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CHEMICAL EFFECTS OF HIGH EXPLOSIVE SHOCK WAVES ON VARIOUS COMPOUNDS
WHICH OCCUR IN THE GNOME CONTAINMENT MEDIUM

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ABSTRACT

The chemical effects of the action of high explosive shock pressures on NaCl , CaSO_4 , MgSO_4 , and polyhalite ($\text{K}_2\text{SO}_4 \cdot \text{MgSO}_4 \cdot 2 \text{CaSO}_4 \cdot 2 \text{H}_2\text{O}$) were extremely small. Alkalinity measurements of the solids showed that up to 0.5% decomposition of polyhalite occurred. The decomposition of all other solids was $< 0.01\%$. It is not known whether the decomposition was a result of straight decomposition by the shock heat or a result of hydrolysis by traces of moisture in the samples when shock heated.

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1.0 INTRODUCTION

The purpose of this investigation was to measure any chemical effects produced by the action of high shock pressures on some of the compounds which occur in rock salt formations at the GNOME site. For example, decomposition of NaCl into Na and Cl₂ or CaSO₄ into CaO and SO₂ might occur at very high shock pressures, if nonequilibrium cooling occurred behind the shock waves such that recombination was prevented. If such decomposition occurred in a contained nuclear explosion in salt and the generated gases escaped from the immediate environment, the region of the medium applicable to isotope recovery would be basic because of the basic oxides which remain. Such decomposition could effect recovery methods of isotopes. A few exploratory experiments were performed to measure any permanent chemical changes produced by the action of high explosive shock waves on NaCl, MgSO₄, CaSO₄, and polyhalite (K₂SO₄·MgSO₄·2 CaSO₄·2 H₂O). The application of the high explosive shock to the test specimens was performed at Frankford Arsenal by W. E. Fogg and C. W. Fleischer of that installation.

2.0 RELATED PREVIOUS INVESTIGATIONS

The work of Ryabinin¹ indicates that solid chemical compounds can be permanently changed chemically when subjected to high explosive shock waves in the 300-1000 Kb range. Lead nitrate and copper nitrate were transformed into the corresponding oxides at 400 Kb, and paraffin wax was converted to carbon. Sodium chloride when subjected to a 300 Kb shock left the salt grey and alkaline, and Ryabinin concluded these characteristics arose from the presence of free sodium. Yields were not reported for the chemical transformations because of low recovery of specimens after detonation of the explosive. Ryabinin's work suggests that nonequilibrium processes occur, otherwise reversible reactions such as the reaction, $\text{NaCl} \rightleftharpoons \text{Na} + \text{Cl}_2$, could not be used to produce the elements. Recombination during decompression would reform the starting material.

Certain types of chemical reactions are favored by very high pressures². Reactions which are accompanied by a decrease in total volume are favored by increases in pressure, whereas the converse reaction is suppressed.



Chemical decomposition of solid compounds usually lead to an increase in volume; however in the case of very high shock pressures, temperature increases are also produced, and then the simultaneous effect of pressure and temperature must be considered. Certain non-equilibrium cooling effects, irreversible reactions, and kinetic factors could lead to permanent chemical changes of solid compounds.

Shock heating is inefficient for the production of high intensity heat energy which is necessary for very high temperature reactions. Calculations on shock heating of NaCl by a nuclear explosion have been reported³. Only 40% of the total energy of the explosion goes to raise the temperature of a portion of the salt by 1000°C or more, and of this 40%, only 2% is available as heat above 2000°C. Extrapolation of the reported data indicates about 0.01% of the total energy goes into heating a portion of the salt above 3000°C. Sodium chloride does not begin to dissociate even at 1 atm. pressure until temperatures of 3200°C are reached. Any effect of dissociation of NaCl in relation to the whole environment would be expected to be very small if conditions are anywhere close to equilibrium.

