AD 689872

ANNUAL REPORT No. 8

for the period ending: 31 May 1969

Contract Nonr - 4008(07)

submitted to

Office of Naval Research

Power Program

MECHANISMS OF REACTIONS OF OXIDIZERS

by

A. G. Keenan

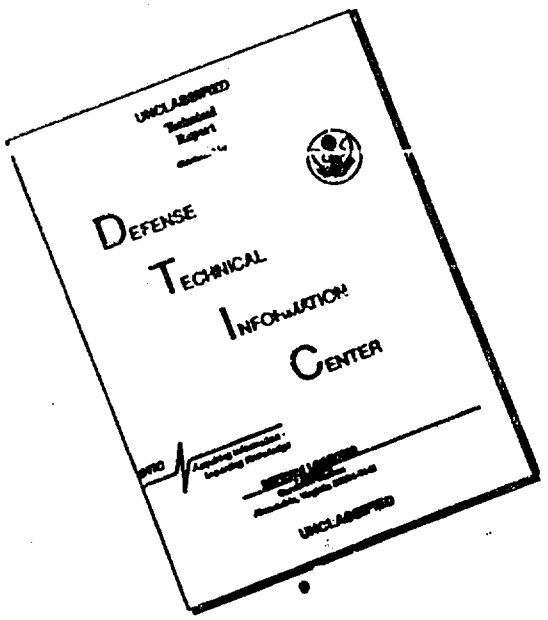
This document has been approved for public release and sale; its distribution is unlimited.

Department of Chemistry
University of Miami
Coral Gables, Florida
33124

D D C
JUL 9 1969

Reproduced by the
CLEARINGHOUSE
for Federal Scientific & Technical
Information Springfield Va. 22151

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

Annual Report No. 8 - 31 May 1969

Office of Naval Research - Contract Nonr - 4008(07)

MECHANISMS OF REACTIONS OF OXIDIZERS

A. G. Keenan

Chemistry Department, University of Miami
Coral Gables, Florida 33124

The following publications have resulted during the past year from research under this contract:

1. Special Report No. 6, "The Thermal Decomposition of Ammonium Perchlorate - A Literature Review", by A. G. Keenan and Robert F. Siegmund, dated 1 August 1968. This has been distributed according to the cognizant distribution list. The report is a review of the unclassified literature on the uncatalyzed thermal decomposition of ammonium perchlorate through May 1968. It comprises 47 pages and 137 references to scientific journals and DDC reports. This is available from CFSTI as AD-673,542 and bears NASA Accession No. N68-36233.

2. "Silver and Sodium Ion Transport Numbers into Pyrex from Binary Nitrate Melts", A. G. Keenan and W. H. Duewer, Journal of Physical Chemistry, 73, 212 (1969). Reprints have been distributed as Special Report No. 7 (1 May 1969), according to the distribution list for the subject contract. The work is taken from the M.S. Thesis of W. H. Duewer, dated August 1966.

3. "Synergistic Catalysis of Ammonium Nitrate Decomposition", A. G. Keenan, K. Notz, and N. B. Franco, Journal of the American Chemical Society, 91, 3168 (1969). Reprints will be issued as Special Report No. 8 as soon as they are available. The work is taken largely from the Ph.D. Dissertation of N. B. Franco, dated January 1968, with some contribution from the Ph.D. Dissertation of K. Notz, dated January 1966. The paper contains a complete summary of the results of the mechanistic studies on catalyzed ammonium nitrate decomposition which have been carried out in this laboratory under the subject contract. Reference is made to seven prior publications.

4. "Ammonium Perchlorate Explosive Composition", A. G. Keenan and R. F. Siegmund, inventors. This patent application was filed on July 15, 1968, and assigned Serial No. 744,989. Filings in foreign countries are also underway.

5. "Determination of Small Amounts of Water in Crystalline Ammonium Perchlorate by High Resolution Proton Magnetic Resonance", A. G. Keenan and Robert F. Siegmund. This manuscript has been submitted for publication and will be eventually issued as Special Report No. 9. Besides providing a method for analytical determination of water, as implied by the title, the paper contains comparative results between perchlorate and nitrate which may form the basis of a method of measuring relative base strengths of inorganic anions in non-levelling nonaqueous solvents. Further work is planned along these lines.

