one of the natural constants, such as $\alpha^2$, only further experiment can decide.

The comparison of the experimental ratio to the calculated ratio is particularly important, since most of the natural constants cancel out. The agreement is much better than for the absolute value but still not exact. The experimental value is about 0.06 percent greater than the calculated value. The error of the calculated ratio arises chiefly from the measured ratio of $\mu_P/\mu_D$ which is claimed to be accurate to about 0.03 percent. Clearly this interesting deviation is worthy of further study.

† Publication assisted by the Ernest Kempton Adams Fund for Physical Research of Columbia University.

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## Phase of Scattering of Thermal Neutrons by Aluminum and Strontium*

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In a previous paper[1] we have described a method for determining whether neutrons scattered by an atom have the same phase as the primary neutron wave or opposite phase. The method has now been applied to two more elements, Al and Sr. The crystals investigated were $Al_2O_3$ (corundum) and $SrSO_4$ (celestite). The measured intensities of various orders of Bragg reflections of monochromatic neutrons are given in the following table, which is arranged like Table I of reference 1.

Table I. Intensities of reflection of thermal neutrons by $Al_2O_3$ and $SrSO_4$.

| Crystal | Plane | Order | Form factor | Intensity |
|---|---|---|---|---|
| $Al_2O_3$ | $1\bar{1}0$ | 1 | 2A1 −1.44 O | 480 |
| | | 2 | 2A1 −1.34 O | 700 |
| | | 3 | 2A1 +2.09 O | 5940 |
| $SrSO_4$ | 001 | 1 | 0.44 Sr +0.77 S +0.12 O | 4351 |
| | | 2 | 0.62 Sr −0.19 S +0.67 O | 3576 |
| | | 3 | 0.98 Sr +0.48 S +1.01 O | 2182 |
| | | 4 | 0.24 Sr +0.93 S −1.81 O | 1682 |
| | 210 | 1 | 0.78 Sr +0.66 S −0.01 O | 6021 |
| | | 2 | 0.21 Sr −0.14 S +0.36 O | 413 |
| | | 3 | 0.44 Sr +0.84 S +1.09 O | 1493 |
| | 101 | 1 | 0.46 Sr −0.65 S −0.54 O | 702 |
| | | 2 | 0.55 Sr −1.16 S −2.54 O | 3182 |
| | | 3 | 1.94 Sr +0.83 S +0.50 O | 5759 |

Attempts to fit these data with actual values of the scattering length for aluminum and strontium have not been satisfactory. It seems unambiguous, however, that the sign of the scattering of aluminum is the same as that of oxygen, namely, positive according to our convention. This is proven by the low intensity of first and second order compared with that of the third order.

A similar behavior of the reflection from the (101) plane of celestite indicates that the scattering length of strontium is also positive. From the scattering cross sections of these two elements, $1.4\times10^{-24}$ cm$^2$ for Al and $9.5\times10^{-24}$ for Sr, one can calculate the scattering lengths $0.35\times10^{-12}$ cm for Al and $0.88\times10^{-12}$ cm for Sr.

* This document is based on work performed under Manhattan Project sponsorship at the Argonne National Laboratory.

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## Pressure and Temperature of the Atmosphere to 120 km

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Pressures and temperatures of the atmosphere up to 120 km were determined from data taken on the V-2 rocket fired at White Sands, New Mexico on March 7, 1947. The methods used in obtaining these data were similar to those used in a previous flight.[1] The pressure measurements were made with bellows gauges for pressures between 1000 mm Hg and 10 mm Hg. For pressures between 2 mm Hg and $10^{-2}$ mm Hg, tungsten and platinum wire Pirani gauges were used. A Philips gauge was used for pressures between $10^{-3}$ and $10^{-5}$ mm Hg.

Ambient pressures (Fig. 1) were measured up to about

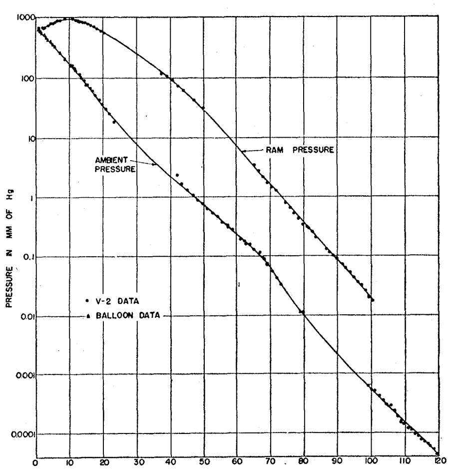


Fig. 1. Ambient and ram pressures as a function of altitude.

80 km with gauges mounted on the side of the V-2, just forward of the tail section. Pirani gauges, mounted in similar positions on opposite sides of the rocket, gave readings which agree within experimental errors, indicating that no appreciable error was introduced by yaw of the missle up to this altitude. A single Philips gauge was mounted on the 15° cone of the warhead. The readings of this gauge were reduced to ambient pressures by use of theories of Taylor and Maccoll.[2] Photographs of the earth made from the missile and gyroscope data indicated a yaw of about 15° at 110 km and a roll period of 40 seconds.

