tially identical results were obtained a week later with a group of 16 pigmented (Long-Evans) rats. In this latter experiment, subjects were male rats, 270 to 370 g, and about 90 days old. Eight tragacanth-injected controls were compared with eight rats injected with magnesium pemoline (10 mg/kg).

Thus, the major finding of our second experiment was that rats injected with magnesium pemoline (either 5, 10, or 20 mg/kg) maintained a higher level of spontaneous activity and responsivity to the buzzing sound used as the conditioned stimulus in experiment 1. There appear to be two major interpretations that could account for the observed increased activity and sustained stimulus responsivity in these drug-treated rats. Since no noticeable differences occurred on trial 1, the growing difference across trials between experimental and control subjects could be interpreted as a slower rate of habituation to the buzzing sound in the drug-treated rats, resulting in the significant differences seen in succeeding trials.

An alternative proposal is that the magnesium pemoline effects are time dependent and the full behavioral effects of the drug are seen only on trials 2 to 6 (50 to 130 minutes after injection). Our experimental design does not allow us to choose between these two alternatives. It is interesting to note, however, that brain RNA polymerase in vivo increases in a linear fashion up to at least 2 hours after intraperitoneal injection (20 mg/kg) in Sprague-Dawley rats, according to Glasky and Simon (*1*).

In experiment 2, spontaneous activity and stimulus-responsivity differences developed without training and within a time period comparable to that of experiment 1 and Plotnikoff's report (*3, 6*). Thus we consider the important finding of this study to be that an alternative explanation, based on increased spontaneous activity and sustained stimulus-responsivity, can be offered to account for the shorter response latencies of the rats treated with magnesium pemoline in experiment 1. This alternative explanation, rather than "enhancement by magnesium pemoline of learning and memory," must also be entertained regarding Plotnikoff's findings (*3*). The fact that percent avoidances, a more meaningful measure of learning, was not increased in the drug-treated rats supports the supposition that when the effects of magnesium pemoline are evaluated on a short time scale, as in the present and previous (*3, 4*) experiments, the behavioral changes observed are primarily due to the effect of the drug on performance systems, not directly on "learning and memory."

GARNET BEACH
DANIEL P. KIMBLE
*Psychology Department,
University of Oregon, Eugene*

References and Notes

1. A. J. Glasky and L. N. Simon, *Science* **151**, 702 (1966).
2. Cylert; Abbott-30400; a combination of 2-imino-5-phenyl-4-oxazolidinone and magnesium hydroxide. We thank Abbott Laboratories, North Chicago, Illinois, for providing the magnesium pemoline.
3. N. Plotnikoff, *Science* **151**, 703 (1966).
4. ———, *Federation Proc.* **25**, 262 (1966).
5. Plotnikoff referred to day 3 as *retention*. However, since the test employed is a questionable measure of memory, and since the unconditioned stimulus is not presented, we prefer the term extinction. Also, slow extinction could be regarded as a failure of learning rather than an enhancement of memory.
6. N. Plotnikoff, personal communication.
7. A circuit diagram for this apparatus is available on request.
8. Supported by PHS grant MH-08545-03, D. P. Kimble, principal investigator. We thank Lee Vernon for technical assistance.

14 December 1966

Primordial Rare Gases in Unequilibrated Ordinary Chondrites

Abstract. *The primordial gases of eight unequilibrated ordinary chondrites are strongly fractionated with respect to "cosmic" proportions. The absolute amounts are roughly proportional to the degree of disequilibration. Apparently, ordinary chondrites originally contained considerably larger amounts of primordial rare gases.*

A few ordinary chondrites (currently some 24 are known) have recently received considerable attention because they contain olivines and orthopyroxenes highly variable in content of Fe (*1–5*). This feature is remarkable because ordinary chondrites proper have silicates of virtually uniform composition (*1*). The unequilibrated ordinary chondrites (UOC) are obviously less recrystallized than the ordinary chondrites proper (*3, 4*); in fact, it has been argued that UOC are the "primitive" precursors of the ordinary chondrites (*6*).

Judging from the known primordial rare-gas contents of another variety of primitive chondrites, the carbonaceous chondrites, we expected the UOC to be systematically richer than ordinary chondrites proper in these gases. Since little could be concluded from available data (*7*), we have determined by mass spectrometry the rare-gas contents (He, Ne, Ar, Kr, and Xe) of nine UOC; the experimental methods and results will be detailed elsewhere (*8*). We now report two salient results that seem to have interesting implications for further work on these chondrites.

First, the noble gases in all the UOC listed in Table 1 are strongly fractionated with respect to their "cosmic" proportions because the Xe^{132}, Kr^{84}, and Ar^{36} abundances are about 10^{-4} to 10^{-5}, 10^{-6}, and 10^{-8}, respectively, of their cosmic abundances (*9*). Only Khohar contains a significant amount of primordial Ne^{20}—20×10^{-8} cm^3/g (standard temperature and pressure)—corresponding to about 10^{-10} of the cosmic abundance of this isotope.