Currently four graduate students are working on the contract. Mr. Siegmund has continued his study of the cupric chloride catalyzed decomposition of ammonium perchlorate by the differential rate method. Catalyst concentrations from 1.3 to 10 weight % and a temperature range from 210 to 235°C have been employed. The catalyst is incorporated by crystallization from aqueous solution and the crystals are ground and sieved to lie in the range 74 to 149 microns. Two computer programs have been written in which the input consists of raw experimental data and the output gives all the reaction parameters and their mean deviations evaluated by least square methods. The programs evaluate n and a for the curve $(-\log(1-a))^n = kt$, average these for the different runs, compute reaction rate constants, plot these according to the Arrhenius function and evaluate activation energies. The determination of an activation energy from the time to rate maximum is also incorporated.

An initial extensive series of runs was done with 10% catalyst. Both the acceleratory and deceleratory portions of the decomposition curve could be fitted by the same equation $\log(1/1-a) = (kt)^n$ with n = 3 for the first part and n = 0.5 for the second. Activation energies were determined in the usual way by plotting log rate constant or other reaction parameter against the reciprocal of temperature. The five methods of determining activation energy and the results in kcal/mole are as follows: (1) from induction period, E = 27.9; (2) from time to maximum decomposition rate, E = 29.9; (3) from time between two arbitrary fractions of decomposition, E = 25.7; (4) from rate constants for rising curve, E = 27.2; and (5) from rate constants for falling curve, E = 27.1. Decompositions extended to about 80%. The stoichiometric factor, i.e., the moles decomposed per mole of gaseous product, remains constant within a few per cent indicating that the same mechanism operates over the regions investigated. In view of the uncertain stoichiometry of AP decomposition available in the literature, it will be necessary to check out this factor over a wide range of conditions before the volumetric rate of product production can be safely used as a measure of reaction rate.

In working with lower catalyst concentrations, it has been found that the activation energy does not change appreciably until the catalyst is decreased from about 3% to 1.3%. Apparently, incorporating the copper chloride within the ammonium perchlorate lattice maximizes the catalytic effect of the $CuCl_2$ at very small concentrations. This tends to substantiate an earlier tentative postulate that the catalyst in the low temperature region simply provides additional surface on which the ammonia and perchloric acid can become absorbed and react. It has also been found that recrystallizing reagent grade ammonium perchlorate changes the reaction rate without, however, appreciable change in activation energy. This appears to contradict the findings of some earlier investigators such as Jacobs (1967) and Rosser (1966). In addition, the critical concentration of $CuCl_2$, that is the one beyond which further additions have no effect on the rate, appears to occur at 1.5%. In contrast to Maycock (1968), additions of catalyst beyond the critical 1.5% and going up to 10% do not inhibit the decomposition but produce the same effect as at 1.5%.

It is hoped that the above work on ammonium perchlorate decomposition will contribute to a resolution of the controversies in the literature over the electron-transfer versus proton-transfer mechanisms and over the effect of impurities as against lattice defects on the initiation of the decomposition.

A new student, Mr. Mark Goldstein, joined the research group during the year and has begun an investigation of the stoichiometry and mechanism of the copper-catalyzed thermal decomposition of ammonium perchlorate using gas chromatographic, infrared, X-ray and other techniques. The stoichiometry of the decomposition of pure AP at 218° gave an O_2/N_2 ratio of 8/1 which agrees with that found by others. With 3% $CuCl_2$, the ratio was 4/1 which is comparable to the results reported in the literature for copper chromite catalyzed AP at 275°. Indications are that the stoichiometry depends on the presence of the catalyst as well as on its concentration but this work is still in a very preliminary stage.

Mr. Lane has been continuing his research which is directed toward establishing a Hammett-type acidity scale in fused salts for application toward the potentiometric study of the role of acidity in oxidizer decomposition mechanisms. This requires accurate values for the molal absorptivities of chromate and dichromate ions and for the standard potential of an oxide-ion sensitive electrode in fused nitrates.

After much careful spectrophotometric work in binary sodium/potassium nitrate eutectics at 300°, it was found that the electrometric results using a Cu/CuO oxide-ion indicating

electrode versus a Ag/Ag^+ reference, could only be interpreted, at least for the present, in pure fused KNO_3 at 350°. The molal absorptivities of chromate and dichromate have therefore been redetermined in KNO_3 at 350° over the wavelength range from 350 to 450 nanometers. We believe these values to be more accurate than any of the partial results in the literature.