3.0 RESULTS

The chemical effects of high explosive shock pressure of a few hundred kilobars on NaCl, CaSO₄, MgSO₄, and polyhalite were extremely small (Table 1). The basicity of solutions or slurries of the compounds were so close to neutral point of water that accurate measurement of the H⁺ or OH⁻ content was not possible. The data certainly show that decomposition is very small. Polyhalite decomposition may have been as much as 0.5% but all other compounds were 0.01%. Thus, it is concluded that the changes produced in the containment medium by an exploding nuclear device are so small that the changes will not effect isotope recovery.

The physical appearance of all compounds after shock were the same as before except for being highly compressed. A grey appearance of NaCl after shock was not observed as reported by Ryabinin¹. It is the opinion of the author that the observed alkalinity is due to hydrolysis of the salt by traces of moisture by reaction, $\text{NaCl} + \text{H}_2\text{O} \rightleftharpoons \text{NaOH} + \text{HCl}$.

Table 1. Measurement of Basicity of Test Compounds

Tube No. or Blank	Material	Weight in 100 ml of H ₂ O	pH	OH ⁻ Conc. by Titration ^c , <u>N</u>
1	NaCl	1.5260	6.10	7 x 10 ⁻⁵
1	NaCl	1.5125	6.50	6 x 10 ⁻⁵
Blank	H ₂ O	--	6.10	< 5 x 10 ⁻⁵
6	NaCl	1.4126	6.58	7 x 10 ⁻⁵
6	NaCl	1.4104	6.76	8 x 10 ⁻⁵
2	MgSO ₄	1.0133	6.23	5 x 10 ⁻⁵
2	MgSO ₄	0.9382	6.33	5 x 10 ⁻⁵
3	CaSO ₄ · 2 H ₂ O	0.6074	7.54	acid ^a
5	Polyhalite	0.6012	7.48	5 x 10 ⁻⁴
Blank	NaCl	1.00	6.04	< 1 x 10 ⁻⁵
Blank	MgSO ₄	1.00	6.50	1.1 x 10 ⁻⁴
Blank	CaSO ₄ · 2 H ₂ O	1.00	6.65	6.0 x 10 ⁻⁵
Blank	Polyhalite	--	8.83	acid ^b

^a Bisulfate was probably formed by action of shock; N = 4 x 10⁻⁵.

^b N = 3 x 10⁻⁵.

^c Normalities probably accurate to a factor of 2.

Hydrolysis reactions of NaCl have been reported⁴ when the salt containing traces of moisture are heated to elevated temperatures. Since highly purified salts were not used in this study it is not known whether the basic properties of the solids are a result of decomposition or of hydrolysis.

4.0 EXPERIMENTAL

The solid specimens were poured into the tubes (12 in. length x 1/2 in. i.d. x 13 g a.) and were filled to the ends. The tubes were lightly tapped at frequent intervals to insure uniform filling. One end was closed via means of masking tape and the other end was closed via means of the fitting as shown in Fig. 1. The samples were shocked using high explosive primer cord wrapped around the tube to 3 turns/in. to an estimated shock pressure of 500-1000 Kb.

