consistent with this proposal, including the apparent anomaly of *Pseudotsuga macrocarpa,* which may be an environmental effect. Any taxonomic value of this report, however, awaits more general survey of the species in the family and between families. Furthermore, genetic make up of varieties (*5*), climate (*3, 4, 6*), and maturity (*7*), have altered the composition of fatty acids in seed. A parallelism which might exist in pollen material might be revealed by further systematic study (*8*).

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Temperature-Independent Morning Emergence in Lizards of the Genus Phrynosoma

Abstract. An investigation of the relationship of morning emergence and body temperature in *Phrynosoma* demonstrated a rhythmic anticipation of conditions favorable for normal activity. Such a rhythm offers a mechanism by which ectothermic reptiles can use safe nocturnal shelters without loss of activity time in the morning.

The daily existence of terrestrial "cold-blooded" animals, especially reptiles, depends upon their ability to utilize available external heat. Their activity is restricted when environmental conditions prove too hot or cold. In many diurnal reptiles there appears to have been selection for high body temperatures with resulting enhanced neuromotor control and celerity (*1*).

Along with the advantages accruing to high body temperatures, these animals must also suffer from a decrease in mobility at low temperature levels. Many of them use underground nocturnal retreats and might not be expected to begin daily activity until sufficient heat had penetrated into these shelters to warm them. Such a delay of emergence would result in the loss of valuable activity time on the surface during the morning. As an alternative, ectothermic animals could remain on the surface exposed throughout the night, but in the resulting cold-comatose condition they would be subject to predation and possibly freezing. However, I have found that horned lizards, *Phrynosoma,* in captivity regularly emerge before sunrise at body temperatures of 19°C, almost 15°C below temperatures of normal activity (*1*). These observations prompted an investigation of the relationship of morning emergence and body temperature.

The nature of morning emergence behavior in horned lizards is particularly advantageous for the study of this problem. In these animals daily activity is initiated by two distinct behavioral patterns. First, the animals may move upward in the sand until their heads are exposed and remain in this position until warmed to their activity levels. Alternatively, they emerge completely and begin basking in a fully exposed position. In either case inactive animals stay buried in the sand and are not visible. With the above criteria for activity, a simple experiment was devised to demonstrate whether there is any direct relationship between body temperature and morning emergence.

Two mixed groups of 15 *Phrynosoma coronatum* and *P. cornutum* were separated and kept in the laboratory at constant ambient temperatures of 18° and 27°C. The animals had access to radiant heat from infrared lights for 8 hours daily. Light was provided during this time and for four additional hours after the heat lamps were turned off; 12 hours were passed in relative darkness. The energy from the heat lamps was sufficient to allow the lizards to achieve normal activity temperatures (34° to 38°C). Although both groups had been adjusted to this daily schedule for several weeks, they were maintained in the new situation for 3 days before measurements were taken.

The lizards were active during the entire period of infrared radiation. All burrowed within 2 hours after the cessation of heating. The horned lizards spent the night buried from 2 to 8 cm in the sand. Many animals in both groups emerged in the darkness shortly before initiation of heat and light. Records on the time of emergence of individual animals were made on four consecutive days. These are shown plotted as a percentage of the total number of animals in Fig. 1. The initiation of daily activity prior to the availability of heat to warm them occurred in both groups.

The first animal came out of the sand about 40 minutes before experimental "sunrise." By 15 minutes before the initiation of heat 70 percent of the animals were active. Body temperatures at this time were the same as environmental temperatures, 18° and 27°C, respectively.

I believe these data show that the initiation of activity in the morning is independent of temperature, at least when the animals are warm enough to move. The similarity of emergence time in the two groups suggests the operation of an endogenous or circadian rhythm.

The possibility of a circadian rhythm integrated with temperature regulation in reptiles is of considerable significance with regard to their biology. By this mechanism emergence in the morning may be timed to place the animal in a situation where it can warm rapidly to normal activity levels, although exposing only a part of the body may mediate this to some extent. This is corroborated by observations of lizards in the field. Norris (*2*) has found that simultaneous morning

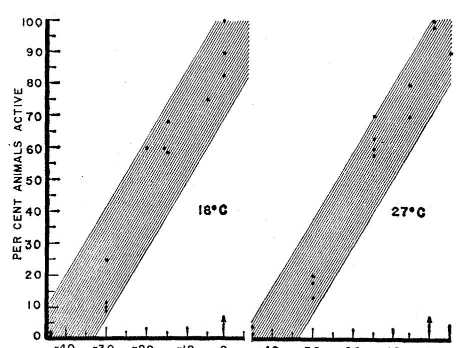

Fig. 1. Comparison of the timing of morning emergence for four consecutive days of two groups of horned lizards maintained at different temperatures. Activity begins prior to experimental "sunrise" indicated by the arrow at time 0.

emergence occurs in the desert iguana, *Dipsosaurus dorsalis*, in late morning several hours after sunrise and at a time when the animal can achieve optimal body temperature levels. Similar observations have been made on horned lizards (*3*). Certainly, the animal's problem of securing safe nocturnal shelter without losing activity time in the morning is met by this mechanism (*4*).

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20 August 1962

Binding of Inert Gas Halogenide Molecules

Abstract. An electronic explanation of the existence of noble gas halides and predictions of the properties to be expected of these compounds is presented.