The standard potential of the Cu/CuO electrode versus a Ag/Ag^+ reference has been found to be -675.8 mV at 350° in KNO_3. This again is believed to be much more accurate than any value available in the literature. The measurements were made by adding weighed amounts of potassium oxalate to provide oxide ion. The quantitative conversion to oxide has been checked analytically. The slopes of the six emf plots checked the Nernst value for a 2-electron electrode reaction within 0.3%. The least squares standard error of estimate averaged 2.9 mV as determined by a computer program. Using this standard potential, the equilibrium constant for the reaction $Cr_2O_7^{2-} + O^{2-} \rightleftharpoons 2\ CrO_4^{2-}$ can now be calculated to be 6.67×10^8 at 350° in KNO_3.

The variation of standard potential with temperature has also been determined over the range 350 to 400°. The standard free energy change for the above reaction at 350° has been calculated to be -25.17 kcal/mole, the enthalpy change -46.06 kcal/mole and the entropy change -27.10 eu.

In trying to extend the electrometric measurements to binary nitrate solvents an anomolous result has been obtained in that the presence of sodium ion appears to cause the oxide ion electrode reaction to change so that it is closer to a one-electron process than to the expected two-electron process. The observed Nernst slope is -115 mV compared to the theoretical one-electron value of -123 mV and the theoretical two-electron value of -62 mV. There is no apparent reason in principle why sodium should have such an effect.

Investigation of this phenomenon is an interesting spin-off from Mr. Lane's electrometric studies and in fact this research problem has already been accepted by a new student, Mr. Carlos Fernandez, who began work on it on 1 June 1969.

None

Security Classification

6

DOCUMENT CONTROL DATA - R&D

(Security classification of title body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY *(Corporate author)*

University of Miami
Department of Chemistry

2a. REPORT SECURITY CLASSIFICATION

None

2b GROUP

3 REPORT TITLE

Mechanisms of Reactions of Oxidizers

4 DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

Annual Report, June 1, 1968 to May 31, 1969

5 AUTHOR(S) *(Last name, first name, initial)*

Keenan, A. G.

6 REPORT DATE

May 31, 1969

7a. TOTAL NO. OF PAGES

6

7b. NO. OF REFS

7

8a CONTRACT OR GRANT NO.

Nonr-4008(07)

b PROJECT NO.

c

d

9a. ORIGINATOR'S REPORT NUMBER(S)

Annual Report No. 8

9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*

10 AVAILABILITY/LIMITATION NOTICES

Qualified requesters may obtain copies of this report from DDC

11 SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY

Office of Naval Research
Power Program, Code 473
Washington, D. C.

13 ABSTRACT

Progress during the year in the investigation of the synergistically catalyzed decomposition of oxidizers such as ammonium nitrate and ammonium perchlorate is summarized. Research has been done in the areas of thermal analysis, rate studies, catalytic and mechanistic studies, and electrometric measurements.

DD FORM 1 JAN 64 1473

None

Security Classification

None

Security Classification

14 KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Ammonium						
Nitrate						
Perchlorate						
Propellant						
Oxidizer						
EMF						
Fused Salts						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through _____."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through _____."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through _____."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)* *(S)* *(C)* or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

None

Security Classification

END

DATE

FILMED

8-14-69

AD 689872

ANNUAL REPORT No. 8

for the period ending: 31 May 1969

Contract Nonr - 4008(07)

submitted to

Office of Naval Research

Power Program

MECHANISMS OF REACTIONS OF OXIDIZERS

by

A. G. Keenan

This document has been approved for public release and sale; its distribution is unlimited.

Department of Chemistry
University of Miami
Coral Gables, Florida
33124

JUL 9 1969

Reproduced by the
CLEARINGHOUSE
for Federal Scientific & Technical
Information Springfield Va 22151

Annual Report No. 8 - 31 May 1969

Office of Naval Research - Contract Nonr - 4008(07)

MECHANISMS OF REACTIONS OF OXIDIZERS

A. G. Keenan

Chemistry Department, University of Miami
Coral Gables, Florida 33124

The following publications have resulted during the past year from research under this contract:

1. Special Report No. 6, "The Thermal Decomposition of Ammonium Perchlorate - A Literature Review", by A. G. Keenan and Robert F. Siegmund, dated 1 August 1968. This has been distributed according to the cognizant distribution list. The report is a review of the unclassified literature on the uncatalyzed thermal decomposition of ammonium perchlorate through May 1968. It comprises 47 pages and 137 references to scientific journals and DDC reports. This is available from CFSTI as AD-673,542 and bears NASA Accession No. N68-36233.

2. "Silver and Sodium Ion Transport Numbers into Pyrex from Binary Nitrate Melts", A. G. Keenan and W. H. Duewer, Journal of Physical Chemistry, 73, 212 (1969). Reprints have been distributed as Special Report No. 7 (1 May 1969), according to the distribution list for the subject contract. The work is taken from the M.S. Thesis of W. H. Duewer, dated August 1966.

