
CONTENTS

1	Introduction	1
2	Classical Ignition Theories	3
2.1	Thermal Explosion Theory	3
2.2	Chain-Branching Kinetics	8
2.3	Induction Period of Ignition and Ignition Mechanism	14
3	Stochastic Theory of Irreversible Phenomena	17
3.1	Irreversible Process	18
3.2	Fluctuation in Irreversible Process	21
3.3	Stochastic Theory for Irreversible Phenomena	23
4	Nucleation in Phase Transition	27
4.1	Classical Nucleation Theory	27
4.2	Stochastic Nucleation Theory at Ebullition of Liquids	29
4.2.1	Experiments for measuring the ebullition induction period	30
4.2.2	Probability of ebullition	31
4.2.3	Activation energies of ebullition	32
4.2.4	Frequency factor	34
4.2.5	Ebullition mechanism	35
4.3	Stochastic Theory for Ice Formation in Water	36
4.3.1	Experiments	36
4.3.2	Probability of ice formation	37
4.3.3	Activation energies of ice formation	40
4.3.4	Ice formation under a radiation of high energy	42
5	Shock Tubes	45
5.1	Shock Waves	45
5.2	Simple Shock Tube	49

6 Stochastic Ignition Theory	57
6.1 Probability of Ignition Behind Shock Waves.	57
6.2 Spontaneous Ignition in a Hydrogen–Oxygen Mixture Behind Shock Waves.	61
6.2.1 Experimental method	62
6.2.2 Experimental results	63
6.2.3 Explosion limits.	68
6.2.4 Quantity effect on the ignition.	71
6.2.5 Reaction mechanism	72
6.3 Spontaneous Ignition in Hydrocarbon–Air Mixtures	74
6.3.1 Ignition probability and mechanism in paraffin–fuel–air mixtures	74
6.3.2 Ignition limits of hydrocarbon fuel-air mixtures	84
6.3.3 Influences of tetraethyl lead on the ignition.	87
6.4 The Chain-Branching Kinetics and Stochastic Ignition Theory	97
7 Ignition in a Fuel Spray	99
7.1 The Most Inflammable State of a Fuel–Air Mixture	99
7.1.1 Ignition probability in lean <i>n</i> -octane–air mixtures	100
7.1.2 The most inflammable state of the mixture	102
7.2 Ignition Probability in a Fuel Spray	103
7.2.1 Partial ignition probability.	103
7.2.2 Experiments using a shock tube.	104
7.2.3 Induction period of ignition in the fuel spray	107
7.2.4 Distribution of the ignition probability	108
7.2.5 Ignition and combustion in a fuel spray.	110
7.2.6 Conclusions.	112
8 Ignition by Electric Sparks.	113
8.1 Igniter Using Induction Coils	114
8.1.1 Spark ignition and characteristics of electric discharge . .	115
8.1.2 Ignition and gap distance between the electrodes.	115
8.2 Application of the Stochastic Ignition Theory to Spark Ignition	116
8.2.1 Stochastic theory of ignition by external energies	117
8.2.2 Experiments.	118
8.2.3 Action of capacity and inductance components	120
8.2.4 Gap distance and ignition	125
9 Nonequilibrium State	137
9.1 Adiabatic Combustion Temperature at Equilibrium	139
9.1.1 Reaction process and dissociation	139
9.1.2 Reaction heat and adiabatic combustion temperature . . .	141
9.1.3 Adiabatic combustion temperature of propane–oxygen mixture	142

9.2	Investigation of Flame by Probe Method	146
9.2.1	Electron temperature and ion temperature	146
9.2.2	Langmuir probe method	148
9.2.3	Double probe method	149
9.2.4	Investigation of ionization in a standing flame by a double probe method	152
9.2.5	Investigation of ionization in a propagating flame by a double probe method	153
9.3	Investigation of Flame by a Laser Light Scattering Method . .	160
9.3.1	Laser light scattering method	161
9.3.2	Notices to be considered at the measurement	164
9.3.3	Investigation of the ionization in a propagating flame using the laser light scattering method	165
9.4	Nonequilibrium and Heterogeneous State behind Shock Waves	174
9.4.1	Spectroscopic temperature measurement method	174
9.4.2	Temperature in argon gas behind shock waves	175
9.4.3	A stochastic phenomenon behind shock waves	182
9.4.4	Nonequilibrium and heterogeneous state behind shock waves	183
10	Interaction Between Combustion and Pressure or Shock Waves	187
10.1	Propagation of Combustion Waves	187
10.2	Flame Propagation as an Irreversible Phenomenon	191
10.2.1	Theoretical treatment	191
10.2.2	Experiments of flame propagation	192
10.2.3	Transition from a laminar flame to a turbulent flame . .	198
10.3	Interaction between Combustion and Shock Waves	199
10.3.1	Interaction modes in the experiments	199
10.3.2	Experimental results	202
10.4	Resonance Pulse Jet Engine (Schmidtrohr)	216
10.4.1	Construction and action mechanism	216
10.4.2	Performance	218
10.4.3	Ignition and combustion	220
11	Gaseous Detonation Waves	223
11.1	The Classical Theories of Detonation Waves	223
11.1.1	Macroscopic structure of detonation waves	224
11.1.2	Microscopic structure of detonation waves	228
11.1.3	Transition from deflagration to detonation waves . . .	232
11.2	Detonation Waves as Irreversible Phenomena	233
11.2.1	Interaction between converging shock and combustion waves	233
11.2.2	Cellular structure formation as a stochastic phenomenon	241
11.2.3	Interaction between shock and detonation waves	251

11.3	Initiation of Detonation Waves	255
11.3.1	Transition from combustion to detonation	257
11.3.2	Transition from shock to detonation waves	270
11.4	Propagation of Detonation Waves	281
11.4.1	Detonation propagating in mixtures having different temperatures	282
11.4.2	Deceleration of the detonation propagation	289
11.4.3	Concluding remarks on the propagation velocity of the detonation wave	295
11.5	Ionization of Gases Behind Detonation Wave	296
11.5.1	Investigation applying a double probe method	297
11.5.2	Investigation by a laser light scattering method	302
12	Industrial Applications of Detonation Waves	307
12.1	Imploding Shock Waves	308
12.1.1	Theoretical calculation of imploding shock waves	308
12.1.2	Radially divergent detonation wave	314
12.1.3	Cylindrically and spherically imploding detonation waves of small size	319
12.1.4	Spherically imploding detonation waves of large size	336
12.1.5	Spherically imploding detonation waves initiated by two-step divergent detonation	343
12.1.6	Nuclear fusion applying spherically imploding detonation waves	354
12.1.7	Nuclear fusion rocket engines applying imploding detonation waves	358
12.2	Hypersonic Combustion for RAM Jet Engine	361
12.2.1	Standing detonation waves	362
12.2.2	Advantage of the ram jet using standing detonation waves	362
12.2.3	Experimental apparatus	364
12.2.4	Experiments	365
12.3	Shock Tubes Driven by Detonation Waves	371
12.3.1	Rarefaction waves behind detonation waves (Taylor expansion)	372
12.3.2	Shock tube directly driven by detonation waves	373
12.3.3	Shock tube using free piston driven by detonation waves	376
	References	389
	Author Index	397
	Subject Index	401

Irreversible Phenomena

Ignitions, Combustion and Detonation Waves

Terao, K.

2007, X, 409 p.,

ISBN: 978-3-540-49901-5