Formation of XeF_4 and XeF_2, recently reported (*1*), invalidates one of chemistry's oldest and most widely accepted rules.

The traditional model of a rare gas atom envisions a series of shells completely filled through ns^2np^6 (Ne, $n = 2$; A, $n = 3$; Kr, $n = 4$; Xe, $n = 5$; Rn, $n = 6$). Each one-electron orbital is occupied by one electron with α spin and another with β spin, and each shell as well as the atom as a whole is spherically symmetric. By virtue of the Pauli exclusion principle, this model adequately describes the instantaneous electron-electron correlation between electrons with the same spin but not that between electrons with antiparallel spin. Correlation between antiparallel pairs of electrons produces a separation between them and causes a slight distortion of the atom. It is the small, time-averaged, spatial separation of these antiparallel electron pairs which gives the possibility of a shared electron (*2*). As in most chemical problems, the one-electron orbitals decrease rapidly with distance, and only the outer *ns* and *np* shells contribute to binding. The number of antiparallel *ns* and *np* pairs in rare gas atoms is four. Thus a maximum of four halide atoms may be bound. The spatial separation of antiparallel spin pairs does not prevent us from setting up a many-electron wave function which is a singlet for either the atom or the molecule (*3*). For both the two-halogen and four-halogen species half of the halogen atoms will have α spin and half β spin, and we expect the molecules to have no net magnetic moment.

A rather complete and detailed picture of the electron configuration in the atom and molecule can be constructed. First, the *ns* shell will be inside the *np* shell by a small amount, and the two ionization potentials are quite different (*4*). This does not imply any chemical discontinuity in the periodic table as the *ns* shell is completed, but it does mean that hybridization between the *s* and *p* orbitals of the conventional sort present in carbon is not favored. Another important fact is the absence of correlation coupling between *s* and *p* shells (*5*), which allows the shells to act independently of one another. Second, Unsöld's theorem (*6*) states that for the undistorted noble gas atoms the three np^α electrons and three np^β electrons are each spherically symmetrical. The correlation distortion will have radial and angular components. Figure 1 shows schematically the radial correlation separation for α, β pairs. Figure 2 is a sketch of the xenon 5*p* and fluorine 2*p* radial functions in the binding region. Similar figures may be drawn for the 5*s* radial functions and for other combinations of noble gas and halogen atoms. Binding is achieved by the difference in the overlap between the α and β functions and the fluorine 2*p* orbitals. Because of the spherical symmetry of the three undistorted np^α and np^β electrons, these two groups of three electrons will be angularly separated as far as possible from one another, thereby giving a high probability to an approximate octahedral distribution of electrons. The two *ns* electrons will tend to be on opposite sides of the nucleus and form an ellipse. Angular correlation produces a separation of α and β spins in angle and a differential overlap effect similar to the radial displacement of Fig. 2.

The obviously high symmetry of the noble gas atoms and a preliminary infrared absorption spectrum (*1*) indicate a tetrahedral or planar configuration for the four halide atoms in tetrahalide molecules. I predict a planar configuration. The electrons forming the *np* octahedron may be pictured as follows:

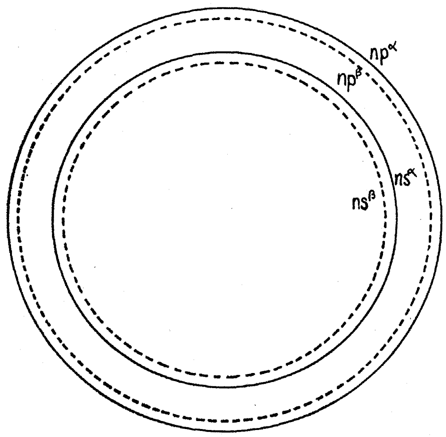

Fig. 1. Radial separation of antiparallel spin pairs in rare gas atoms.

there are four equidistant electrons (two α and two β) on the equator of a sphere, and the spins alternate around the equator. One pole has an electron of α spin, the other an electron of β spin. Four halogen atoms may become associated with the four equatorial electrons, deriving three-fourths of their binding from the *np* shell and one-fourth from the *ns* shell. Bonding of the four equatorial atoms is enhanced by a large average separation of antiparallel spins, and this favors an orientation of the *ns* double ellipsoid with its long axis on a line joining the two polar electrons. Closer proximity of the *ns* electrons to the two polar *np* electrons reduces the average spin separation and discourages binding to the polar electrons. The effective radii for the halogen atoms may be approximately equal to the smallest nonbonded radius if the fluorine does not penetrate deeply into the xenon. If the xenon radius is taken directly from the observed interatomic distances in crystals, the bond length in XeF_4 may be as great as 1.90 + 0.85 = 2.75 Å (*7*). This prediction does not follow from any fundamental aspect of the model, and it could be considerably less. Preliminary Raman

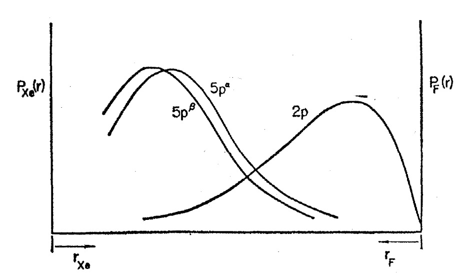

Fig. 2. Radial wave functions in binding region for XeF_4 or XeF_2. [$P^2(r) \equiv r^2R^2(r)$ = proportional to radial charge distribution]