From the above data it has been calculated that at 110 km the aspect of the rocket was such that the Taylor and Maccoll corrections used were valid (Fig. 1). However, at 100 km the pressure shown is probably too high, while at 120 km it is too low, in each case by a factor of less than two.

The temperature of the atmosphere was calculated from the slope of the pressure *vs.* altitude curve and from the ratio of ram to ambient pressures. Figure 2 is a plot of the

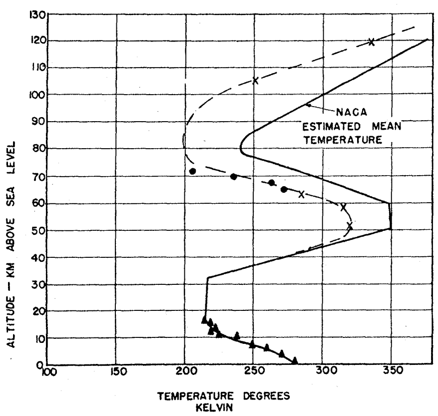


FIG. 2. Temperature as a function of altitude. The crosses indicate data calculated from slope of pressure curve; the black circles, data calculated from ram pressure; the triangles represent balloon data.

temperatures derived by this method. Also shown are the temperatures measured by means of a weather balloon released within an hour of the time of the rocket's flight. For comparison, the NACA estimated mean temperature[3] is included on the curve. The probable error is ±25° from 50 to 60 km., ±15° at 65 to 70 km, and ±20° at 72.5 km. The probable error above 100 km is ±40°. Temperatures calculated from ram pressures for altitudes between 10 and 20 km are 5 to 20° lower than the expected temperature. This discrepancy is possibly caused by errors in the velocities calculated from the poor radar data obtained during the first 20 km of the flight.

Pitot tube theory was used to obtain Mach number from the ratio of ram pressure to ambient pressure. The velocity of the rocket divided by Mach number gave the velocity of sound from which temperature was calculated.

It has been found necessary to apply corrections in the readings of the Pirani gauges to allow for their time constants. This effect resulted in a 1.5-second lag in the gauge used in October, corresponding to 2 km at altitudes between 60 and 80 km. When the October data were recalculated to allow for the lag, they were found to agree with the March data at 60 km, but to be higher than the March data at 80 km. This difference may be a seasonal effect and not experimental error. To establish the seasonal effect definitely, accurate data are needed between 75 and 100 km.

Two platinum resistance temperature gauges were installed to measure temperature of sections of the 15° nose cone. The temperature rise on the 0.1-inch thick aluminum forward section of the nose was 120°±5°C. On the 0.1-inch steel section immediately behind the aluminum, the temperature rise was 85°±5°C.

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## The λ-Point of $NH_4Cl$ and Thermodynamic Equilibria of the Second Order

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May 16, 1947

IN a recent article, E. F. Lype[1] undertook a discussion of thermodynamic equilibria of higher orders. Using Lype's equations, an interesting correlation has been found between the observed and the calculated slope of the equilibrium curve for $NH_4Cl$ at its λ-point.

We substitute in Lype's formula (18a) which gives for second-order equilibria,

$$dp/dT = \tfrac{1}{2}(c_p'' - c_p')/T(\partial v''/\partial T - \partial v'/\partial T),$$

where the dashes refer to the two phases. From the data of Simon, v. Simson, and Ruhemann,[2] we have the maximum specific heat given as $c_p = 177.4$ cal./mole-deg., with the specific heat immediately after transition as 18 cal./mole-deg. Hence,

$$c_p'' - c_p' = 159.4 \text{ cal./mole-deg.}$$
$$= \frac{159.4 \times 4.2 \times 10^7}{53.5 \times 981} \text{cm/deg.}$$

The transition temperature is $T_0 = 242.8$°K.

There are, unfortunately, no data giving in absolute measure the variation of $v$, (the specific volume) with $T$. Smits and McGillavry[3] express their results in terms of arbitrary dilatometer readings. The writer was therefore forced to modify the equation as follows:

$$\frac{dp}{dT} = \frac{c_p'' - c_p'}{2Tv(\partial v''/v\partial T - \partial v'/v\partial T)},$$

and assuming $v'' = v' = v$ (which is only approximately the case), this may be written as

$$dp/dT = (c_p'' - c_p')/2Tv(\alpha'' - \alpha'),$$

where $\alpha''$ and $\alpha'$ are the coefficients of cubical expansion in the two phases. These were determined from the graph given by Adenstedt,[4] and it was found from linear extrapolation of the highest values given on either side of $T_\lambda$ that

$$\alpha'' \doteqdot 19.0 \times 10^{-3}/\text{deg., and } \alpha' \doteqdot 13.0 \times 10^{-3}/\text{deg.}$$

The density of $NH_4Cl$ is given by Wulf and Cameron[5] as 1.527 g/cc.

Substituting in the formula, we now obtain

$$\frac{dp}{dT} = \frac{159.4 \times 4.2 \times 10^7 \times 1.527 \times 10^3}{2 \times 53.5 \times 981 \times 6 \times 242.8} = 6.68 \times 10^4 \text{ g/cm}^2\text{-deg.}$$
$$= 66.8 \text{ kg/cm}^2\text{-deg.}$$

Variation of the λ-point with pressure has been studied by Bridgman,[6] who found that under pressures of 3370