3. "Synergistic Catalysis of Ammonium Nitrate Decomposition", A. G. Keenan, K. Notz, and N. B. Franco, Journal of the American Chemical Society, 91, 3168 (1969). Reprints will be issued as Special Report No. 8 as soon as they are available. The work is taken largely from the Ph.D. Dissertation of N. B. Franco, dated January 1968, with some contribution from the Ph.D. Dissertation of K. Notz, dated January 1966. The paper contains a complete summary of the results of the mechanistic studies on catalyzed ammonium nitrate decomposition which have been carried out in this laboratory under the subject contract. Reference is made to seven prior publications.

4. "Ammonium Perchlorate Explosive Composition", A. G. Keenan and R. F. Siegmund, inventors. This patent application was filed on July 15, 1968, and assigned Serial No. 744,989. Filings in foreign countries are also underway.

5. "Determination of Small Amounts of Water in Crystalline Ammonium Perchlorate by High Resolution Proton Magnetic Resonance", A. G. Keenan and Robert F. Siegmund. This manuscript has been submitted for publication and will be eventually issued as Special Report No. 9. Besides providing a method for analytical determination of water, as implied by the title, the paper contains comparative results between perchlorate and nitrate which may form the basis of a method of measuring relative base strengths of inorganic anions in non-levelling nonaqueous solvents. Further work is planned along these lines.

Currently four graduate students are working on the contract. Mr. Siegmund has continued his study of the cupric chloride catalyzed decomposition of ammonium perchlorate by the differential rate method. Catalyst concentrations from 1.3 to 10 weight % and a temperature range from 210 to 235°C have been employed. The catalyst is incorporated by crystallization from aqueous solution and the crystals are ground and sieved to lie in the range 74 to 149 microns. Two computer programs have been written in which the input consists of raw experimental data and the output gives all the reaction parameters and their mean deviations evaluated by least square methods. The programs evaluate n and a for the curve $(-\log(1-a))^n = kt$, average these for the different runs, compute reaction rate constants, plot these according to the Arrhenius function and evaluate activation energies. The determination of an activation energy from the time to rate maximum is also incorporated.

An initial extensive series of runs was done with 10% catalyst. Both the acceleratory and deceleratory portions of the decomposition curve could be fitted by the same equation $\log(1/1-a) = (kt)^n$ with n = 3 for the first part and n = 0.5 for the second. Activation energies were determined in the usual way by plotting log rate constant or other reaction parameter against the reciprocal of temperature. The five methods of determining activation energy and the results in kcal/mole are as follows: (1) from induction period, E = 27.9; (2) from time to maximum decomposition rate, E = 29.9; (3) from time between two arbitrary fractions of decomposition, E = 25.7; (4) from rate constants for rising curve, E = 27.2; and (5) from rate constants for falling curve, E = 27.1. Decompositions extended to about 80%. The stoichiometric factor, i.e., the moles decomposed per mole of gaseous product, remains constant within a few per cent indicating that the same mechanism operates over the regions investigated. In view of the uncertain stoichiometry of AP decomposition available in the literature, it will be necessary to check out this factor over a wide range of conditions before the volumetric rate of product production can be safely used as a measure of reaction rate.

In working with lower catalyst concentrations, it has been found that the activation energy does not change appreciably until the catalyst is decreased from about 3% to 1.3%. Apparently, incorporating the copper chloride within the ammonium perchlorate lattice maximizes the catalytic effect of the $CuCl_2$ at very small concentrations. This tends to substantiate an earlier tentative postulate that the catalyst in the low temperature region simply provides additional surface on which the ammonia and perchloric acid can become absorbed and react. It has also been found that recrystallizing reagent grade ammonium perchlorate changes the reaction rate without, however, appreciable change in activation energy. This appears to contradict the findings of some earlier investigators such as Jacobs (1967) and Rosser (1966). In addition, the critical concentration of $CuCl_2$, that is the one beyond which further additions have no effect on the rate, appears to occur at 1.5%. In contrast to Maycock (1968), additions of catalyst beyond the critical 1.5% and going up to 10% do not inhibit the decomposition but produce the same effect as at 1.5%.

It is hoped that the above work on ammonium perchlorate decomposition will contribute to a resolution of the controversies in the literature over the electron-transfer versus proton-transfer mechanisms and over the effect of impurities as against lattice defects on the initiation of the decomposition.