Second, the absolute amounts of primordial Ar^{36}, Kr^{84}, and Xe^{132} are roughly proportional to the percentage mean deviation of the Fe contents of the olivine (*5*); this trend is seen in Fig. 1, and plots for Kr^{84} and Xe^{132} are similar. The quantity plotted along the abscissa (Fig. 1) is calculated from measurements of the Fe contents of many olivine grains (*5*). In UOC, the Fe contents usually differ substantially from the mean, or bulk, Fe content of the Fe-Mg orthosilicate. Thus, a high value for percentage mean deviation corresponds to a highly unequilibrated chondrite, and vice versa. Note that high primordial rare-gas contents occur in general among the most highly unequilibrated UOC, and vice versa.

It is generally accepted that the strongly fractionated noble gases were acquired by the meteorites, together with carbon and other volatiles, at an early stage in their history (for discussion of this point see *10*). In this respect it is interesting that UOC generally have significant carbon contents and that several contain organic compounds, although not to the degree of carbonaceous chondrites of types I and II (*4*). The relatively high contents of fractionated noble gases are thus compatible with structural and compositional characteristics.

The trend of Fig. 1 suggests that the recrystallization of the UOC and the redistribution of Fe in the silicates were accompanied by progressively greater losses of primordial rare gases. Since the ordinary chondrites proper are virtually completely equilibrated in this sense, we conclude that they were originally substantially richer in primordial gases. [Bruderheim, a typical ordinary chondrite, contains primordial Xe^{132}, Kr^{84}, and Ar^{36} at only about 10^{-6}, 10^{-7}, and 10^{-9} to 10^{-10} times cosmic abundance, respectively (*11*).] Zähringer (*12*) recently reached the same conclusion.

Table 1. Primordial rare gases in the unequilibrated ordinary chondrites used. Numbers in parentheses refer to Fig. 1. *A* and *B* refer to different samples of the respective meteorites—not to two determinations from the same sample.

Meteorite	Rare gas $[10^8\ cm^3/g(STP)]$			
	Ne^{20}	Ar^{36}	Kr^{84}	Xe^{132}
Bremeervörde (1)	~6	9.8		
Prairie Dog Creek (2)		7.8	0.16	0.11
Krymka *A* (3)		36.3	.38	.34
Krymka *B* (4)		63		
Bishunpur *A* (5)		39	.41	.33
Bishunpur *B* (6)		60		
Manych (7)		15.4	.19	.15
Khohar (8)	~21	25.1	.21	.16
Mezö-Madaras (9)		15.5	.13	.14
Chainpur *A* (10)		50	.31	.24
Chainpur *B* (11)		60		
Parnallee (12)		13.6	.17	.13

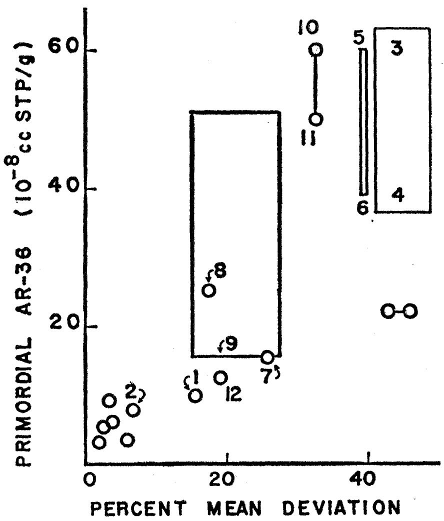

Fig. 1. Primordial Ar^{36} versus percentage mean deviation of olivine composition. Rare-gas data are from our work and from the literature (*7*); olivine composition from (*5*). In several UOC, Ar^{36} varies considerably between two samples. Variations of percentage mean deviation also occur (*5*); in such instances the highest and lowest values of the two quantities are indicated by solid lines between data points or by rectangles (unfortunately the Ar^{36} measurements and the determinations of olivine composition were never made on the same samples, so that these quantities cannot be correlated unambiguously). Note that high contents of Ar^{36} occur in general among the most highly unequilibrated UOC, and vice versa. For key to numbers, see Table 1.

But it is doubtful that the original rare-gas contents of the ordinary chondrites resembled present contents of the most highly unequilibrated UOC, Krymka and Bishunpur. Wood (*4*) has suggested that the UOC were heated in their parent planets to several hundred degrees Celsius and were cooled very slowly at about 0.1°C per million years. Any gas "originally" trapped in sites of poor retention would have been released under such conditions. In fact, the absence of primordial Ne in all but two of the UOC, Bremervörde and Khohar, appears to be consistent with this hypothesis.