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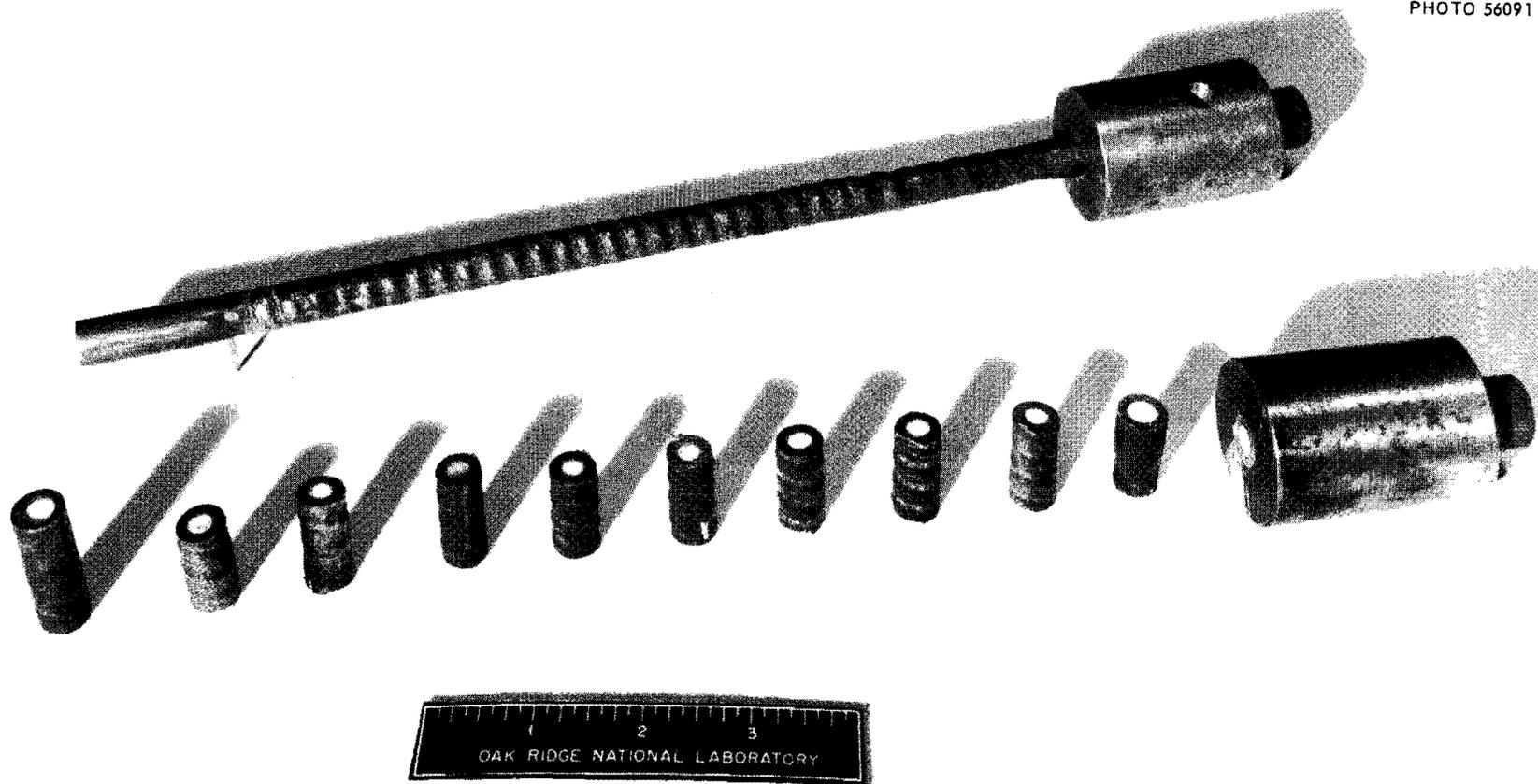
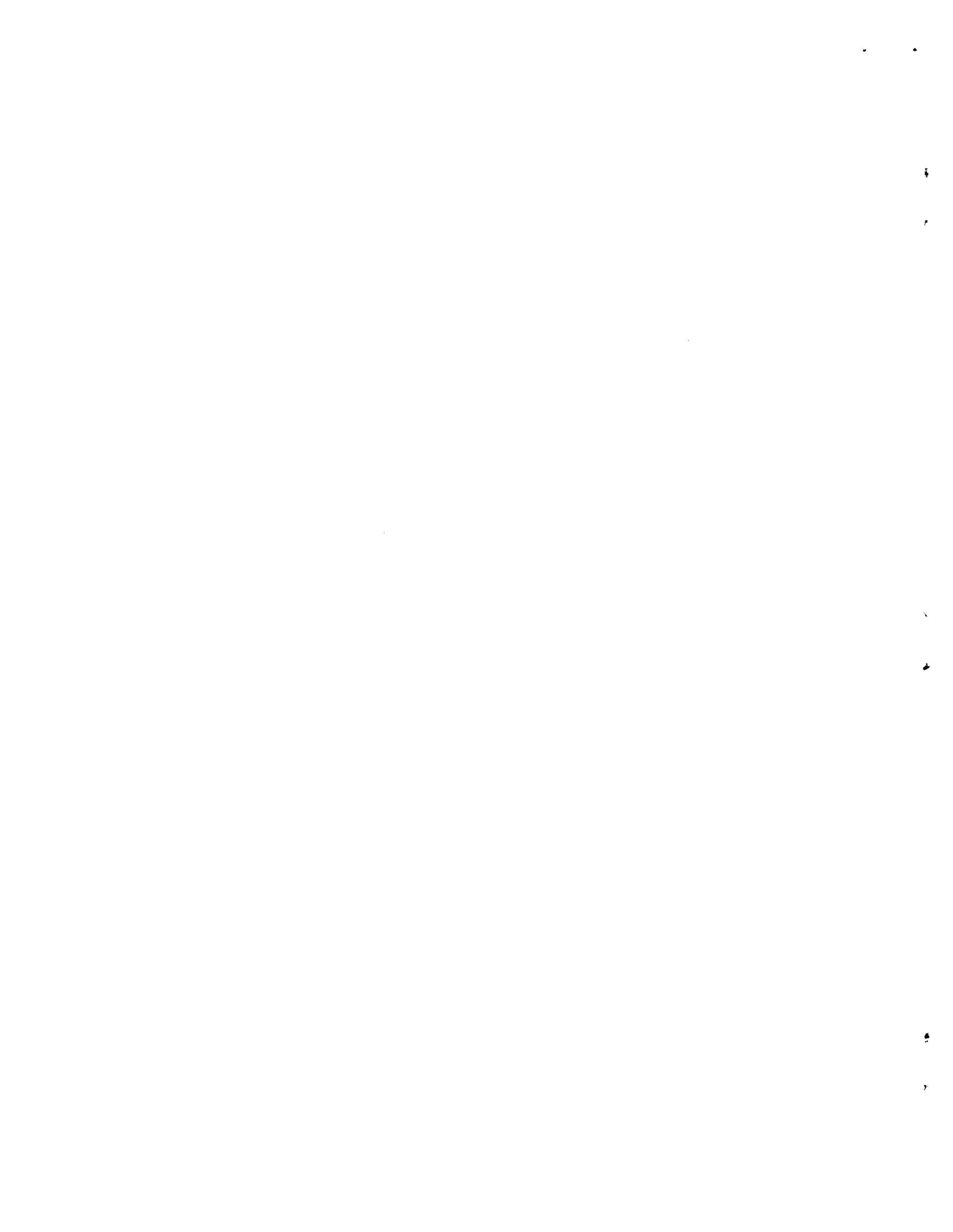


Fig. 1. Sodium chloride specimen subjected to high explosive. Left: Unsectioned NaCl specimen after shock. Right: NaCl specimen sectioned in 1 in. lengths.

After the samples had been subjected to the shock pressure, the tubes were cut into 1 in. sections to facilitate removal of the test materials (Fig. 1). One of the several sections which was highly densified by the shock was randomly selected for chemical measurements. The material was removed from the tube by gouging with a small stainless steel rod and the entire contents dissolved or slurried in 100 ml of H_2O for pH and OH^- concentration measurement. The polyhalite and $CaSO_4$ samples were compacted so highly that drilling was required for removal and hence some of the material was lost. All of the samples were compacted to the extent that removal was slow. Inside diameters were decreased from 30-60% by the shock depending on the solid specimens.

5.0 REFERENCES

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