A new student, Mr. Mark Goldstein, joined the research group during the year and has begun an investigation of the stoichiometry and mechanism of the copper-catalyzed thermal decomposition of ammonium perchlorate using gas chromatographic, infrared, X-ray and other techniques. The stoichiometry of the decomposition of pure AP at 218° gave an O_2/N_2 ratio of 8/1 which agrees with that found by others. With 3% $CuCl_2$, the ratio was 4/1 which is comparable to the results reported in the literature for copper chromite catalyzed AP at 275°. Indications are that the stoichiometry depends on the presence of the catalyst as well as on its concentration but this work is still in a very preliminary stage.

Mr. Lane has been continuing his research which is directed toward establishing a Hammett-type acidity scale in fused salts for application toward the potentiometric study of the role of acidity in oxidizer decomposition mechanisms. This requires accurate values for the molal absorptivities of chromate and dichromate ions and for the standard potential of an oxide-ion sensitive electrode in fused nitrates.

After much careful spectrophotometric work in binary sodium/potassium nitrate eutectics at 300°, it was found that the electrometric results using a Cu/CuO oxide-ion indicating

electrode versus a Ag/Ag^+ reference, could only be interpreted, at least for the present, in pure fused KNO_3 at 350°. The molal absorptivities of chromate and dichromate have therefore been redetermined in KNO_3 at 350° over the wavelength range from 350 to 450 nanometers. We believe these values to be more accurate than any of the partial results in the literature.

The standard potential of the Cu/CuO electrode versus a Ag/Ag^+ reference has been found to be -675.8 mV at 350° in KNO_3. This again is believed to be much more accurate than any value available in the literature. The measurements were made by adding weighed amounts of potassium oxalate to provide oxide ion. The quantitative conversion to oxide has been checked analytically. The slopes of the six emf plots checked the Nernst value for a 2-electron electrode reaction within 0.3%. The least squares standard error of estimate averaged 2.9 mV as determined by a computer program. Using this standard potential, the equilibrium constant for the reaction $Cr_2O_7^{2-} + O^{2-} \rightleftharpoons 2\ CrO_4^{2-}$ can now be calculated to be 6.67×10^8 at 350° in KNO_3.

The variation of standard potential with temperature has also been determined over the range 350 to 400°. The standard free energy change for the above reaction at 350° has been calculated to be -25.17 kcal/mole, the enthalpy change -46.06 kcal/mole and the entropy change -27.10 eu.

In trying to extend the electrometric measurements to binary nitrate solvents an anomolous result has been obtained in that the presence of sodium ion appears to cause the oxide ion electrode reaction to change so that it is closer to a one-electron process than to the expected two-electron process. The observed Nernst slope is -115 mV compared to the theoretical one-electron value of -123 mV and the theoretical two-electron value of -62 mV. There is no apparent reason in principle why sodium should have such an effect.

Investigation of this phenomenon is an interesting spin-off from Mr. Lane's electrometric studies and in fact this research problem has already been accepted by a new student, Mr. Carlos Fernandez, who began work on it on 1 June 1969.

None

Security Classification

6

DOCUMENT CONTROL DATA - R&D

(Security classification of title body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author)

University of Miami
Department of Chemistry

2a. REPORT SECURITY CLASSIFICATION

None

2b GROUP

3 REPORT TITLE

Mechanisms of Reactions of Oxidizers

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)

Annual Report, June 1, 1968 to May 31, 1969

5 AUTHOR(S) (Last name, first name, initial)

Keenan, A. G.

6. REPORT DATE

May 31, 1969

7a. TOTAL NO. OF PAGES

6

7b. NO. OF REFS

7

8a CONTRACT OR GRANT NO.

Nonr-4008(07)

b PROJECT NO.

c.

d.

9a. ORIGINATOR'S REPORT NUMBER(S)

Annual Report No. 8

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10 AVAILABILITY/LIMITATION NOTICES

Qualified requesters may obtain copies of this report from DDC

11 SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY

Office of Naval Research
Power Program, Code 473
Washington, D. C.

13 ABSTRACT

Progress during the year in the investigation of the synergistically catalyzed decomposition of oxidizers such as ammonium nitrate and ammonium perchlorate is summarized. Research has been done in the areas of thermal analysis, rate studies, catalytic and mechanistic studies, and electrometric measurements.

DD FORM 1 JAN 64 1473

None

Security Classification

None

Security Classification

14 KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Ammonium Nitrate Perchlorate Propellant Oxidizer EMF Fused Salts						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through _____."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through _____."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through _____."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13 ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)* *(S)* *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

None

Security Classification