It is also doubtful that the noble gases were originally trapped in ordinary chondrites with abundance ratios now found in UOC [incidentally, these abundance ratios are similar to those of "planetary" gas of the two-component model of Signer and Suess (*13*)]. Zähringer (*12*) suggests that the loss of Xe, Kr, and Ar was probably small compared to the loss of Ne; we concur. It is interesting in this respect that the $Ne^{20}:Ne^{22}$ ratio of primordial Ne in Khohar is less than 10 (this ratio cannot be determined very accurately because of a substantial Ne^{22} correction arising from cosmic ray–produced Ne^{22})—considerably below the "solar" value of 14 found in the gas-rich chondrites (*13*). It seems that the $Ne^{20}:Ne^{22}$ ratio in Khohar may have arisen by isotope fractionation of as much as 50 percent during diffusive loss of Ne from the meteoritic grains. Argon in the UOC, on the other hand, shows no significant isotope fractionation, since the $Ar^{36}:Ar^{38}$ ratios of primordial Ar range from 4.9 to 5.6, with most values near 5.3—the ratio of atmospheric argon.

It is of interest that the dark portions of gas-rich chondrites such as Pantar probably do not agree with the Ar^{36} trend in Fig. 1. Unfortunately, the only instance in which dispersion of the olivine composition is known is Pantar itself (*2*); its dark portion has a percentage mean deviation of $\lesssim 2$ percent, and the Ar^{36} content is $\sim 10 \times 10^{-8}$ cm^3/g (STP) (see *14*). Thus literature data on Ar^{36}, available for several gas-rich chondrites, can only be used on the assumption that the dispersion of olivine composition in their dark portions resembles that of Pantar. It is likely, but not established in fact, that the gas-rich chondrites will all fall close to the left vertical axis of Fig. 1, with Ar^{36} ranging up to about 700×10^{-8} cm^3/g (STP) (see *14*). This remarkable systematic difference would imply that the large amounts of "solar" He and Ne, generally present in the dark portions, are not simply superimposed upon a *résidu* of originally trapped fractionated Ar^{36}, but that certainly significant amounts of Ar^{36} from some other source are present. One source could be solar wind, which according to Suess *et al.* (*15*) has supplied solar He and Ne. Another source could be shock-emplacement of Ar^{36} from an ambient gas phase (*16, 17*).

DIETER HEYMANN
EMANUEL MAZOR

Enrico Fermi Institute for Nuclear Studies, University of Chicago, Chicago, Illinois

References and Notes

1. B. Mason, *Geochim. Cosmochim. Acta* **27**, 1011 (1963).
2. K. Keil and K. Fredriksson, *J. Geophys. Res.* **69**, 3487 (1964).
3. R. T. Dodd and R. Van Schmus, *ibid.* **70**, 3801 (1965).
4. J. A. Wood, *Icarus*, in press.
5. R. T. Dodd, W. R. Van Schmus, D. M. Koffman, preprint, 1966.
6. R. A. Schmitt, R. H. Smith, G. G. Goles, *Science* **153**, 644 (1966).
7. T. Kirsten, D. Krankowsky, J. Zähringer, *Geochim. Cosmochim. Acta* **27**, 13 (1963); J. Zähringer, "Chronology of chondrites with rare-gas isotopes," before 11th Meteorite Conf. Acad. Sci. U.S.S.R., Moscow, 1964; H. Hintenberger, H. König, L. Schultz, H. Wänke, *Z. Naturforsch.* **19a**, 327 (1964); **20a**, 983 (1965); A. P. Vinogradov and I. K. Zadorozhny, *Geochimia* **7**, 587 (1964); P. Eberhardt, O. Eugster, J. Geiss, K. Marti, *Z. Naturforsch.* **21a**, 414 (1966); K. Marti, P. Eberhardt, J. Geiss, *ibid.*, p. 398; D. Heymann, *Icarus*, in press.
8. D. Heymann and E. Mazor, in preparation.
9. A. G. W. Cameron, "Nuclear astrophysics," lecture series, Yale Univ., 1962–63.
10. E. Anders, *Space Sci. Rev.* **3**, 583 (1964).
11. J. Zähringer, *Z. Naturforsch.* **17a**, 460 (1962).
12. ———, preprint, 1966.
13. P. Signer and H. E. Suess, "Rare gases in the sun, the atmosphere, and in meteorites," in *Earth Science and Meteoritics*, J. Geiss and E. D. Goldberg, Eds. (North-Holland, Amsterdam, 1963).
14. R. O. Pepin and P. Signer, *Science* **149**, 253 (1965).
15. H. E. Suess, H. Wänke, F. Wlotzka, *Geochim. Cosmochim. Acta* **28**, 595 (1964).
16. K. Fredriksson, P. S. De Carli, R. O. Pepin, J. H. Reynolds, G. Turner, *J. Geophys. Res.* **69**, 1403 (1964).
17. E. Anders and J. Larimer have just informed us that their study of 31 volatile elements in meteorites, including the rare gases, leads them to conclude that the fractionations occurred in the solar nebula as it cooled from high temperatures. This suggestion constitutes an alternative explanation to the one adopted in this report: that chondrites originally contained comparable amounts of gas, and that the vast differences have arisen from diffusion *in situ*.
18. Aided by AEC contract AT(11-1)-382 and by NASA grant NsG-366 Research. We thank E. Anders, R. T. Dodd, E. K. Krinov, C. B. Moore, W. R. Van Schmus, and J. A. Wood for making the meteorite samples available.

25 November 1966