



Note: Assume any data required, state your assumption clearly. Answer all the following Questions

Combustion tables are allowed
Table of Some Bond and Resonance Energies (Given)

Question (1)

(25 Marks)

- (1.1) Describe: Thermodynamic equilibrium and Gibbs free energy.
- (1.2) Show that the fugacity of a real gas is related to the pressure P and compressibility factor Z by $\ln \frac{f}{P} = \int_0^P (Z-1) d(\ln P_r)_T$, where P_r is the reduced pressure $P_r = \frac{P}{P_{critical}}$. Discuss the use of this equation.
- (1.3) Using bond energies, determine the heat of formation of gaseous normal Butane (C_4H_{10}).

Question (2)

(25 Marks)

- (2.1) Explain: Dissociation, Mixture fraction, Bond energy, Heat of formation and Heat of reaction.
- (2.2) Propane (C_3H_8) is burned with 30% excess air. Determine
- (a) Air-fuel ratio. (b) The gravimetric analysis of wet flue gases.
(c) The mixture dew point. (d) The heat of reaction at $T_p = 2000$ K.
(e) Mean specific heat at T_p . (f) The adiabatic flame temperature if $T_R = 298$ K

Question (3)

(25 Marks)

- (3.1) Discuss: Rates of reactions and their functional dependence.
- (3.2) Explain: One-step chemical reactions of various orders.

Question (4)

(25 Marks)

- (4.1) Explain: consecutive reactions, competitive reactions, opposing reactions, chain reactions and surface reactions.
- (4.2) A mixture of 1 mole of N_2 and 0.5 mole of O_2 is heated to 4000 K at 1 atm pressure, resulting in an equilibrium mixture of N_2 , O_2 and NO only. If the O_2 and N_2 were initially at 298 K and were heated steadily, how much heat was required to bring the final mixture to 4000 K on the basis of 1 initial mole of N_2 .

Table: Some Bond and Resonance Energies
Bond Energies in Some Diatomic Molecules¹⁶

Bond	Energy, D_{298}° (kcal/mol)	Bond	Energy, D_{298}° (kcal/mol)
H-H	104.20	C-O	≥ 141.97
F-F	37.95	C-Cl	94.89 ± 6.93
Cl-Cl	57.98	Br-C	66.92 ± 5.02
Br-Br	46.08	C-I	49.95 ± 5.02
I-I	36.11	C-F	131.93
C-H	80.88 ± 0.29	N \equiv N	225.94 ± 0.14
H-N	≤ 81.02	C=C	145.08 ± 5.02
H-O	102.20	O=O	119.11
Cl-H	103.16	Al-O	122.13 ± 0.72
Br-H	87.55	C \equiv N	180.28 ± 2.39
H-I	71.32		

Mean Bond Energies^{14, 16}

Bond	Energy (kcal/mol)	Bond	Energy (kcal/mol)
Br-Br	46	H-F	135
C-C	85	H-H	103
C=C	145	H-I	72
C \equiv C	194.3	H-P	76
C-Br	67	H-S	81
C-Cl	78	I-I	36
C-F	102	N-H	88
C-H	98.1	N-N	60
C-I	64	N \equiv N	225
C-N	81	O-H	109
C \equiv N	210	O-N	150
C-O	86	O-O	33.1
C=O	173	O=O	117
C-S	64	P-Br	64
Cl-Cl	57	P-Cl	78
F-F	36	P-P	48
H-Br	88	S-Cl	60
H-Cl	103	S-S	50

Resonance Energies of Selected Compounds

Compound	Resonance Energy (kcal/mol)
Benzene, C_6H_6	48.9
-COOH group (carboxyl group)	28
CO ₂	33
Naphthalene, $C_{10}H_8$	88.0
Aniline, $C_6H_5NH_2$	69.6