethane	$C_2H_6(g)$	−84,680	−32,890	229.49
Propylene	$C_3H_6(g)$	+20,410	+62,720	266.94
Propane	$C_3H_8(g)$	−103,850	−23,490	269.91
n-Butane	$C_4H_{10}(g)$	−126,150	−15,710	310.12
n-Octane	$C_8H_{18}(g)$	−208,450	+16,530	466.73
n-Octane	$C_8H_{18}(\ell)$	−249,950	+6,610	360.79
n-Dodecane	$C_{12}H_{26}(g)$	−291,010	+50,150	622.83
Benzene	$C_6H_6(g)$	+82,930	+129,660	269.20
Methyl alcohol	$CH_3OH(g)$	−200,670	−162,000	239.70
Methyl alcohol	$CH_3OH(\ell)$	−238,660	−166,360	126.80
Ethyl alcohol	$C_2H_5OH(g)$	−235,310	−168,570	282.59
Ethyl alcohol	$C_2H_5OH(\ell)$	−277,690	−174,890	160.70
Oxygen	$O(g)$	+249,190	+231,770	161.06
Hydrogen	$H(g)$	+218,000	+203,290	114.72
Nitrogen	$N(g)$	+472,650	+455,510	153.30
Hydroxyl	$OH(g)$	+39,460	+34,280	183.70

(b). By Mistake, aperson kept opened the hydrogen cylinder for 1 hour which fills the 12 feet ×13 feet ×10 feet factory room at 298 K and 0.1 MPa, at flow rate of 2 LPM. Determine wether the mixture is flammable or not? A flame arrester is to be designed by using bundle of smaller dimeter tube for stoichiometric CH_4 air flame. Note that initial CH_4 air mixture is supplied at 298 K, 0.1 MPa. Determine the maximum diameter of the tube, which can prevent flame passing through the arrester. Consider Univeral Gas Constant as 8.314 kJ/kmol.K. Use the below given data tables for solving the problem.



Fuel	*Oxidizer*	*Stoichiometric (% fuel)*	*LFL (% V)*	*UFL (% V)*
Methane CH_4	Air	9.5	5	15
Ethane, C_2H_6	Air	5.6	2.8	12.4
Propane, C_3H_8	Air	5.6	2.1	9.1
Acetylene, C_2H_4	Air	7.7	2.5	80.0
Carbon monoxide, CO	Air	29.5	12	74.2
Hydrogen, H_2	Air	29.2	4	74.2
Methanol, $CH_3OH(g)$	Air	12.2	5.8	49.9